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Greenium or myth

Do green labels affect bond yields in the Nordic markets?

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Abstract

Estimates show that there is a significant need for more investments into sustainable projects to meet the climate goals set in the Paris Climate Agreement. Green bonds are a relatively new type of financial security developed to channelize capital into more environmental-friendly projects. “Green” financial securities, like green bonds, creates an opportunity for investors to contribute to the green shift. However, it is unclear whether investors sacrifice some of their returns when investing in environmental-friendly securities instead of conventional securities. The objective of our study is to investigate whether investors receive lower yields on their green bond investments, compared to what they would have earned on identical conventional bonds. More precise, our study examines if investors receive lower yields from labeled green bonds compared to what they earn on similar conventional bonds in the Nordic secondary markets. As previous research on this topic is limited, our study will contribute with new insight into the Nordic bond markets, which will be valuable for both investors and issuers.

A matching method is used to examine whether investors receive lower yields on Nordic green bonds compared to conventional bonds. In this method, each green bond is matched with a similar conventional synthetic bond, which is composed of two conventional bonds. Further, a fixed effects regression is conducted to investigate whether there is a difference in the secondary market yield between the green bond and the matched synthetic bond, both for the whole sample and for various subsamples. A total of 77 Nordic green bonds are matched and analyzed in this research. Additionally, the estimated greeniums is regressed on different bond characteristics to capture potential determinants of the green bond premium.

The findings show no statistically significant difference in the yield between green and conventional bonds when the full sample is analyzed. Hence, there cannot be stated that there is a greenium for the full sample. However, when the full sample is divided into subsamples, three of the subsamples have statistically significant greeniums. These subsamples are bonds issued in SEK, Investment grade bonds, and bonds with an issue amount between 251-500 million SEK. The greeniums found for the respective subsamples are 0.64 bp, 0.60 bp, and 1.2 bp.

Sammendrag

Det er estimert at det trengs en enorm mengde investeringer i bærekraftige prosjekter for at verden skal nå de målene satt i Parisavtalen. Grønne obligasjoner er en relativt ny type finansielt aktiva, hvor hovedhensikten er å kanalisere mer kapital inn i miljøgunstige investeringer. Disse grønne obligasjonene gir investorene muligheten til å bidra til det grønne skiftet. Det er samtidig uklart hvorvidt dette bidraget kommer med en ekstra kostnad for investorene, i form av lavere avkastning. Hensikten med denne oppgaven er å analysere om investorer oppnår lavere avkastning ved å investere i grønne obligasjoner, kontra hva de ville oppnådd ved å investere i konvensjonelle obligasjoner. Mer presist vil denne studien undersøke om investorer oppnår lavere annenhåndsmarkeds avkastning i nordiske grønne obligasjoner enn hva de ville gjort ved å investere i ellers like nordiske konvensjonelle obligasjoner. Tidligere forskning på dette temaet er begrenset, og vår analyse vil derfor tilføre ny informasjon som er verdifull for både investorer og utstedere av grønne obligasjoner i Norden.

For å undersøke om investorer oppnår en lavere avkastning på nordiske grønne obligasjoner sammenlignet med konvensjonelle obligasjoner benyttes en sammenligningsmetode. I denne metoden blir hver grønne obligasjon satt sammen med en syntetisk konvensjonell obligasjon. Den syntetiske obligasjonen er her sammensatt av to konvensjonelle obligasjoner. Deretter undersøkes det om det eksisterer en forskjell i avkastning ved å sammenligne annenhåndsmarkedets avkastning mellom obligasjonene i hvert obligasjonspar. I tillegg til å kjøre analysen på hele datasettet, blir også mindre segmenter av datasettet analysert individuelt. Totalt blir 77 grønne obligasjoner satt sammen med konvensjonelle obligasjoner og videre analysert. I tillegg utføres også en regresjonsanalyse hvor den grønne premien fungerer som avhengig variabel for å finne potensielle forklaringsvariabler.

Vi finner ingen signifikant forskjell i avkastning mellom grønne og konvensjonelle obligasjoner når hele datasettet blir analysert. Vi finner derfor ingen grønn premie i det nordiske markedet i sin helhet. Når datasettet deles inn i mindre datasett, finner vi signifikante forskjeller i avkastning mellom grønne og konvensjonelle obligasjoner. For obligasjoner utstedt i SEK, for obligasjoner betegnet som investeringsgrad og for obligasjoner med et utstedelsesvolum mellom 251-500 millioner SEK finner vi negative grønne avkastningspremier på henholdsvis 0,64 bp, 0,60 bp og 1,2 bp.

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1. Introduction

1.1 Motivation

“Climate change increasingly poses one of the biggest long-term threats to investments.’’ Christiana Figueres secretary of the UNFCCC

Climate change through global warming is one of the most prominent threats to humanity in the 21st century (United Nations, 2019). As a result, many global organizations as The United Nations (UN), IPPC, Green Climate Fund, and Bellona have highlighted the threat over the past decades. Consequently, public attention and acceptance have gradually increased all over the world.

Recognition of the urgency in the situation has also materialized in the financial world. In 2006 the Principles of Responsible Investments (PRI) were established. Up until now, 2300 investors have signed to invest in line with the principles (Principles of Responsible Investment, 2019). Further, the Paris Agreement stresses the contribution from investors and the finance industry in article 2.1.C (2015), which states that the signatories commit to making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

It seems like investors have accepted that they need to contribute as an increasing focus on environmental, social, governmental (ESG) and corporate, social, responsibility (CSR) factors have developed. In 2018 this development resulted in an allocation of at least USD 30,7 trillion into sustainable or green investments globally, which is a rise of 24 percent from 2016 (Global Sustainable Investment Alliance, 2018).

However, going forward, investments into sustainable and green finance are still sorely needed. The Organisation of Economic Co-Operation and Development (OECD) estimates an investment need of USD 95 trillion into energy, transport, water, and telecommunications infrastructure from 2016 to 2030. This need equals an annual amount of USD 6.3 trillion to reach the goals signed in the Paris Agreement (OECD, 2017). The European Union (EU) estimates that to reach their agreed 2030 emission goals, they must fill an investment gap of EUR 280 billion per year (European Commission, 2016). These estimates show that there is still a substantial need for green financing and contributions going forward. And that these investments must come from both public- and private investors.

There are three main green investment categories where it is possible to invest in green finance. These are green lending, stocks with high ESG scores, and green bonds. Despite this, there is still lacking a clear definition of what “green finance” actually is. This lack of definition makes it both a challenging and time-consuming asset class for investors due to the significant due-diligence needs (Chatterjee, Fabian & Feller, 2016). However, some types of green investments are more defined than others. One such category is green bonds.

A green bond is a fixed income debt instrument where the issuer uses the proceeds to finance “green” projects, which are projects with clear environmental benefits. The green bond market emerged in 2007-08 (European Commission, 2016). However, a corporate green bond market did not appear up until 2013 (Climate Bond Initiative, 2019d). Supporting the green bond development and the following exponential issue growth was the launch of the Green Bond Principles (GBP) and their framework in 2014 (World Bank, 2019). However, the green bond market is still self-regulated, but external reviews of the green bonds and their associated projects are possible to show that the bond is not just a greenwashing[1] item.

1.2 Existing literature

The growing allocation into green finance has made it a hot topic for both academic and professional researchers studying whether there is a link between ESG and CSR performance and the return of an investment. Increasing amounts of research points in the direction of a connection between corporations’ ESG and CSR activities and the pricing of their securities, e.g., Dhaliwal et al., 2011, Christensen, 2016, Christensen et al., 2017.

In recent years, after the boom in the green bond market, research on it has accelerated but is still at an early stage. Harrison (2019) studied the oversubscription of green bonds in the primary market from July to December in Europe. He finds a higher oversubscription for green bonds than their vanilla equivalents on average, resulting in a slightly lower spread. However,

[1] Greenwashing is the process of conveying a false impression or providing misleading information about how a company’s products are more environmentally sound.

the reliability of the results is discussable due to the short research period and the low number of observations in the research.

Ehlers and Packer (2017), Zerbib, (2019), Larcker & Watts (2019) has conducted research trying to determine if green labeling a bond affects its price and yield. In other words, if investors' decisions merely are based on expected risk and return or if a non-monetary characteristic as a green label affects the pricing of an asset, everything else held equal. In these studies, the findings have been contrary. Zerbib (2019) finds a statistically significant yield difference between green bonds and their conventional equivalents where green bonds, on average, have 1,4 bp lower yield, while Larckey and Watts (2019) find no evidence of a yield difference.

1.3 Research question

The described studies and results have triggered our curiosity. Until now, there is conducted little research on the Nordic markets[2]. Our research will, therefore, look further into these markets by investigating the following research question:

Does a green label affect the yield and price of a bond and thereby create a greenium[3] in the Nordic secondary bond market, and which characteristics determine the potential greenium?

In standard theory, investors are rationale and optimize their expected risk-adjusted return according to the expected risk and return. Based on that, there should not be a yield difference between green- and conventional bonds when the green label is the single aspect separating them. Hence, the belief of symmetric pricing forms our primary hypothesis, H_0, namely that there is no greenium in the Nordic Green bond markets. An alternative hypothesis, H_1, is that there is a greenium, and green bonds are trading at lower yields than conventional bonds. While a third hypothesis is that green bonds trade at higher yields than conventional bonds.

An explanation for greeniums is that there is too much capital allocated to asset managers with an investment mandate to buy green assets as green bonds. However, if investors are rationale

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[2] The Nordic market is here defined as the bond markets of Danmark, Finland, Iceland, Norway, and Sweden.

[3] Greenium is defined as the negative yield difference between a green- and conventional bond, in other words the yield of the green bond minus the yield of the conventional bond.

and not willing to accept lower yields on green bonds, this should not be possible because investors should then reallocate their investments. A plausible explanation can be that investors do not only account for expected risk and return, but also the sustainability of their investments. Thereby the sustainability factor can outweigh a loss of monetary profit to some degree. Finding plausible rationale explanations for why green bonds should return a higher yield than equal conventional bonds in our study is hard to imagine.

1.4 Contribution to literature

Research on green bonds in the Nordic markets is limited, as green bonds are a relatively new research topic. Consequently, there are not many papers covering the subject. However, Drage and Sundt (2018) have written a master thesis about green premiums in the Norwegian and Swedish bond markets, where they perform both a quantitative and qualitative approach to look at investors' preferences.

Our study will contribute new information on this research topic by dividing the Nordic green bond markets into different subsamples and analyze if the greenium varies between them and not just identifying if there is a greenium for the market as a whole. Further, it will analyze whether some characteristics affect that potential greenium, e.g., issuance amount or coupon level, etcetera. Lastly, our thesis is going to contribute to the existing literature by describing the Danish, Finnish, Icelandic, Norwegian, and Swedish bond markets. This study will, therefore, contribute with valuable insight for both (potential) issuers of green bonds, and investors considering investing in green bonds in the Nordic markets.

1.5 Methodology

Our methodology is a matching approach inspired by Zerbib (2019). The central concept is to match one green bond with two similar conventional bonds from the same issuer, making triplets consisting of three bonds. The bonds should be similar on all characteristics except for the green label. Various imposed constraints ensure a high similarity between the bonds in each triplet. Bloomberg Terminal and Stamdata are used to retrieve the bond characteristics and their corresponding bid- and ask yields. Combining the yields from the two conventional bonds in each triplet then forms a synthetic conventional bond with the same maturity as the green bond match. Doing this makes it possible to isolate the effect of the green label as the green- and synthetic bond matches shall be similar in all characteristics except for the green label of the bond.

After creating all possible matches complying with our constraints, a fixed effects regression is run to isolate the effect of the green label in all our 77 pairs, resulting in a sample of 77 fixed effects. Afterward, a Wilcoxon test is conducted on the sample and on different subsamples to see if there is a difference in yield between the green- and conventional bonds in the full sample or some of the subsamples. Lastly, an OLS regression is conducted to see whether different bond characteristics can explain the greeniums.

1.6 Findings

For the full sample of matched bonds, findings show that green bonds have a yield that is, on average, 0.4 bp lower than the conventional bonds. However, this greenium is not statistically significant from zero. Dividing the sample into subsamples to see whether there are greeniums in some of the subsamples provides other results. In some of the subsamples, findings show statistically significant greeniums. They are quite small; hence the economic significance can be discussed; but they are observable.

For bonds issued in Swedish Krona, a greenium of 0.64 bp is found. While for investment grade bonds and bonds with an issue amount between 251-500 million SEK, green bonds have respectively 0.6 bp and 1.2 bp lower yield. Lastly, when regressing the yield differences as the dependent variable, it was only the current coupon size that had a significant effect explaining the difference in greeniums.

1.7 Disposition of the thesis

The rest of this thesis consists of eight sections and is organized in the following manner. The upcoming section describes the background and development of the global and Nordic green bond market. Selection three describes and discusses relevant literature on green bond premiums and pricing. In the fourth selection, the methodology used building the dataset, as well as, the dataset is going to be explained. Further, selection five describes the empirical methodology. The result of our empirical model is then presented in section six. After that, in section seven, a discussion of our results and the limitations of the thesis is conducted. Lastly, the conclusion summarizes our findings and conclude in selection eight.

2. Background

2.1 Green bond definition

The International Capital Market Association's (ICMA) definition of a green bond is (ICMA, 2018, p. 2):

"Green bonds are any type of bond instrument where the proceeds will be exclusively applied to finance or re-finance, 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."

2.2 Green Bond Principles and Certification

In 2014 the ICMA, along with thirteen major investment banks, among others Bank of America Merrill Lynch, Goldman Sachs, JPMorgan Chase, and SEB, formed the Green Bond Principles (GBP) (Climate Bonds Initiative, 2014). The principles are voluntary process guidelines for the issuers of green bonds. These guidelines aim to encourage transparency and disclosure of the use of proceeds from green bond issuances and thereby promote integrity and trust to green bonds and the green bond market's development. Because the green bond market is self-regulated, these principles minimize the risk of issuers issuing green bonds with the intent of greenwashing their reputation using proceeds on non-green projects.

The GBP is composed of four core components, which are (1) the use of proceeds, (2) the process for project evaluation and selection, (3) management of proceeds, and (4) reporting (ICMA, 2018). The first principle, use of proceeds, is the cornerstone of the GBP. It states that the proceeds of a green bond should be used in green projects with clear environmental benefits and that the legal document shall describe information about the project and consequences related to the project.

The second principle, the process for project evaluation and selection, states that the issuer should clearly show and communicate the environmental sustainability objectives. They should also present the process of which the bond is determined to fit the category of a green bond, and the related eligibility criteria (ICMA, 2018).

Management of the proceeds is the third principle. This principle describes how the proceeds should be managed. It encourages a high level of transparency in the management of the proceeds. It states, among other things, that the net proceeds of the bond should be credited to a sub-account and traced by the issuer to ensure that all proceeds used are associated with the intended green project (ICMA, 2018).

The last principle is reporting. It gives information about how the issuer should inform the public, with up to date information, about the use of proceeds until the full amount is employed. Additionally, the expected impact of the use of the proceeds should be reported (ICMA, 2018). For a closer look at the GBP, please read the report from ICMA[4] *Green Bond Principles Voluntary Process Guidelines for Issuing Green Bonds* from 2018.

In addition to the mentioned principles, ICMA (2018) strongly recommends an external review of the project evaluation and selection process linked to the green bond to verify if it is in line with the GBPs. The goal of external reviews and certifications of the green bonds is to provide credibility to the green bond being an environmentally friendly project. The price of a third party review increases issuance costs for green bond providers. However, these costs are modest and vary from approximately USD 12 000 - 40 000 (Andersson et al., 2017). S&P, Moody's, DNV GL, CICERO, and EY are examples of the agents providing these reviews.

It is possible to go beyond just external reviews and certify the green bond. Certifications follow the requirements of the Climate Bond Standard and Certification Scheme (CBSCS). The CBSCS is fully integrated with the GBP and where established in 2010 by the Climate Bond Initiative (Climate Bond Initiative, 2018a). The CBI is an international investor-focused non-profit organization established to mobilize the market for climate change solutions.

2.3 The green bond market's role and history

ICMA (2018, p 2) defines the aim of the green bond market as "*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*". The development of the green bond market has

[4] The report is available at https://www.icmagroup.org/green-social-and-sustainability-bonds/green-bond-principles-gbp/

rallied in later years due to an increased focus on the climate and thereby environmentally friendly investments.

In the early 2000s before the establishment of the green bond market, the attention for climate change had been rising among investors. As a result, the PRI was established in 2006, with support from the United Nations (UN). Until 2019 approximately 2300 investors have signed to follow the principles (Principles of Responsible Investment, 2019). PRI aims to make investors and asset managers integrate ESG factors into their overall investment strategy.

The pioneering bond of the green bond market was issued in 2007 by the European Investment Bank (European Investment Bank, 2019). The bond was the world's first Climate Awareness Bond and had an issue amount of EUR 600 million focusing on renewable energy and energy efficiency. One year later, after collaboration with SEB, the World Bank issued the world’s first labeled green bond. It raised an amount of 2.35 billion SEK, equivalent to USD 440 million at that time (The World Bank, 2019).

In the first years, only Multilateral Developments Banks issued green bonds. The tracking of the labeled green bond market started in 2009 when the Climate Bond Initiative[5] (CBI) started tracking it (CBI, 2019a). Over the years, the market has developed, and in 2013-2014 corporates and private banks entered the market, issuing their first green bonds (European Commission, 2016). Supporting this entry and the later development was the creation of the GBP in 2014. After the entry, there has been an exponential growth in issues volumes of green bonds, as seen from Figure 1.

The growth has further been supported by the UN, which created the Sustainable Development Goals in 2015, climate action is one of the seventeen goals, and green bonds is one of many possible climate actions (United Nations Development Program, 2019 and United Nations, 2019). The latest updated statistics from the CBI states that issuances aligned with CBI’s green bond definitions have increased past USD 200 billion and reached USD 211.4 billion as of 21.10.2019.

[5] The Climate Bond Initiative is an international investor-focused non-profit organization established to mobilize the market for climate change solutions.

Figure 1: Annual green bonds issuings

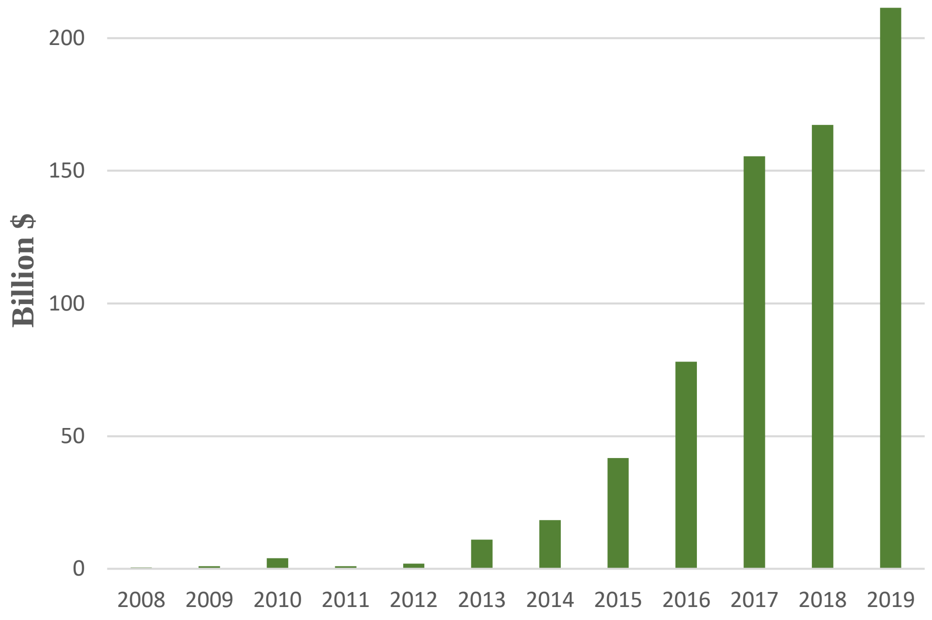

***Figure 1** presents the global annual issuance amount of green bonds aligned with the standards of the CBI from 2008 to 21.10.2019; only externally reviewed bonds are counted. Source: CBI, 2018, authors' calculations.*

Three world regions account for almost the entire issuance of reviewed green bonds. These regions are Europe, Asia-pacific, and North America, as seen in Figure 2. In 2018 approximately 28 percent of the issuances came from Asia-pacific. While North-America held approximately 23% of the market, both their issuance amount and proportion of the total issuance amount decreased from 2017 to 2018. Europe has the highest proportion of the green bond issuances, and in 2018 it accounted for around 40 percent of the total global issuance volume. Statistics from CBI (2019b) show that approximately 85 percent of the proceeds move into energy-, building-, transport-, and water projects. CBI (2019b) also describes that financial corporates, asset-backed securities, non-financial corporates, development banks, and government-backed entities are the major groups of issuers.

Figure 2: Issuing levels of green bonds

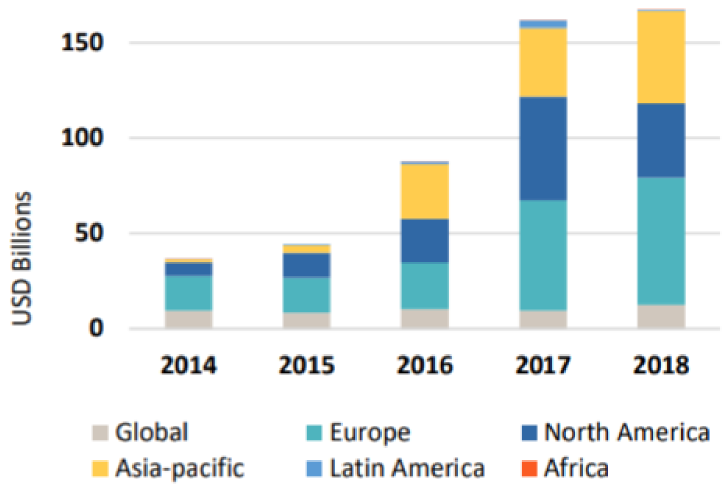

Figure 2 *presents the development in issuance amount divided between the continents over the period 2014 to 2018. Source: CBI 2019*

2.4 The Nordic green bond market

The development of listed green bonds in the Nordics started in Norway in May 2010 when Kommunalbanken issued the first green bond in the Nordics (Climate Bond Initiative, 2018c). While Vasakonan, a Swedish real estate firm, issued the world's first-ever corporate green bond in 2013 (Vasakronan, 2018). The first municipal green bond was also issued that year by the city of Gothenburg (UNFCC, 2019).

Sweden has been one of the frontrunners in the development of green bonds. The Swedish development is, among other things, a result of SEB’s central role in the creation of the first-ever green bond, as mentioned in the past selection. Another explanation is the substantial focus on sustainability and the environment in Sweden. A consequence of this early adaption and focus is that the green bond market in Sweden has become, by far, the largest green bond market in the Nordics, as seen from Figure 3.

The development of the green bond market in the rest of the Nordic countries has lagged that of the Swedish, as shown in Figure 3. The first green bonds in Denmark and Finland were issued in 2015 and 2016. However, these bonds were not listed (Climate Bond Initiative, 2018c). Furthermore, Iceland's first green bond was issued as late as December 2018 (Nasdaq Nordic, 2018).

In 2015, in the early days of the listed green bond market, Oslo Børs became the first stock exchange to launch a separate list for green bonds (Oslo Børs, 2019), facilitating green bond issuances in Norway. However, the development of the issue amount in the Norwegian green bond market has not had the same development as seen in the Swedish market.

Figure 3: Yearly Issuance Amount Listed Green Bond in the Nordics

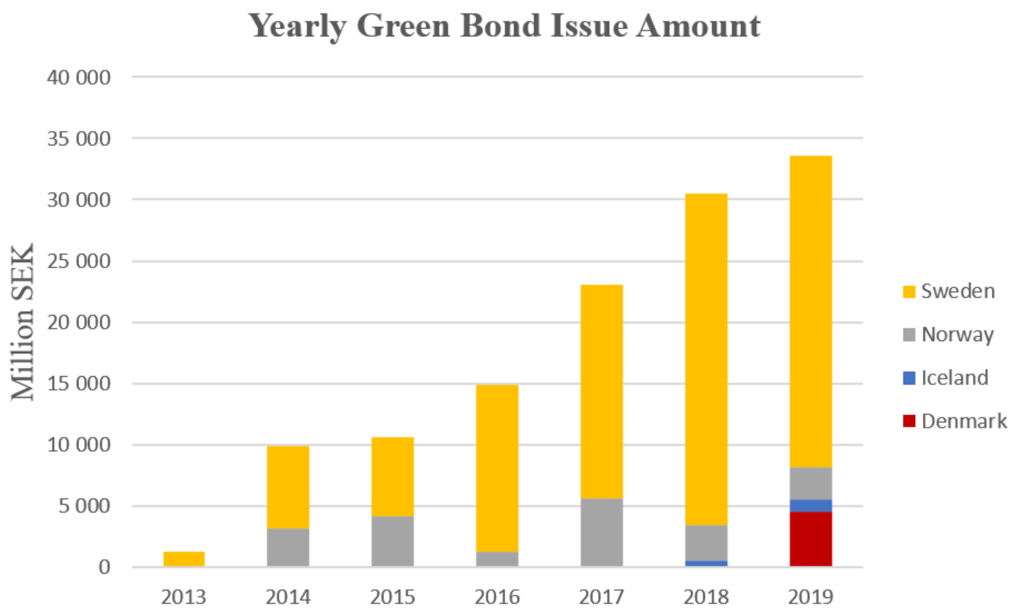

Figure 3 *shows the yearly issuance amount of listed green bonds in the Nordic market. The bars show both the issuance of the total issuance amount in the Nordic market and the amount of each country. The issuance amount for 2019 is the issuance amount until 07.11.2019. Source: Stamdata, Nasdaq Nordic, authors' calculations.*

In Finland, Iceland, and Danmark, the green bond markets are still in a very early development stage. The Finnish market has no listed green bonds, but there have been a few issuances of non-listed municipal green bonds in 2018 and 2019 (Nasdaq Nordic, 2019). For the Icelandic market, the first green bond issuances took place in 2018, followed by two new issuances in 2019. The first issuance of listed green bonds in the Danish market took place in 2019. Real estate has accounted for the majority of the green bond issuance amount from the beginning in 2013 until today, as shown in figure 4. However, the development of the Nordic green bond markets has increased the diversity of firms issuing green bonds. Until now[6], companies from eleven different industry groups have issued green bonds.

Figure 4: Share of Green Bond Issuance Amount per Industry Group

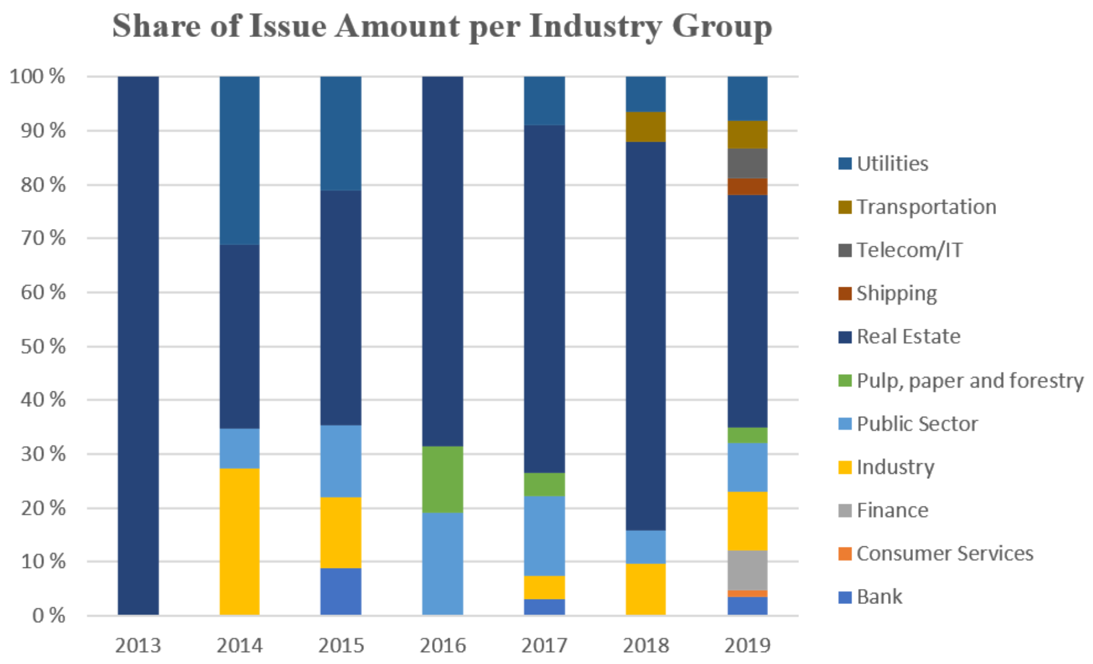

***Figure 4** presents the share of the total issuance amount each industry group has contributed within each year after 2019. Source: Stamdata, Nasdaq Nordic, Authors' calculations.*

[6] Date: 21.10.2019

3. Literature Review

With the exponential growth in the number of green bond issuances during the last couple of years, the number of research covering green bonds has also slowly increased. This section will present some of the previous studies conducted. The first part of this section will describe previous research on the relationship between environmental performance and the cost of financing. Then, previous research done on green bond premiums will be presented and discussed.

3.1 Environmental performance and the cost of financing

The relationship between a company's environmental profile and its financial performance is the subject of numerous studies. As the results from these studies vary a lot, no real consensus seems to have been reached. However, most of these studies seem to report a positive effect from CSR and ESG (in which environmental focus is an essential factor) on financial performance. The vast majority of these studies focus on the equity market, while studies investigating the debt market has historically been more limited.

Kempf and Osthoff (2007) find that a high CSR score, on average, has a positive effect on the company's stock return. In their study, they construct a trading strategy that buys/sells stocks with high/low CSR scores and manage to achieve significant alphas. This positive effect from CSR on financial performance is also found by Sharman and Fernando (2008) in their study on US firms. They find that firms with high environmental performance tend to achieve lower volatility, reducing their equity cost of capital. Additionally, they suggest that firms with high environmental performance are more popular among equity investors, driving up the demand for these stocks, further lowering their equity cost of capital. Chava (2014) finds that investors require a higher expected return for stocks that are subject to environmental concerns, such as substantial emissions or hazardous chemicals, driving up the equity cost of capital

In addition to the increase in the equity cost of capital, Chava (2014) finds that less environmentally friendly firms, on average, have to pay higher interest on their bank loans, increasing their cost of debt. Menz (2010) is one of the first to run research on how CSR affects bond yields. Surprisingly, in his study on European firms, he finds that socially responsible firms, on average, get a higher credit spread on their bonds, increasing the debt cost of capital. However, it is worth noting that as his results are just marginally significant, he suggests that

CSR not yet has been incorporated into the pricing of bonds. Oikonomou et al. (2014) find the opposite results in their study on US corporate bonds. Their findings suggest a negative relationship between corporate social performance (CSP) and bond credit spread. A study on 582 US firms, conducted by Bauer and Hann (2010), yields similar results. According to them, environmental concerns are associated with higher credit spreads, and therefore an increase in the debt cost of capital. Stellner et al. (2015) investigate Eurozone corporate bond yields and find only weak evidence that CSP reduces credit spreads. Additionally, their findings suggest that the relationship between CSP and bond credit spread highly depends on the country's ESG performance.

The majority of the studies presented above seem to indicate that environmental performance has a positive effect on both equity- and debt cost of capital. However, it is essential to remember that this relationship, to a large degree, is determined by investor preferences. As these preferences vary over time, so can the relationship between environmental performance and cost of capital. Additionally, it is worth noting that these studies investigate if firms with an excellent environmental profile achieve a better cost of financing compared to less environmental friendly firms. These studies do not indicate whether there exists a price difference between green and conventional bonds from the same issuer.

3.2 Current knowledge about the green bond premium

As pointed out in the background section, green bonds are a rather new type of financial instrument. The number of green bonds outstanding has also been small. Hence previous studies investigating the price of green bonds relative to conventional bonds are limited. However, with the recent exponential growth in the number of green bonds, the amount of studies has also increased. These studies vary both in the method used, and in the results presented.

Research conducted by the CBI (2019c) on a total of 61 EUR and USD denominated green bonds issued in the first half of 2019 finds that around 1/3 of these bonds experienced an oversubscription and a tighter spread compared to equivalent conventional bonds. These findings indicate the existence of a greenium in the primary market. The CBI (2019c) finds this difference in yield by comparing the green bonds with baskets of conventional bonds. The baskets are created by finding the most similar conventional bonds to that of the green bond.

Barclays (2015) uses a cross-sectional analysis where they regress the credit spreads on several explanatory variables explaining spread, including a dummy for green. Barclays (2015) studies the global green bond market and finds an average greenium of 17 bp in the secondary market in the period between March 2014 and August 2015. Barclays (2015) also find that the greenium has increased steadily over time.

Zerbib (2019) analyze the existence of a greenium in the secondary market. He does so by using a matching methodology, in which he matches 135 investment grade fixed-rate bullet green bonds issued worldwide, with a conventional synthetic bond. The synthetic bond is based on two conventional bonds, with similar characteristics as the green bond. After controlling for differences in liquidity, he estimates the greenium by conducting a fixed effects regression. The greenium is defined as the time-invariant fixed effect. His findings suggest that overall, green bonds trade at a lower yield of -1.8 bp compared to conventional bonds. Additionally, Zerbib (2019) divides his full sample into subsamples based on the main characteristics of the bond. For some of the market segments, he finds no greenium. Hence, his findings suggest the estimated yield difference between green- and conventional bonds vary between different markets and industries.

NN Investment Partners (2018) study the yield difference between labeled global investment-grade green bonds and similar conventional bonds from the same issuer, having the same maturity and seniority as the green bond. They split their analysis into two parts: one where they study 67 green bonds in the period between December 2014 to May 2016, and one where they study 126 green bonds in the period between June 2016 and November 2017. For the first period, they find greenium equal to 1.1 bp. For the second period, they find a greenium of 0.7 bp. Their results indicate that the absolute greenium has decreased over the years.

Karpf and Mandel (2018) examine the yield term structures of 1880 US municipal green bonds and conventional municipal bonds from the same issuer, in the period between 2010 and 2016. They report that green bonds on average trade at a higher yield of 7.8 bp compared to conventional bonds, arguing that the green label seems to be penalized by investors. However, they also find that the yield difference went from positive to negative from 2015 and onwards.

Ehlers and Packer (2017) examine the yield difference at issuance between 21 green bonds and conventional bonds from the same issuer. They document that these green bonds priced at a greenium of 18 bp relative to conventional bonds at issuance. They also examine yield differences in the secondary market by comparing the return of green bond indices with global bond indices. To control for differences in currency composition between the two indices, they examine the hedged-returns. Ehlers and Packer (2017) find no statistically significant difference in secondary market returns between green bond indices and global bond indices.

Larcker and Watts (2019) perform a study on 568 individual US municipal green bonds. They estimate the yield difference between the green bond and the most similar conventional bond issued on the same day by the same issuer. Larcker and Watts (2019) argue that the US municipal market is advantageous for this type of research because municipal issuers commonly issue loads of bonds at the same time, making it possible to match identical bonds which only differ by the green label. This characteristic makes it possible to control for maturity without matching each green bond with several conventional bonds. They find no evidence of a greenium in the US municipal bond market and state that investors are unwilling to sacrifice wealth to invest in environmental-friendly securities.

As described, there is a vast variation in the estimated greenium in these previous studies, ranging from positive to negative values. The majority of the studies focus on the global green bond market, and there is only a defined number of studies on smaller market segments. This focus is, among other things, due to the limited amount of green bonds outstanding up until recent years, making analyses on some specific market segments difficult. Consequently, our study of the Nordic green bond markets will contribute to new and valuable insight into these markets.

4. Data retrieval, matching methodology, liquidity proxy, and data description

Chapter 4 starts with elaborating on the data retrieval, the matching process, and the creation of the liquidity proxy. This elaboration will give an understanding of the construction of our data set. Lastly, the structure and descriptive statistics of our data are presented to give a clear understanding of what the data set looks like and what characteristics it contains.

4.1 Data retrieval and cleaning

The first step was to identify all green bonds issued in the Nordic markets from 2013 up until 21.10.2016. Only listed green bonds were identified due to the need for regular liquidity and quoted bid and ask yields in our methodology. The rationale behind using bonds issued from 2013 and onwards is that 2013 was the starting year of the corporate green bond market and the year when the issuance growth started rallying. Nordic issuers have issued green bonds listed on London Stock Exchange and other non-Nordic exchanges (CBI, 2018b). These bonds are not included as the scope of this thesis is to study the Nordic markets and thereby the Nordic stock exchanges.

Another requirement for becoming a part of our green bond sample is that the green bond needs to have undertaken an external review. There are two primary reasons for this criterion. Firstly, all filtrable green bonds on Stamdata and Nasdaq Nordic are reviewed by third parties. Hence, finding the self-labeled green bonds is problematic, given our data-source. Secondly, as earlier mentioned, the green bond market is self-regulated, resulting in the possibility to self-label bonds as green with the intent to greenwash the company profile. In our belief, this threat is almost removed by excluding bonds without external reviews. Therefore the probability of finding a greenium between externally reviewed green bonds and conventional bonds, compared to a pool of both externally reviewed and self-labeled green bonds and regular bonds, should be higher. The rationale behind this belief is that an external review gives the green bond more credibility of actually being green, and not just a greenwashing item.

Initially, all externally reviewed green bonds (hereafter just referred to as green bonds) listed on the Nordic stock exchanges[7] were identified using Stamdata filtering for green bonds. Then Nasdaq Nordic was used to find all green bonds listed on the Iceland Stock Exchange/Nasdaq Island (ICEX). This process resulted in findings of 217 green bonds from 72 different issuers. Of these bonds, 80 percent are denoted in SEK while approximately 15 percent in NOK, 1 percent in DKK, 2 percent in Euro, and 1 percent ISK. The majority of the green bonds are, as expected, listed on Nasdaq Stockholm. For a view of the full sample of the different issuers, amounts, and the number of bonds, see Appendix Figure A3.

After the retrieval of the green bonds, all conventional bonds in the Nordics were retrieved from Stamdata. From that sample, the detection of all bonds issued by the same issuers and in the same period as the green bonds where done filtering on issuers and time. Lastly, the combination of these samples was completed to enable the matching procedure of the green and conventional bonds creating our triplets[8]. In the find the best matches, all bonds were sorted on characteristics such as issuer, maturity date, issue amount, coupon size, among other things to combine the most efficient triplets following our matching criteria, which will be described further in selection 4.2.

Subsequent to matching the triplets, daily bid- and ask-yields for all bonds in our matched sample from their issue date until 21.10.2019 were retrieved, with the use of Bloomberg Terminal. Then a merging of the yield observations with their respective bonds was done. Lastly, all dates where one or more of the bonds in a triplet were missing a yield observation was removed from all bonds in the respective triplet. The preference for daily yield observations is due to the relatively recent issuances for many of the bonds in our sample. Hence, using daily data will give a better view of the difference in yield and liquidity between the green- and conventional bonds. However, using daily data might impose some challenges because of low liquidity in the Nordic bond markets. Thereby, the low liquidity might infer yield observations that deviate from the real market value. As a robustness test of our results,

[7] Nordic stock exchanges: Nordic ABM (ABM), Oslo Stock Exchange (OSE), Stockholm Stock Exchange/Nasdaq Stockholm (OMX), Copenhagen Stock Exchange/Nasdaq Copenhagen (KFX), Nordic Derivatives Exchange (XNDX), First North Sweden (FNSE), and Helsinki Stock Exchange/Nasdaq Helsinki (HEX);

[8] A triplet is a group of bond consisting of two conventional bonds and one green bond. These are matched to create a synthetical conventional bond which is similar to the green bond in all aspects except for the greenness.

the fixed effects regression, described in Selection 5.1, is also conducted with weakly and monthly observations.

4.2 Matching Method

As described earlier, green bonds are a relatively new type of financial instrument. Hence, previous research on green bond premiums in the secondary market is still relatively limited. A small selection of different methods has previously been conducted, with various strengths and weaknesses. One possible method to try to identify a greenium would be to use an OLS regression similar to the one used by Barclays (2015). However, not managing to include all relevant variables would make the regression biased, leading to misleading results. Additionally, because yield observations are not independent of each other, such a method can have biases.

Avoiding omitted variable biases can be done with a matching methodology. Here all green bonds are matched with conventional bonds that are similar in all aspects except for the green label. Hence, this method is preferred because it allows us to ignore all variables that do not differ between the green and the conventional bonds. The matching method is known as a quantitative model-free approach, and it is previously applied for assessing a potential green premium by Zerbib (2019) and Larcker & Watts (2019). It has also been used to investigate potential additional returns of ethical funds (Kreander et al. (2005) and Renneboog et al. (2008)), and to investigate the costs of liquidity (Helwege et al. (2014)).

Matching can be done by matching a green bond with one or more conventional bonds. Helwege et al. (2014) and Larcker & Watts (2019) have matched each green bond with one conventional bond. In Larcker & Watts (2019), this method is suitable because they study the American municipality market where a group of bonds is issued at the same time with the same maturity from the same issuer. Hence, they can match exactly on all characteristics and isolate the effect of the green label completely. However, in our bond sample, very few bonds are issued by the same issuers on the same dates. Therefore, matching just one conventional bond with each green bond would create a maturity bias, which is the case in Helwege et al. (2014). To avoid the occurrence of such a bias, the method used in this thesis is similar to Zerbib (2019), where each green bond is matched with two conventional bonds. Further, having two conventional bonds for each green bond makes it possible to combine the conventional matches into a synthetic conventional bond with the same maturity as the green bond.

Optimally the green bonds and the conventional matches should be equal in all characteristics except that one is green and the conventional bonds are not. However, liquidity is impossible to match precisely. Additionally, it is troublesome to accurately match the maturity date, issue date, issue size, and coupon size while at the same time, get a sufficiently large data sample. Therefore, to get a sufficiently big sample while still getting reliable results, various restrictions on the difference between the matched bonds have been imposed.

The matching restrictions used in this thesis is similar to the restrictions used in Zerbib (2019). Potential conventional bond matches need to be issued by the same issuer, with identical currency, seniority, high yield/investment grade, sector, bond structure, collateral, and coupon type as their respective green bond matches. In terms of maturity, a restriction for conventional bonds is imposed. The conventional bond matches can mature at most two years before or two years after the green bond. These restrictions will make the estimated yield for the synthetical bond more accurate.

As mentioned, it is not possible to match the liquidity of the different bonds exactly. However, it is critical to control for difference in liquidity, because it can affect the yield of a bond (Chen et al. (2007), Beber et al. (2009), Bao et al. (2011), Dick-Nielsen et al. (2012), de Jong & Driessen (2012)). Therefore, various restrictions are imposed on the issue date and issue amount similar to Zerbib (2019). In addition, a limitation on the allowed variation in the coupon level is set as a requirement. These restrictions let us control for some of the liquidity bias, as bonds' liquidity can partly be controlled through the mentioned bond characteristics (Bao et al. (2011) and Houweling et al. (2005), Helwege et al. (2014)). Further, these restrictions will make our results more reliable as there is less residual liquidity to control for by our bid-ask spread liquidity proxy, which will be described in selection 4.7.

The first restriction is that the issue date of the conventional bonds should not be greater than six years before or six years after the green bond. While the issue amount of the conventional bonds cannot be more(less) than four times (one fourth) of the issue amount of the green bond, furthermore, the current coupon size must be within a range of plus/minus 80 basis points. In the matching process, the two conventional bonds that match the respective green bond best and fulfill all our criteria are chosen. This process resulted in a loss of 139 green bonds, leaving us with a sample of 77 triplets containing as many green bonds and 154 conventional bonds. A further description of the final sample is conducted in selection 4.6.

4.3 Removing maturity bias

Removing maturity bias is done by combining the two conventional bonds in each triplet to create a synthetic conventional bond with the same maturity date as their green match. This process is done in the same way as Zerbib (2019), by linear interpolation or extrapolation of the conventional bonds ask-yields[9] at the green bonds' maturity date. Extrapolation is used when the green bond mature either before or after both the conventional bonds. While interpolation is conducted when one of the conventional bonds mature before the green bond, and the other conventional bond matures after the green bond[10].

Inter- and extrapolation is here a reliable solution because the yield curve is generally assumed to be monotonic, and generally increasing. Additionally, a linear approach is efficient as the triplets contain bonds that have maturity dates in close proximity. Hence, a possible deviation due to the linear approximation should be close to nothing. For a further discussion about the strengths and weaknesses of our method, see Selection 7.2. The following formula is used when extrapolating/interpolating:

(1) $$y_{\sim B} = y_{B1} + \frac{y_{B2} - y_{B1}}{X_{B2} - X_{B1}} * (X_G - X_{B1})$$

where:

- $y_{\sim B}$*: Conventional synthetic bond ask yield*
- y_{B1}*: Conventional bond 1 ask yield*
- y_{B2}*: Conventional bond 2 ask yield*
- X_G*: Days until maturity green bond*

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[9] Ask-yields are preferred in our thesis because it investigates investors demand and preferences for green bonds and they buy at the ask price and thereby get the return of the ask yield.

[10] See Appendix Figure A1a and A1b for illustrative figures of extra- and interpolating.

- X_{B1}*: Days until maturity conventional bond 1*
- X_{B2}*: Days until maturity conventional bond 2*

The rationale behind using ask-yield is, as mentioned in the footnote, to study investor's demand for green bonds, thereby, what they must pay for a green bond compared with a conventional bond. Other possible solutions would be to look at the bid-yield or the average of the bid- and ask-yields. However, using the ask yield should not have any practical effects on our results because the bid-ask spread of the green and conventional bonds are practically equal for both the conventional- and the green bonds[11].

4.4 Liquidity proxy

Numerous studies are investigating whether investors get compensated for holding relatively illiquid securities. Friewald et al. (2012) examine whether liquidity affects bond yields by analyzing more than 20 000 US corporate bonds, using several different liquidity proxies. They find that liquidity explains as much as 14 % of the corporate bond yield changes. Lin et al. (2011) use both the Pastor-Stambaugh[12] and Amihud[13] measures as liquidity proxies in their research on corporate bond yields. Their findings suggest the existence of a statistically significant liquidity premium. It is, therefore, necessary to control for the residual difference in liquidity between bonds. Houweling et al. (2005) argue that the issue date and the issue amount are suitable measures for bond liquidity. Since restrictions are set on the difference in issue amount, issue date, and coupon level within the triplets during the matching process, some of the potential differences in liquidity are already removed.

Further, to control for the residual liquidity difference, which is the difference not captured during the matching process, a liquidity proxy is included in our regression model. As in

[11] As the bid-ask spread of the green and conventional bonds are practically equal this choice shall not affect our results, because using bid-yields or the average of the bid- and ask-yield will give the same results. See selection 4.6, for a descriptive statistics of the bid-ask yields of the bonds.

[12] The Pastor-Stambaugh liquidity measure captures temporary price changes linked to order flow. This measure relies on the principle that order flow generate greater return reversal when liquidity is lower.

[13] The Amihud liquidity measure focuses on how trades affect prices. According to this measure the liquidity for a given security is high if a large volume of that particular security can be traded with little impact on the the price.

Zerbib (2019), this thesis uses the difference in bid-ask spread between the green bond and the synthetic bond as a liquidity proxy. Fong et al. (2017) argue that the bid-ask spread is the most accurate liquidity proxy for this type of research. The bid-ask spread has been broadly used as a liquidity proxy in previous studies, such as Dick-Nilsen et al. (2012) and Chen et. Al. (2007)

First, the bid-ask spread for the synthetic conventional bonds was calculated. The spread is computed by taking the bid-ask spreads of the two conventional bonds and weighting them based on the difference between their and the green bond's maturity date. A distance weighted estimation is preferred over extrapolation in the calculation of the synthetic bid-ask spread due to the implicit assumption of a linear relationship between the bid-ask spread and maturity when extrapolating. While the distance weighting approach lays most weight to the bond that has the closest maturity to the green bond. This method should yield sufficient precision as the spreads between the two conventional bonds in each triplet is small, see Section 4.7. Therefore, and similar to Zerbib(2019), the following equation is used to make the synthetic bid-ask spread:

(2) $$BA_{i,t}^{\sim B} = \frac{d2}{d1 + d2} * BA_{i,t}^{B1} + \frac{d1}{d1 + d2} * BA_{i,t}^{B2}$$

Where:

$BA_{i,t}^{B1}$ and $BA_{i,t}^{B2}$ are the bid-ask yield spreads for conventional bond i 1 and 2 at time t.

and

d1 = |Green bond maturity - CB1 maturity|
d2 = |Green bond maturity - CB2 maturity|

When the bid-ask spreads for the conventional synthetic bonds ($BA_{i,t}^{\sim CB}$) is created, the liquidity proxy, used in our regression model in Selection 5.1, is estimated. The liquidity proxy is defined as the difference in bid-ask spread between the green- and synthetic bond:

(3) $$\Delta BA_{i,t} = BA_{i,t}^{GB} - BA_{i,t}^{\sim CB}$$

where $BA_{i,t}^{GB}$ is the bid-ask yield spread for green bond i at time t.

4.5 Defining the yield spread

After matching each conventional synthetic yield to its respective green bond yield, the daily yield difference between the green bond and the conventional synthetic bond was calculated. Calculations are done by subtracting the ask-yield of the conventional synthetic bond from the green bond's ask yield. The yield difference is defined as:

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

Where $y_{i,t}^{GB}$ and $y_{i,t}^{\sim CB}$ is the green- and the conventional synthetic bond i's ask yield on day t.

Our data sample may contain possible errors from Stamdata, Bloomberg Terminal, or our data handling, e.g., inter-/extrapolation. As seen from Figure 5, there are a few extreme outliers in the dataset. To control for the effect of spurious outliers and make sure they are not passed on to the analysis a winsorization of the estimated yield difference, $\Delta\tilde{y}_{i,t}$, is obtained at the 0,5th and 99,5th percentile.

Figure 5: Yield difference distribution

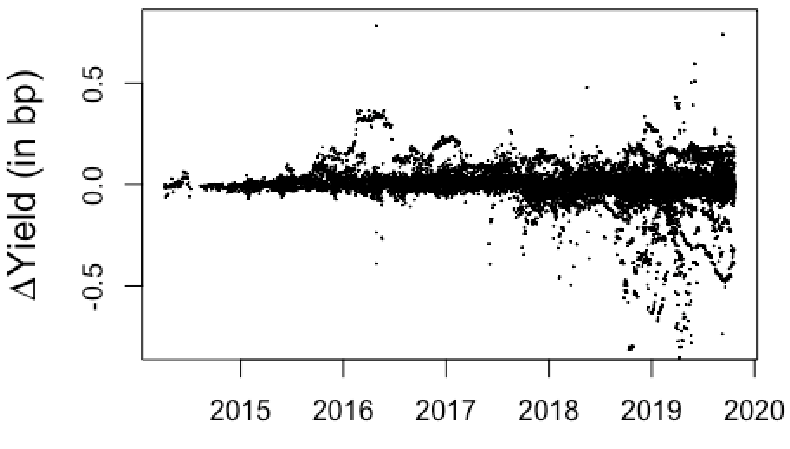

Figure 5 *shows the distribution of the yield difference between the green- and conventional bonds. ΔYield is expressed in basis points.*

4.6 Data description

There is a total of 216[14] green bonds listed on the Nordic stock exchanges, including Iceland. Use of the matching criteria given in selection 4.2 resulted in 77 matched triplets containing as many green bonds and 154 conventional bonds. Of the 154 conventional bonds, 117 are unique. Hence, some conventional bonds are used to match several green bonds. As the conventional synthetic bonds are extrapolated/interpolated at the green bonds' maturity, all synthetic yields are modified to their respective green matches. Using the most similar conventional bonds in this process will give the best results, even though it leads to the use of some conventional in more than one match.

As Table 1 shows, our dataset started with 72 unique Nordic green bond issuers. In the matching process, the number of issuers shrunk to 29 issuers. The currency dominating our sample is Swedish Krona (SEK). Seventy-one of the triplets are denominated in SEK, and just six triplets are denominated in NOK. Hence, all bonds from Finland, Denmark, and Island are lost. This fact is not surprising as there are very few listed green bonds in those markets. Also, worth noting is the fact that 72 of our triplets contain investment grade bonds, while just five have high yield bonds.

Furthermore, the majority of our triplets are formed of bonds issued by real estate companies, are in the risk class senior unsecured, and have a floating coupon. These characteristics are equal for both the green bonds and their matched conventional bonds. However, some traits vary between the green- and conventional bonds, namely issue date, maturity date, maturity length, and issue amount, which are going to be further elaborated in the next section.

[14] Icelandic green bonds are not included in the Nordic universe in the further description, as they are not on Stamdata. Not including them in the description should not give any bias for the description of the Nordic green bond universe because there are only three Icelandic green bonds.

Table 1: Sample construction and composition

Panel A: Sample Construction

	Bonds	Issuers
Full Stamdata Green bond sample	213	71
Total matched green bonds	77	29
Unique Conventional Bonds	117	29

Panel B: Sample Composition

	Variable	Matched GB	% of total	Matched CB	% of total
Issue	Unique Issuers	29		29	
	Issue Date (mean)	17.03.2017		30.10.2016	
Maturity	Maturity Date (mean)	27.05.2021		09.03.2021	
	Maturity Length (Mean Years)	4,20		4,36	
Currency	SEK	71	*92,2 %*	142	*92,2 %*
	NOK	6	*7,8 %*	12	*7,8 %*
Yield	Investment Grade	72	*93,5 %*	144	*93,5 %*
	High Yield	5	*6,5 %*	10	*6,5 %*
Issue Amount	Issue Amount (Total SEK MM)	39 272	*89,0 %*	66 723	*87,2 %*
	Issue Amount (Total NOK MM)	4 875	*11,0 %*	9 760	*12,8 %*
	Issue Amount (Mean SEK MM)	553		470	
	Issue Amount (Mean NOK MM)	813		813	
Risk	Government Guaranteed	7	*9,1 %*	14	*9,1 %*
	Municipality	1	*1,3 %*	2	*1,3 %*
	Senior Secured	2	*2,6 %*	4	*2,6 %*
	Senior Unsecured	67	*87,0 %*	134	*87,0 %*
Current Return Type	Fixed	23	*29,9 %*	46	*29,9 %*
	FRN	54	*70,1 %*	108	*70,1 %*
Industry Group	Bank	2	*2,6 %*	4	*2,6 %*
	Consumer Services	1	*1,3 %*	2	*1,3 %*
	Industry	1	*1,3 %*	2	*1,3 %*
	Public Sector	8	*10,4 %*	16	*10,4 %*
	Pulp, paper and forestry	1	*1,3 %*	2	*1,3 %*
	Real Estate	58	*75,3 %*	116	*75,3 %*
	Transportation	3	*3,9 %*	6	*3,9 %*
	Utilities	3	*3,9 %*	6	*3,9 %*
Total Number of Bonds		77		154	

***Table 1** Panel A shows the number of listed green bonds in the Nordics (except Iceland) and how many of these we have used. Further, it shows how many conventional bonds we have used to match the green bonds. Panel B shows the composition of our combined dataset and how our bonds are divided into different groups.*

Understood from the previous paragraph and Table 1 is that most of the different dimensions have one category that contains a large percentage of the total number of triplets. These categories are SEK denominated-, investment grade-, senior unsecured-, floating coupon-, and real estate bonds. As a result, the mentioned categories contain many of the same triplets. An overview is presented in Table 2. It shows how many triplets that are present in two different categories.

Most categories contain a high number of SEK and investment grade triplets, which is as expected due to the that almost all triplets are SEK denominated and investment grade rated. The investment grade and SEK categories hold a high degree of the same triplets. Hence, it can be expected that they are yielding similar results in terms of greenium. Section 6.2 is going to analyze this expectation. However, there are fewer triplets that occur in all the major categories, 31 in total. Therefore it is reasonable to believe that the greenium may vary more between other categories than it does between investment grade and SEK.

Table 2: Matrix of the number of triplets in the different categories

	#Triplets	%	#Triplets	%	#Triplets	%	#Triplets	%	#Triplets	%
SEK	71	100 %	66	93 %	62	87 %	50	70 %	57	80 %
Investment Grade	66	92 %	72	100 %	62	86 %	49	68 %	53	74 %
Senior Unsecured	62	93 %	62	93 %	67	100 %	46	69 %	56	84 %
Floating Coupon	50	93 %	49	91 %	46	85 %	54	100 %	37	69 %
Real Estate	57	98 %	53	91 %	56	97 %	37	64 %	58	100 %
	SEK		Investment Grade		Senior Unsecured		Floating Coupon		Real Estate	

***Table 2** presents a matrix of how many of the same triplets which are used in the same subsamples both in absolute numbers and in % overlap. The diagonal, marked in grey, represents the total number of triplets in each category. The percentage numbers in each row are the percentage overlap between two categories and the total number of triplets in the category on the left column. In other words, the total of observations that are in both categories divided by the total number of triplets in the category. The number shows how many triplets that are present in both categories.*

4.7 Descriptive Statistics

Table 3, Panel- A, and B presents various descriptive statistics characterizing the green- and conventional bonds. While Panel D shows the difference between the green bonds and the conventional bonds individually. Lastly, Panel E shows the difference between the green bond and the average of the two conventional bonds. Additionally, a Wilcoxen signed-rank test is conducted to determine if some features are significantly different between the green- and conventional bonds.

Some characteristics vary between the green bond sample and the matched conventional bond sample. First, the mean (median) issue amount for the SEK and NOK denoted green bonds are SEK 553 (500) million and NOK 813 (450) million. While for the non-green bonds, it is SEK 469 (500) million and NOK 813 (500) million. Further, the mean issue date has an approximate difference of five months. However, most characteristics are very similar, as the current coupon level, maturity date, bid-ask spread, and maturity length have similar characteristics in both samples.

As Panel E shows, the issue amount of the average the two conventional bonds in each triplet divided on their respective green bond is not statistically significant from one. Hence, there is no systematic difference in the issue amount between the green bond sample and the conventional bond sample. The similarity in the issue amount can also be seen from Panel D. However when investigating SEK denominated triplets, a significant difference is found.

Green bonds have, on average, an issue amount which is SEK 83 million higher than the conventional bonds. This difference indicates that the SEK denominated green bonds have a systematically higher issue amount compared to the average issue amount of their conventional matches.

Another finding is that the maturity date of the green bonds, on average, is 79 days after that of the conventional bonds. This difference is removed in the synthetic bonds by using inter- and extrapolation, as described in Section 4.3. Further, the issue date is also different as the green bonds are on average issued 139 days after their conventional matches. However, the maturity length of the different bonds is not significantly different from each other. The differences in some of our bond characteristics may have some influence on our results. However, the differences are relatively small in economic terms, and most are on characteristics that affect the liquidity of our bonds. As liquidity is controlled for in the first step of our fixed effect regression, the differences should not bias our results.

Table 3: Descriptive statistics

Panel A: Bond Characteristics (Matched Green Sample)	Mean	Median	SD	Min	p25%	p75%	Max	N
Issue Amount (SEK MM)	553	500	395	100	300	700	2 500	71
Issue Amount (NOK MM)	813	450	757	75	400	1 250	2 000	6
Current Coupon (%)	1,075	0,953	0,827	-0,287	0,539	1,250	3,964	77
Maturity Length (Days)	1532	1826	558	731	1096	1826	3652	77
Maturity Date	27.05.2021	04.10.2021	762	20.05.2016	14.04.2020	26.09.2022	31.01.2028	77
Issue Date	17.03.2017	30.08.2017	561	25.11.2013	03.06.2016	04.04.2018	02.09.2019	77

Panel B: Bond Characteristics (Convental Bond Sample)	Mean	Median	SD	Min	p25%	p75%	Max	N
Issue Amount (SEK MM)	469	500	264	100	250	600	1 500	142
Issue Amount (NOK MM)	813	500	757	150	219	1 559	2 000	12
Current Coupon (%)	1,040	0,900	0,809	-0,357	0,573	1,170	4,272	154
Maturity Length (Days)	1593	1826	619,742	639	1096	1826	3703	154
Maturity Date	12.03.2021	10.06.2021	769,1422	12.05.2016	18.10.2019	10.05.2022	07.02.2029	154
Issue Date	31.10.2016	25.10.2016	596,3918	12.03.2013	24.08.2015	01.02.2018	22.08.2019	154

Panel C: Difference Between Green- and Conventional Bonds	Mean	Median	SD	Min	p25%	p75%	Max	N
Issue Amount (SEK) CB1 / G	0,97	0,90	0,57	0,25	0,50	1,29	2,51	77
Issue Amount (SEK) CB2 / G	1,20	1,00	0,77	0,27	0,67	1,61	4,00	77
Issue Amount (NOK) CB1 / G	1,07	1,00	0,51	0,50	0,81	1,12	2,00	77
Issue Amount (NOK) CB2 / G	1,16	1,13	0,51	0,45	1,00	1,25	2,00	77
Maturity Date G - CB1 (Days)	12	45	271	-730	-179	180	504	77
Maturity Date G - CB2 (Days)	144	154	357	-673	-97	449	699	77
Issue Date G - CB1 (Days)	72	45	436	-1204	-183	263	1321	77
Issue Date G - CB2 (Days)	206	134	517	-916	-118	505	1883	77
Current Coupon G - CB1 (%)	0,02734	0,005	0,2137696	-0,775	0,086	0,12125	0,604	77
Current Coupon G - CB2 (%)	0,0415	0,0425	0,3008644	-0,725	-0,1113	0,2192	0,791	77

Panel D: Difference Between Green- and average of the Conventional Bonds (with t-test)	Mean	Median	SD	Min	p25%	p75%	Max	N
Issue Amount CB / GB	1,08	1,00	0,55	0,33	0,72	1,50	2,50	77
Issue Amount GB - CB (SEK MM)	83*	0	289	-375	-122	244	1400	77
Issue Amount GB - CB (NOK MM)	-1	0	90	-118	-56	38	138	77
Maturity Date G - CB (Days)	79***	28	224	-355	-57,5	223	586	77
Issue Date G - CB (Days)	138**	65	427	-756,5	-148	332	1317	77
Maturity Length G - CB (Days)	-59	0	438	-1643	-183	156	913	77
Current Coupon G - CB (%)	0,0353	0,0150	0,1979	-0,4200	-0,0625	0,1360	0,6230	77

Note: *p<0,1; **p<0,05; ***p<0,01

***Table 3** Panel A presents bond characteristics from our matched green bond sample, while Panel B shows the same characteristics for the matched conventional bond sample. While the differences between the green- and conventional bond samples are presented in Panel C. Lastly, Panel D presents the difference between the green bond sample and the combined conventional bond sample. Also, there is a Wilcoxon test conducted to see if there are significant differences between the two bond samples.*

A presentation of the bid-ask spread summary statistics is shown in Table 4. The different bid-ask spreads of the different bonds in each triplet has a very similar mean, median, and standard deviation. Hence, the restrictions imposed to control for liquidity in our matching criteria have worked well. Another finding is that the mean $\Delta BA_{i,t}$, which is the difference between the bid-ask spread of the green bond and the synthetic matched bond is -0,028 basis points. In economic terms, that is essentially zero. From these results, it can be interpreted that the bid-ask spread is equally wide for both the synthetic- and green bonds. Consequently, the findings described in chapter 5 should be the same regardless of the yield used, namely ask-yield, bid-yield, or an average between the bid- and ask yields. A plot of the distribution of $\Delta BA_{i,t}$ is presented in Appendix Figure A2.

Table 4: Descriptive statistics bid-ask spreads

	Mean	Median	SD	Min	p25%	p75%	Max	N
$BA_{i,t}^{GB}$ (%)	0,09418	0,10000	0,02333	0,00000	0,08700	0,10000	0,36000	29629
$BA_{i,t}^{\sim CB}$ (%)	0,09446	0,09958	0,02626	0,00000	0,08433	0,10000	0,93661	29629
$\Delta BA_{i,t}$ (%)	-0,00028	0,00000	0,01876	-0,83911	-0,00100	0,00028	0,26813	29629

***Table 4** presents descriptive statistics of the bid-ask yields of the bonds in our dataset. All numbers are shown in percentage points except N, which describes the number of observations. $\Delta BA_{i,t}$ is the difference between the bid-ask difference of the green bond and the conventional synthetic bond.*

The mean ask-yield of the green bond is 0,3999 percentage points, while the median is 0,2280 percentage points, which is higher than the ask-yield of both the conventional matches. Table 5 presents an overview of these yields. After interpolating/extrapolating the conventional bonds into synthetic bonds, the mean and median ask-yield has risen slightly above that of the green bonds. These results might be an indication of a greenium, but the liquidity proxy is not included as a control yet. Therefore, concluding on a greenium is too early.

Table 5: Descriptive statistics ask-yields

	Mean	Median	SD	Min	p25%	p75%	Max
$y_{i,t}^{GB}$ (%)	0,39990	0,22800	0,61599	-0,55800	-0,01700	0,62800	3,64500
$y_{i,t}^{\sim CB}$ (%)	0,40490	0,23498	0,62175	-0,97400	-0,01684	0,64100	3,50488
$\Delta\tilde{y}_{i,t}$ (%)	-0,00028	0,00000	0,01876	-0,83911	-0,00100	0,00109	0,26813

***Table 5** shows the ask yields of the green matched green bonds and the synthetic conventional bonds in our sample in addition to the difference between the yield of the green- and synthetic bonds, $\Delta\tilde{y}_{i,t}$. Numbers are presented in percentage points.*

Contrary to Zerbib (2019), our thesis includes both fixed- and floating coupon bonds, which might lead to different findings than his. A visual test to see if the distribution of the fixed-rate bonds and floating-rate bonds differ from each other is, therefore, conducted to see if this should make a difference between the findings. Figure 6 presents the plot.

The plot shows that both fixed and floating- coupon bonds have approximately the same distribution. However, the distribution of yield differences for floating coupon bonds is wider than for fixed coupon bonds. These findings are as expected because our sample consists of a higher number of floating- than fixed coupon bonds, especially before 2018. As there has been issued more bonds of both coupon types and the relative difference in the number of bonds have decreased, and the variance between them has also decreased. Hence, the results should be approximately equal for the bonds with fixed- and floating coupons. It is, therefore, expected that this difference should not produce significant differences between our findings and that of Zerbib (2019). However, this statement will be analyzed further in the subsampling in Selection 6.2.

Also worth noting is that over the time period, the yield difference between the bonds has increased, as seen by the width of the plot. This increase is not surprising as the number of triplets has increased in later years, and thereby increasing the number of observations. When the variation is held constant, and the number of observations has increased the width of the plot increases.

Figure 6: Distribution of the yield difference for fixed- and floating coupon bonds

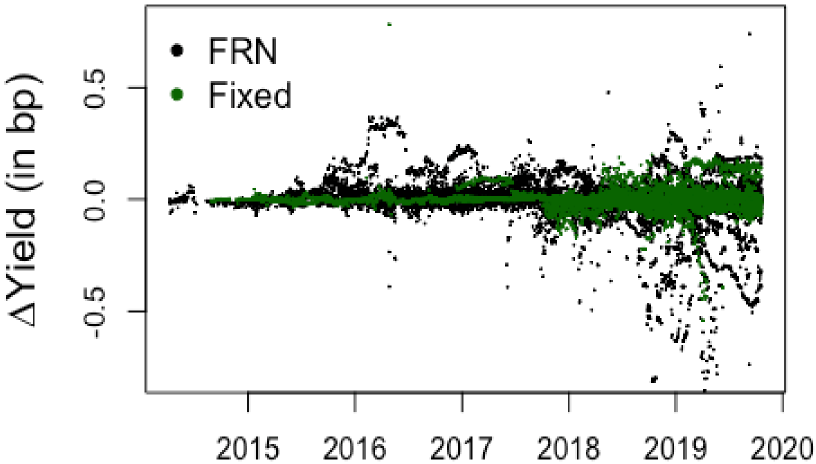

Figure 6 *shows the distribution of yield difference of the bonds with fixed coupons and floating (FRN) coupons. ΔYield is expressed in basis points. Source: Bloomberg, Stamdata, Authors calculations*

4.8 Sample Comparison: All green bonds and our green sample

As mentioned earlier, our matched sample consists of 77 triplets resulting in 77 green bonds. The Nordic green bond universe, not including bonds on Iceland, consists of 213 green bonds. Consequently, a large proportion of the total Nordic green bond universe is dropped. Further, our selection of green bonds is not made up of a random draw because all matches that fulfill our matching criteria are included. Therefore, a comparison of our sample and the Nordic universe of green bonds is conducted to consider if our findings can be generalized for the whole Nordic bond market. For the full list of the matched sample, see appendix figure A5.

Table 6 shows sample characteristics of the full Nordic listed green bond sample and our matched green bonds. Additionally, a test[15] is conducted to determine whether they are statistically different. The full population has a mean issue date 135 days after that of the matched sample, but the difference is not statistically significant. Neither are the differences in issue amounts and coupon types. Nevertheless, many characteristics differ significantly between the two samples, as maturity date and maturity length. The full sample has a maturity date with a mean which is 261 days after that of our sample, while the length of the bonds in the full sample is, on average, over four months longer than the green bonds in our sample. The current coupon is also higher for the full sample than for our sample. Maturity length and coupon levels affect the duration of a bond. Hence, there can be a difference in duration and thereby variation in pricing between our sample and the population.

There is also a difference between the seniority in the samples. The matched sample has a high percentage of senior unsecured bonds and few of the other types, while the population has a more diverse spread between the different types of seniority. Additionally, there is an observed difference between the distribution of bonds in different industry groups. The matched sample has a tilt toward real estate and away from utilities and industry compared to the population.

[15] The difference is tested by a Wilcoxon signed-rank test comparing the mean of the total sample with the mean of our sample. The Wilcoxon test it preferred over a vanilla t-test as the data is not normally distributed, which is tested through a Shapiro-Wilk Normality Test.

Further, our sample only consists of bonds issued in NOK and SEK, while the population also has bonds denoted in DKK and Euro. Lastly, it is reasonable to believe that our sample, on average, contains larger companies than the average of the total population. This is because the matching process requires two conventional bonds from the same issuer to match one green bond. In addition, the matches must satisfy our matching criteria. Then firms with a higher number of bonds, which usually correlate with firm size, have an elevated probability of getting included in our sample. However, this is not tested between the samples, but would be consistent with the findings of Larcker and Watts (2019).

As described, our green bonds and the population differs in several aspects. Because there are few green bonds in both Finland and Denmark in the population, and none of them are in the matched sample, our results cannot be generalized to all Nordic green bond markets. The systematic differences between our matched sample and the total population in the non-country specific aspects such as the coupon rate, seniority, industry group, reduces our ability to generalize our result to all green bonds in Norway and Sweden. However, our results can be taken as an indication of what might be valid for the whole population.

Table 6: Comparison of the full green bond sample and the matched green bond sample

		Variable	Full GB	% of total	Matched GB	% of total	(1) - (2)
Issue		Different Issuers	70		29		
		Issue Date (mean)	jul.17		mar.17		135
Maturity		Maturity Date (mean)	feb.22		mai.21		261 ***
		Maturity Length (Mean Years)	4,55		4,20		0,35 **
Currency	(1)	DKK	3	*1,4 %*			
	(2)	EURO	5	*2,3 %*			
	(3)	NOK	33	*15,5 %*	6	*7,8 %*	
	(4)	SEK	172	*80,8 %*	71	*92,2 %*	
		Currency as a Factor	3,76		3,92		-0,17 ***
Yield	(1)	High Yield	28	*13,1 %*	5	*6,5 %*	
	(2)	Investment Grade	185	*86,9 %*	72	*93,5 %*	
		Yield as a Factor	1,87		1,94		-0,07 ***
Issue Amount		Issue Amount (Total SEK MM)	93 230	*81,1 %*	39 272	*86,3 %*	
		Issue Amount (Total NOK MM)	17 940	*15,6 %*	4 875	*10,7 %*	
		Issue Amount (Total DKK MM)	1 690	*1,5 %*			
		Issue Amount (Total EURO MM)	352	*0,3 %*			
		Issue Amount (Mean SEK MM)	542	*0,5 %*	553	*1,2 %*	-11
		Issue Amount (Mean NOK MM)	544	*0,5 %*	813	*1,8 %*	-269
		Issue Amount (Mean DKK MM)	563	*0,5 %*			
		Issue Amount (Mean EURO MM)	70	*0,1 %*			
Risk	(1)	Covered Bonds	3	*1,4 %*			
	(2)	Government Guaranteed	20	*9,4 %*	7	*9,1 %*	
	(3)	Municipality	1	*0,5 %*	1	*1,3 %*	
	(4)	Senior Secured	21	*9,9 %*	2	*2,6 %*	
	(5)	Senior Unsecured	168	*78,9 %*	67	*87,0 %*	
		Risk as a Factor	4,55		4,68		-0,12 ***
Coupon Type	(1)	Fixed	75	*35,2 %*	23	*29,9 %*	
	(2)	FRN	138	*64,8 %*	54	*70,1 %*	
		Coupon Type as a Factor	1,65		1,70		-0,05
Current Coupon		Current Coupon (%)	1,714591		1,074805		0,639786 ***
Industry Group	(1)	Bank	4	*1,9 %*	2	*2,6 %*	
	(2)	Consumer Services	1	*0,5 %*	1	*1,3 %*	
	(3)	Finance	4	*1,9 %*			
	(4)	Industry	19	*8,9 %*	1	*1,3 %*	
	(5)	Public Sector	23	*10,8 %*	8	*10,4 %*	
	(6)	Pulp, paper and forestry	6	*2,8 %*	1	*1,3 %*	
	(7)	Real Estate	131	*61,5 %*	58	*75,3 %*	
	(8)	Telecom/IT	1	*0,5 %*			
	(9)	Transportation	7	*3,3 %*	3	*3,9 %*	
	(10)	Utilities	17	*8,0 %*	3	*3,9 %*	
		Industry Group as a Factor	6,59		6,71		-0,13 ***
Total Number of Bonds			213		77		

Table 6 *compare our matched green bond sample with the full Nordic green bond sample (except the Icelandic bonds) on various characteristics. Column (1)-(2) shows the difference between the full- and matched green bond samples, it is also conducted a Wilcoxon test to see if there is a significant difference between the samples. Note: *p<0,1; **p<0,05; ***p<0,01*

5. Empirical Methodology

The methodology chapter will present and describe the methods used in this analysis. First, section 5.1 will present the fixed effect regression model used to capture the potential greenium. Secondly, section 5.2 will explain how the subsamples are constructed and how it will be used to investigate potential differences in the greenium in different types of bonds. At last, section 5.3 will present the OLS regressions used to estimate the determinants of the greenium.

5.1 Regression model

As in Zerbib (2019), a fixed effect (FE) regression model is used to retrieve the bond specific greenium. The regression model used in our thesis, similar to the one used by Zerbib (2019), is defined as:

(5) $$\Delta\tilde{y}_{i,t} = p_i + \beta\Delta BA_{i,t} + \varepsilon_{i,t}$$

The dependent variable, $\Delta\tilde{y}_{i,t}$, is defined as the difference in ask-yield between the green bond i and the conventional synthetic bond i at time t. To control for differences in liquidity, a liquidity proxy is included, $\Delta BA_{i,t}$ as the explanatory variable with β as the coefficient. The time-invariant FE, $P_{i,}$ represents the bond specific greenium. In other words, this approach will estimate one greenium for each of the 77 bond pairs.

An FE regression model is preferred in this research as it allows us to capture the unobserved effect of a green label on the bond yield, without imposing restrictions on distribution or including additional information about the bonds in our dataset. Secondly, using FE regression is preferred as it, under the strict exogeneity assumption, does not require the unobserved time-invariant effect to be uncorrelated with the explanatory variable in all time periods (Wooldridge, 2015).

A Hausman-test is conducted to verify if an FE estimation is preferred over a random effect (RE) estimation. The results indicate that the FE and RE yield similar estimates, but that the estimation of the RE will be more efficient. However, for the RE to be relevant, one must truly believe that the unobserved effect is uncorrelated with all of the explanatory variables.

Wooldridge (2015) argues that in many panel data methods, the data is not a result of a random draw from a large population. If that is true, FE estimation should be used instead of RE. Because our research aims to isolate the bond specific greenium by allowing a different intercept for each bond, and because our data is not a result of a random draw but a matched sample, this thesis uses an FE estimation.

To test whether FE estimation is preferred over pooled ordinary least squares (OLS) estimation several tests; an F-test, a Honda test, a Wooldridge test, and a Lagrange Multiplier test (Breusch-Pagan test); are performed, all with a null hypothesis that there exists no individual effect. In all these tests, the null hypothesis is rejected at the one percent significance level. The low p-values[16] retrieved from these tests indicate that our data is highly incompatible with a model without individual effects. Hence, an FE estimation is preferred. Table 7 presents the results from the Hausmann-test and the tests for individual effects.

Table 7: Hausmann-test, and tests for individual effects

	Hausmann-test	F-test	Honda-test	Lagrange/Breusch-Pagan-test	Wooldridge's test
p-value	0.1189	< 2.2e-16	< 2.2e-16	< 2.2e-16	1.402e-05
Conclusion	FE=RE	Significant effects	Significant effects	Significant effects	Unobserved effect

Table 7 *shows the p-value from the Hausmann-test, F-test, Honda-test, Lagrange/Breusch-Pagan-test, and Wooldridge-test.*

OLS standard errors are only unbiased when the residuals are independent and identically distributed (i.i.d). A violation of the i.i.d assumption can lead to either an overestimation or underestimation of the true variability of the coefficients (Petersen, 2009). To test if this assumption holds in our model, a control for heteroscedasticity is conducted by implementing a Breusch- Pagan test. The results indicate the existence of heteroscedasticity in the residuals. A Wooldridge test, a Breusch-Pagan test, and a Durbin Watson test are also applied. All these tests indicate that the residuals are serially correlated. Results from these tests are presented in table 8.

[16] 2.2e-16 is the smallest number larger than 0 than can be stored by the floating system in R studio

Table 8: Robustness tests on the fixed effect regression (specification (5))

	Breusch-Pagan	Breusch-Godfrey/Wooldridge test	Durbin Watson test	Wooldridge Test
p-value	0.0045	< 2.2e-16	< 2.2e-16	< 2.2e-16
Conclusion	Heteroscedasticity	Serial Correlation	Serial Correlation	AR(1) Serial Correlation

Table 8 *shows the p-value from the Breusch-Pagan test, Breusch-Godfrey test, Durbin Watson test, and Wooldridge test.*

Newey-West robust standard errors are estimated to address the problem of heteroscedasticity and serial correlation. Petersen (2009) finds that in the case of both cross-sectional dependence and time-series dependence, Newey-West robust standard errors can still be biased. Therefore, similar to Zerbib (2019), Beck-Katz robust estimators are used, as Beck and Katz (1995) find that their robust standard error estimator works well in small panel data samples.

In specification (5) the bonds´ ask yields are used in both the dependent variable, $\Delta\tilde{y}_{i,t}$, and in the independent variable, $\Delta BA_{i,t}$. In the independent variable, ask yields are only used indirectly, as this variable is defined by equation (2) and (3). Hence, the dependent and the independent variable is not necessarily correlated. Conducting a correlation analysis tests this and Table 9 presents the results. Because of a low correlation of -0.055, it should not be problematic to use the ask yields in both the dependent- and independent variables.

Table 9: Correlation analysis between $\Delta\tilde{y}_{i,t}$ and $\Delta BA_{i,t}$

Pearson correlation coefficient	-0.0551

Table 9 *presents the Pearson correlation coefficient for the correlation analysis between the dependent variable,* $\Delta\tilde{y}_{i,t}$*, and the independent variable,* $\Delta BA_{i,t}$*.*

5.2 Subsampling

In order to identify if potential greenium varies between different types of bonds, the data set is divided into subsamples based on the main characteristics of the bond. For each of the isolated subsamples, the mean and median greenium is calculated. A Shapiro-Wilk normality test is conducted to test the normality assumption in each of the subsamples. The Shapiro-Wilk normality test is preferred as it has the highest power[17], especially in the cases of relatively small sample sizes (Yap and Sim (2011).

[17] *Power* is one of the most frequent used normality test measures (Ghasemi and Zahediasl, 2012)

In all subsamples, the normality assumption is violated. Therefore, a non-parametric Wilcoxon signed-rank test is used to test whether the estimated greenium is significantly different from zero. This test is a useful substitute for the student t-test when there is a violation of the normal distribution assumption (Whitley and Ball, 2002). Since there is little point in running such a test on the mean of small samples, only subsamples consisting of eight or more pairs are tested. The dataset is divided between the following characteristics: Industry group, Currency, Coupon type, High Yield/Investment Grade, Risk type, and Issue Amount.

5.3 Determinants of the greenium

In the first part of the analysis, the estimated greeniums is isolated using an FE regression. In this part, an examination of different bond characteristics and their explanatory power of the potential greeniums. A linear OLS regression is conducted to identify possible determinants of the potential greenium. The regression regresses the isolated greenium on the different bond characteristics. Zerbib (2019) uses the same method, but our research differs in some of the explanatory variables included. Our research uses other variables mainly because our descriptive data is collected using Stamdata, which presents different bond characteristics compared to Bloomberg, used in Zerbib (2019). Additionally, some of the variables included by Zerbib (2019) is irrelevant in our thesis as it only focuses on the Nordic market, while Zerbib (2019) examines the global market.

(6) $$P_i = \beta_0 + \sum_{j=1}^{N_{Currency}-1} \beta_{1,Currency_j} 1_{Currency_j} + \sum_{j=1}^{N_{HY/IG}-1} \beta_{2,HY/IG_j} 1_{HY/IG_j} + \sum_{j=1}^{N_{Seniority}-1} \beta_{3,Seniority} 1_{Seniority_j} + \beta_4 Coupon\ rate + \beta_5 Maturity + \beta_6 \log(Issue\ Amount) + \varepsilon_i$$

(7) $$P_i = \beta_0 + \sum_{j=1}^{N_{Currency}-1} \beta_{1,Currency_j} 1_{Currency_j} + \sum_{j=1}^{N_{\frac{HY}{IG}}-1} \beta_{2,\frac{HY}{IG}_j} 1_{\frac{HY}{IG}_j} + \sum_{j=1}^{N_{Industry\ Group}-1} \beta_{3,Industry\ Group_j} 1_{Industry\ Group_j} + \beta_4 Coupon\ rate + \beta_5 Maturity + \beta_6 \log(Issue\ Amount) + \varepsilon_i$$

Two regression models are constructed and defined by specification (6) and (7). In both of our specifications, the estimated 77 greeniums are regressed on currency, coupon type, issue amount (in SEK), maturity, High yield vs. Investment grade, and the coupon rate (at 21.10.2019). In specification (6), the seniority of the bond is also included. While in the specification (7), industry grouping is instead chosen as an explanatory variable. They are not included in the same model due to the high correlation between the industry group and seniority. Because of the high correlation between the seniority and industry group, these variables are not included in the same model. Both specifications use the logarithm of the issue amount in SEK to linearize the values and get a relative change in the dependent variable. Since variation in the explanatory variables is needed to run the regression, qualitative variable modalities with only one observation are not included in the regressions. Hence, “municipality” bonds, which is a modality of the Seniority variable is not included. Also, “Industry”, “Customer Services” and “Pulp, paper, and forestry” bonds, which are modalities of the variable Industry group is removed.

A Breusch Pagan-test indicates heteroscedasticity in the residuals. To address this problem, robust standard errors are used. The variance inflation factors (VIF) is calculated for both specifications, to check for multicollinearity between the explanatory variables. A rule of thumb often used in practice is that a VIF >10 indicates that multicollinearity is a “problem” (Wooldridge, 2015 & Houweling et al., 2005). Based on the relatively low VIF values, multicollinearity between our variables seems not to be a problem in neither of the specifications. The results from both the Breusch Pagan-test and the calculated VIFs are presented in Table 10.

Table 10: Results from tests on specifications (6) and (7)

Test		Specification 6	Specification 7
Breusch Pagan		0.00342	0.0148
VIF	Issue Amount	1.2266	1.4767
	Currency	1.4814	2.3689
	FRN/Fixed	1.1602	1.2093
	Maturity	1.8561	1.8336
	HY/IG	1.7109	1.7005
	Current Coupon	2.3602	2.4413
	Risk	1.2972	//
	Industry Group	//	3.0763

Table 10 *shows the results from the Breusch-Pagan test for heteroscedasticity and the variance inflation factors (VIF) to test for multicollinearity in specifications (6) and (7).*

6. Results

This section will present the results from the FE model defined by specification (5). Following, it will go through the subsampling, looking at whether there exists a difference in the yield between green- and conventional bonds in the different subsamples. Lastly, this section will present the results from the OLS regressions defined by specification (6) and (7), where the estimated yield difference is regressed on different characteristics of the bond in an attempt to capture determinants of the greenium.

6.1 Estimated Greenium

The results from the FE estimation defined by specification (5), is presented in Table 11. The estimated liquidity control- coefficient (ΔBA) equals -0.416 and is statistically significant at the one percent level for both the standard within regression and the estimated robust standard error estimations. Our results indicate that a one bp increase in the Bid-Ask spread between the green and the synthetic bond is associated with a 0.416 bp decrease in the yield difference between the green and the synthetic bond. Our coefficient results are identical in direction but differ in magnitude to what is found by Zerbib (2019), who finds a coefficient estimate of -9.88.

Similar to Zerbib (2019), our model has a low R-square of 1.1 percent, indicating that our liquidity proxy explains little of the total variation in yield difference. However, the liquidity proxy coefficient is highly significant. Therefore, it should not be left out. The key idea behind the matching method is that all of the differences in yield not explained by the potential greenium are already controlled for, leaving the greenium to account for the rest of the variation in yield difference between green and conventional bonds. Hence, the R-square is not of much relevance here.

Table 11: Results from the fixed effect regression specification (5)

Regression Results

	Dependent variable: $\Delta y_{i,t}$		
	Within	Newey-West robust std.err	Beck-Katz robust std.err
$\Delta BA_{i,t}$	-0.416***	-0.416***	-0.416***
	t = -17.860	t = -5.117	t = -3.762
Observations	29,629		
R^2	0.011		
Adjusted R^2	0.008		
F Statistic	318.995*** (df = 1; 29551) (p = 0.000)		
Note:			*p<0.1; **p<0.05; ***p<0.01

Table 11 *shows the results from the fixed effect regression defined by specification (5):* $\Delta Y_{i,t} = P_i + \beta BA_{i,t} + e_{i,t}$. *The standard within regression is presented first, followed by Newey-West and Beck-Katz robust standard error estimations.*

Since the liquidity proxy (ΔBAi,t) is included in this model only to control for differences in liquidity between the green and the synthetic bond, it is of limited interest in this analysis. Of particular interest is the 77 fixed effects (Pi) estimated, corresponding to 77 greeniums. The model analyzes each bond pair separately and estimates one greenium (fixed effect) for each of the bond pairs. For example, if a bond pair consists of 1000 daily yield difference observations, the fixed effect model will use those 1000 observations to estimate one single greenium for that given pair. Having 77 matched pairs, then, gives a total sample size of 77 estimated greenium values, reduced down from a total sample size of 29,629 yield difference observations. Since the fixed effects model allows for individual treatment of each bond pair, one can argue that the estimated greenium values will be independent of each other. Hence, the number of yield observations within each pair of bonds will not affect the overall distribution of the estimated greeniums.

Table 12 presents the summary statistics of the estimated fixed effects from the FE regression. The estimated fixed effects are distributed between -25.67 bp and 15.34 bp, with a median value of -0.18 bp and a mean equal -0.4 bp. 57.14 percent of the fixed effects calculated are negative. Since greenium is defined as the yield of the green bond minus the yield of the conventional bond, a negative fixed effect value here indicates a greenium. In other words, our findings of a negative fixed effect mean of -0.4 bp are the same as a mean greenium of 0.4 bp.

Table 12: Distribution of the full sample fixed effects

Min	1st Qu	Median	Mean	3rd Qu	Max
-0.2567	-0.0182	-0.0018	-0.0040	0.0062	0.1534

***Table 12** presents the distribution of the 77 estimated greeniums defined as the fixed effect (P_i) of specification (5):* $\Delta Y_{i,t} = P_i + \beta BA_{i,t} + e_{i,t}$,

The results show that the green bonds in our sample trade on average at a lower yield of 0.4 bp compared to the synthetical conventional bond matches. The estimated negative yield difference calculated is relatively small compared to the average bond ask yield, and it can be argued that it is irrelevant in practical economic terms. A Wilcoxon signed-rank test with a null hypothesis, $P_i = 0$, is conducted on the whole sample to test whether the calculated mean greenium is, in fact, statistically different from zero. With a p-value equal to 0.1451, the test fails to reject the null hypothesis at the 10 % level, and the estimated mean greenium of 0.4 bp can, therefore, not be said to be statistically different from zero. So even though the distribution and mean estimation indicate the existence of a greenium in the Nordic market, it cannot be concluded that this estimated negative yield difference is, in fact, different from zero.

As mentioned in Selection 4.1, a robustness test is conducted to control low turnover in the Nordic bond markets by doing the regression on both weekly and monthly yield observations. The results of this test are presented in Appendix Figure A4. The main findings from these regressions are that both weekly and monthly observations yield similar results, as in the case of daily data, with no significant greenium for the full sample.

6.2 Greenium in different subsamples

For the whole sample, the estimated mean greenium of 0.4 bp is not statistically different from zero. However, to identify if the greenium varies for different types of bonds, the full sample is divided into subsamples based on different bond characteristics. Table 13 presents the fixed effect mean and median for the different subsamples, and the calculated p-value from the Wilcoxon signed-rank test for the subsamples consisting of eight or more bonds.

Three of the created subsamples have a greenium, which is significantly different from null. Thereby the null hypothesis of no yield difference is rejected for these three market segments. For green bonds issued in SEK, findings show a mean greenium of 0.64 bp, significant at the 10 % level. The estimations also show a 0.60 bp mean greenium for investment grade green bonds, significant at the 5% level. Additionally, a mean greenium of 1.2 bp is found for bonds with an issue amount between 251-500 million SEK, significant at the five percent level. For the other subsamples, the estimated mean and median greeniums are not significant, but it is worth noting that most of them are negative.

Table 13: Greenium in different subsamples

		Mean(P_i)	Median(P_i)	$P_i = 0$	# GB
		-0.0040	-0.0018	0.1451	77
Industry Group	Consumer Services	-0.0140	-0.0140		1
	Industry	0.0120	0.0120		1
	Public Sector	0.0006	0.0005	0.8438	8
	Pulp, Paper and Forestry	-0.0486	-0.0486		1
	Transporation	-0.0188	-0.0059		3
	Utilities	-0.0004	0.0493		3
	Real Estate	-0.0057	-0.0019	0.1197	58
	Bank	0.0628	0.0628		2
Currency	NOK	0.0240	0.0240		6
	SEK	-0.0064	-0.0019	0.0598*	71
HY/IG	High Yield	0.0244	0.0486		5
	Investment Grade	-0.0060	-0.0021	0.0327**	72
Risk Type	Municipality	0.0033	0.0033		1
	Senior Secured	0.0043	0.0043		2
	Senior Unsecured	-0.0048	-0.0022	0.1176	67
	Government Guaranteed	0.0003	0.0005		7
Fixed/FRN	Fixed	-0.0009	-0.0012	0.3294	23
	FRN	-0.0018	-0.0023	0.2704	54
Issue amount (m SEK)	0-250	0.0023	-0.0018	0.6112	17
	251-500	-0.0112	-0.0055	0.0449**	30
	501-750	0.0000	-0.0006	0.5614	15
	>751	-0.0007	0.0033	0.7197	15

Note: *p<0.1; **p<0.05; ***p<0.01

Table 13 *shows the estimated mean and median fixed effect for the different subsamples. The table also presents the level of significance at which the null H0: $P_i = 0$ is rejected. Additionally, the number of green bonds in each subsample is presented.*

The results from the subsampling indicate a variation in greenium between different types of green bonds. Our findings are consistent with the finding of Zerbib (2019), who also reports variation in the green bond premium between different subsamples.

As described in section 4.6, some of the subsamples contain many of the same triplets. Table 14 presents an overview of how many of the same triplets that are used in the three subsamples in which there exist statistically significant greeniums. There seems to be a clear overlap of bonds used between these subsamples. Ninety-two percent of the investment grade bonds are also denominated in SEK, while 93 percent of SEK denominated bonds are investment grade. The high degree of overlap might explain why the estimated greenium for SEK denominated bonds and Investment Grade bonds are quite similar. Additionally, all of the bonds with an issue amount between 251-500 million SEK are investment grade bonds. However, just 42 percent of the investment grade bonds and only 39 percent of SEK denominated bonds have an issue amount between 251-500 million SEK. This difference might explain why the estimated greenium for bonds with an issue amount between 251-500 million SEK is different compared to the other two subsamples.

Table 14: Matrix of how many triplets that are used in the subsamples with significant greeniums

	#Triplets	%	#Triplets	%	#Triplets	%
SEK	71	100 %	66	93 %	28	39 %
Investment Grade	66	92 %	72	100 %	30	42 %
Issue amount 251-500 (Msek)	28	93 %	30	100 %	30	100 %
	SEK		Investment Grade		Issue amount 251-500 (Msek)	

***Table 14** presents a matrix of how many of the same triplets that are used in the same subsamples, both in absolute numbers and in % overlap. The diagonal, marked in grey, represents the total number of triplets in each category. The percentage numbers in each row are the percentage overlap between two categories and the total number of triplets in the category on the left column. In other words, the total of observations that are in both categories divided by the total number of triplets in the category. The number shows how many triplets that are present in both categories.*

6.3 Determinants of the green bond premium

In order to analyze whether different bond characteristics can explain the variations in the greenium, the linear regressions from specifications (6) and (7) are performed. The estimated greeniums is regressed on different bond characteristics. Specification (6) and (7) differs in the included explanatory variables. Specification (6) includes Seniority, while specification (7), instead include Industry group as an independent variable. Because robustness tests indicate the existence of heteroscedasticity, both specifications are made robust by using

White-Robust standard error estimators. The R-square of the two specifications equals 0.121 and 0.139. Hence the included variables explain little of the total variation in the greenium.

Table 15 presents the results of specification (6) and specification (7). "Current coupon” is the only statistically significant coefficient in both specifications. The Current Coupon coefficient equals 0.023 for specifications (6) and 0.022 for specification (7). Both of these results are significant at the 10 % level. According to these results, a 1-bp increase in the bond coupon is associated with 0.023(0.022) bp positive increase in the greenium. Similar to Zerbib (2019), this thesis includes log issue amount, maturity, and currency as explanatory variables. Our results are consistent with Zerbib (2019), who finds that issue amount, maturity, and currency have no significant effect on the level of greenium.

Table 15: Results from specification (6) and (7)

	Linear regression w/ White-Robust SE	
	Dependent variable: Green Premium (P_i)	
	(6)	(7)
Log Issue Amount (SEK)	-0.010	-0.009
	(0.012)	(0.011)
Currency: NOK	0.017	0.004
	(0.059)	(0.078)
Coupon type: FRN	-0.005	-0.008
	(0.010)	(0.009)
Maturity	-0.001	-0.001
	(0.007)	(0.006)
HY/IG: High Yield	0.008	0.009
	(0.070)	(0.071)
Current Cupon	0.023*	0.022*
	(0.013)	(0.012)
Risk: Government Guaranteed	0.016	
	(0.014)	
Risk: Senior Secured	0.017	
	(0.019)	
Industry Group: Bank		0.051
		(0.046)
Industry Group: Public Sector		0.016
		(0.012)
Industry Group: Transportation		-0.013
		(0.021)
Industry Group: Utilities		0.002
		(0.094)
Constant	0.187	0.170
	(0.239)	(0.209)
Observations	73	73
R^2	0.121	0.139
Adjusted R^2	0.011	0.0001
Residual Std. Error	0.057 (df = 64)	0.057 (df = 62)
F Statistic	1.097 (df = 8; 64)	1.001 (df = 10; 62)
Note:		*p<0.1; **p<0.05; ***p<0.01

***Table 15** presents the results of specification (6) and (7), used to explain the potential determinants of the greenium. The estimated greenium from specification (5) serves as the dependent variable and is expressed in basis points. For qualitative explanatory variables, modalities consisting of only one observation is deleted. **Maturity** is the length of the bond expressed in years from issuance until the maturity date. **Current Coupon** is the last Coupon rate of the bond before 21.10.2019. **Log Issue Amount (SEK)** is the logarithm of the Issue Amount expressed in SEK. **Currency** is a qualitative variable with two values: SEK (reference value) and NOK. **Coupon type** is a qualitative variable with two values: Fixed (reference value) and FRN (floating rate). **HY/IG** is a qualitative variable with two values: Investment Grade (reference value) and High Yield. **Risk** is a qualitative variable with three values: Senior Unsecured (reference value), Government Guaranteed, and Senior Secured. (Municipality not included because of only one observation). **Industry group** is a qualitative variable with five values: Real Estate (reference value), Bank, Public Sector, Transportation, and Utilities. Industry, Consumer services, and Pulp, paper and forestry are not included because of only one observation*

7. Discussion

This section will discuss and compare the findings of our thesis with the findings from existing literature on bond greeniums. The second part of the section will discuss potential limitations with the methodology and the data used in our thesis.

7.1 Discussion of results

The results from the fixed effect regression indicate that our sample of Nordic green bonds, on average, trade at a 0.4 bp lower yield in the secondary market compared to identical conventional bonds from the same issuer. However, this estimated yield difference is neither statistically nor economically significant. Hence, based on this finding, the null hypothesis, stating that there is no difference in yield between green and conventional bonds in the Nordic market as a whole, cannot be rejected.

The findings of no statistically significant greenium are in line with the findings of Larcker and Watts (2019), who examine green US municipal bonds and find no evidence of a greenium in the secondary market. The overall result, of no significant yield difference in the secondary market between green and conventional bonds in the Nordics, differs from the overall findings of Zerbib (2019) and Barclays (2015), who report a significant greenium of respectively 1.8 bp and 17 bp in their research on the global market.

A possible explanation for why our results differ from the findings of Zerbib (2019) and Barclays (2015) is the structural dissimilarities between the Nordic and the global green bond market. As shown in section 4.8 (Table 5), SEK denominated green bonds account for around 80 percent of the Nordic green bond market. Simultaneously, according to Danske Bank (2019), only eight percent of the global green bond market is issued in SEK. Additionally, as shown in table 5, around 60 percent of Nordic green bonds are issued by real estate companies. However, only 30 percent of global green bond proceeds are used on real estate projects (CBI,2019d). Hence, it seems that the Nordic green bond market, to a larger extent, is dominated by real estate companies compared to the global green bond market.

Structural dissimilarities between the Nordic and the global green bond market, like to ones presented above, might attract different types of investors with different preferences towards green bonds. A different investor base between market segments can again lead to a variation in the estimated greenium between these markets. It is also worth noting that Zerbib (2019), who finds a significant negative yield difference between green and conventional bonds when analyzing the full sample, also reports a significant variation in the greenium between different currencies. For some of the currencies he analyzes, he does not find statistically significant greenium. His results, therefore, indicate that the existence of a greenium can vary between different market segments. This might explain why Larcker and Watts (2019), who study the US municipal market, and our study on the Nordic market, finds no significant greenium.

Another possible explanation for why our results differ from the findings of Zerbib (2019) is that our analysis includes both fixed- and floating rate coupon bonds, while Zerbib (2019) only analyzes fixed rate coupon bonds. Also worth mentioning is the sample size of Zerbib's study, which contains 110 triplets. Due to the limited amount of bonds, it can be discussed whether the findings can be generalized to the global population of green bonds.

As mentioned, our findings cannot reject the null hypothesis and say with certainty that there exists a greenium in the Nordic market as a whole. However, the findings in our study show that in some subsamples, there exist small statistically significant greeniums. For green bonds issued in SEK, green bonds issued by investment grade companies, and green bonds with an issue amount between 251-500 million SEK, there exist small, but statistically significant greeniums of respectively 0.64 bp, 0.60 bp, and 1.12 bp. These negative yield differences are all statistically significant. However, because of the low magnitude, one can argue that the greeniums found has limited economic value.

Nevertheless, the number of SEK denominated bonds and Investment grade bonds in our sample are relatively much higher compared to the number of NOK and High Yield bonds. The considerable variation in the number of bonds between subsamples most likely explains why there exist significant results for some subsamples consisting of many bonds, and not for subsamples only consisting of few bonds, such as NOK and High yield. Also, as described in section 6.2, there is a clear overlap in the bonds used between the two subsamples; SEK and Investment Grade. This overlap might explain why the statistically significant greeniums for these two subsamples are almost identical.

The statistically significant greenium fund for bonds issued in SEK is inconsistent with the findings of Zerbib (2019), which find no significant greenium for SEK denominated bonds. However, it is worth mentioning that Zerbib (2018) uses a sample consisting of 17 green bonds issued in SEK, while ours include a total of 71 SEK green bonds. Hence, the small sample size used by Zerbib (2019) might explain why he does not find a statistically significant greenium for SEK denominated green bonds.

These findings of a statistically significant negative yield difference for some of the subsamples can be an indication of a small mismatch between the demand and the supply of these green bonds. If the demand for green bonds is relatively high compared to the supply, then this will drive up the price of these bonds, lowering their yields. Another potential explanation is that some investors have incorporated the sustainability of their investments in their required rate of return, and thereby require a lower return from green projects than from regular projects.

A possible reason for a hike in demand for green bonds is the increased focus on ESG among investors. This hypothesis is supported by the substantial growth in the number of institutional investors who have signed the UN-backed Principles of Responsible Investments (PRI, 2019) and the sharp increase in the number of so-called responsible investment funds during the last couple of years (KPMG, 2019). The increased focus on ESG can, among other things, been seen as a result of different initiatives such as the Paris Climate Agreement and the Sustainable Development Goals, explained in section 2.3. Initiatives like these have stressed the important role capital markets play in the effort to move the world in a more sustainable direction. Green bonds are viewed as instruments that can help mobilize the capital required to achieve these goals, leading to an increase in demand.

The indicated increase in demand might also be e result of the development of better and more mainstream standards and procedures when it comes to verifying the greenness of the bonds. Better standards have made the green bond market more trustworthy by reducing the risk of greenwashing (KPMG, 2016). This has potentially attracted a broader investor base and increased the transaction rate, which has further risen the demand for green bonds.

There are also several reasons why the supply of green bonds might be insufficient relative to the demand. One viable explanation can be that there are not enough profitable green projects for companies to invest in, or that financial incentives to invest in green projects are too few. According to the European Commission (2016), several companies also struggle to obtain a good credit rating on their green bonds compared to conventional bonds. The lower credit rating on green bonds will increase the cost of capital, making a green issuance less attractive for those companies. Another reason can be the higher cost associated with a green bond issuance (I4CE, 2017). This extra cost consists of among other things, getting an external review on the greenness of the bond, monitoring cost (monitoring the use of proceeds), and possible reputational and legal cost if the proceeds are not used as intended. These extra costs can be a burden for the companies, increasing the barriers to issue green bonds instead of conventional bonds.

The small negative greenium found in some of the subsamples can be beneficial for issuers. Firstly, it is an indication that investors have an appetite for certain types of green bonds in the Nordic market. Secondly, the findings can be an indication that investors are willing to receive a lower yield on these green bonds compared to conventional bonds when trading in the secondary market. Hence, it is also possible that issuers can offer a lower yield on their green bonds compared to identical conventional bonds at issuance, reducing their cost of financing. However, our quantitative results on the secondary market alone are not sufficient enough to conclude on investors' preferences. Additionally, it is worth noting that even though our analysis indicates the existence of a statistically significant greenium in some of the subsamples, the greeniums are all relatively small compared to the ask yields. Hence the possible effect on the cost of capital might be quite limited in economic terms.

7.2 Limitations

Our research has used the same empirical methods as Zerbib (2019). The key idea behind this method is to isolate the greenium by calculating the yield difference between the green bond and two identical conventional bonds from the same issuer. Still, because it is not possible to find completely identical matches, some limitations need to be addressed.

As mentioned in section 4.2, the matching method builds on the prerequisite that the matched samples are entirely identical, except for the variable of interest. In our case, this means that the green bond and the two conventional bonds should be equal in all variables/characteristics except for one, whether or not the bond is labeled as green. However, it is close to impossible to find bonds absolutely identical in all characteristics and still get a sufficient sample size. Therefore, our thesis follows Zerbib (2019), and implements limitations in the allowance of variation between the green bond and the conventional bonds for characteristics were identical matching is impossible. Since this method does not match the green bonds with truly identical conventional bonds, there is a chance that some of the estimated yield differences are a result of structural differences in our triplets and not evidence of a greenium.

To control for differences in maturity between the green bond and the two conventional bond matches, a synthetic bond with the same maturity as the green bond is creased using inter-/exptrapolation. For linear interpolation/extrapolation to be relevant, one needs to assume that there is a linear relationship between maturity and yield. Since the yield curve can take various shapes, there is a chance that the “linear” assumption does not hold over large intervals. However, the potential error from linear interpolation/extrapolation is diminished by restricting the maturity differences of our matches, leading to small intervals between the three bonds in each triplet.

Another limitation of this research is the sample size and the quality of the data used. As this study focus on the Nordic green bond market, there is a limited number of green bonds accessible to analyze. As a result, our analysis may suffer from a small sample size bias, leading to misleading results. Another concern is that most of the bonds listed on the Nordic exchanges do not trade frequently. Hence there is a possibility that the yields do not reflect the fair values of the bonds. As a consequence, the estimated yield differences between green and conventional bonds may not reflect a greenium, but rather be a result of noise.

Additionally, and as described in section 4.9, descriptive statistics show that there are significant structural differences in several characteristics between our sample of 77 green bonds and the whole Nordic green bond universe. Because our bonds are not truly representative of the whole Nordic bond universe, the possibility to generalize the results to also apply for the whole Nordic green bond market is limited.

8. Conclusion

Climate change is recognized as one of the most prominent threats to humanity in the 21st century. Different Initiatives such as the Paris Climate Agreement, and the development of Principles for Responsible Investments (PRI), have stressed the vital role financial markets play in the effort to move the world in a more environmentally friendly direction. It is estimated that a significant amount of investments into sustainable projects are needed to meet the goals set in the Paris Climate Agreement. Green bonds are a relatively new type of financial instrument developed to address this problem by channelizing capital into more environmentally friendly projects.

The main objective of our thesis was to determine if there exists a greenium in the Nordic secondary bond market. The potential greenium was found by analyzing the yield difference between green bonds and constructed synthetic bonds. Each synthetic bond was made by combining two conventional bonds, which are similar to the green bond in all aspects except for not being green. Then a fixed effects regression was run where the yield difference between the green and the synthetic bond was regressed on a liquidity proxy to control for differences in liquidity. The greeniums is defined by the estimated fixed effects in the regression. The sample was further divided into subsamples to test for potential differences between different market segments. Lastly, a regression of the estimated greenium on different bond characteristics was conducted to capture the potential determinants of the greenium.

In the analysis of our whole bond sample, no significant difference between green- and conventional bonds in the secondary market is found. Hence, the null hypothesis cannot be rejected for the Nordic market as a whole. Our results, therefore, support standard theory, stating that investors only take the trade-off between risk and reward into consideration when making investment decisions.

On the other hand, the results from the subsample analysis indicate that for some of the market segments, there exist small greenium (Green bonds have a lower yield than conventional bonds). For bonds issued in SEK, a greenium of 0.64 bp statistically significant at the 10 percent level is found. For bonds issued by investment grade companies, the greenium equals 0.60 bp. Bonds with an issue amount between 251-500 million SEK has a greenium of 1.12 bp. Both of these findings are significant at the 5 percent level. For the other subsamples, the estimated yield differences between green and conventional bonds are not significant, but it is worth noting that most of them are negative. These findings of significant greeniums in some subsamples may be an indication of a small mismatch between the demand and supply of these green bonds. Or that investors account for the sustainability of their investments in their investment decisions. The greenium found is small and potentially not of much relevance in economic terms. It can, therefore, be discussed if our null hypothesis can be rejected for these subsamples. Further, as the matched sample is systematically different from the whole Nordic green bond market, our findings cannot be generalized to be applicable for the whole Nordic green bond market. However, they can be used as an indication or a hypothesis of what results might be expected in the market.

Further, our analysis of potential determinants of the greenium yields low explanatory power. Hence, the bond characteristics included in the model explain little of the total variation in the yield difference between green and conventional bonds. In both specifications, only the coupon rate has statistically significant explanatory power.

Our thesis creates opportunities for further research. Green bonds are a relatively new type of financial security, and our results are based on a limited number of observations. As the green bond market grows, more data will become available. Future research can take advantage of the extended amount of data and provide stronger evidence on the potential yield differences between green and conventional bonds, both globally and in sub-markets such as the Nordic market. Additionally, future research can investigate whether the issuance of green bonds affects conventional bonds from the same issuer. For example, one could analyze if a green bond issuance changes a firm's ability to issue conventional bonds, or if there exist other synergies associated with green bond issuance. As our research is quantitative, another idea for further research could be to use a qualitative approach. Interviewing both issuers and investors of green bonds could give valuable insight into investor preferences, not captured by a quantitative approach, like motivation for issuance and investor's motivation for buying. Our study on Nordic green bonds could also be extended to other specific markets, or other types of bonds, for example, social impact bonds.

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10. Appendix – Figures

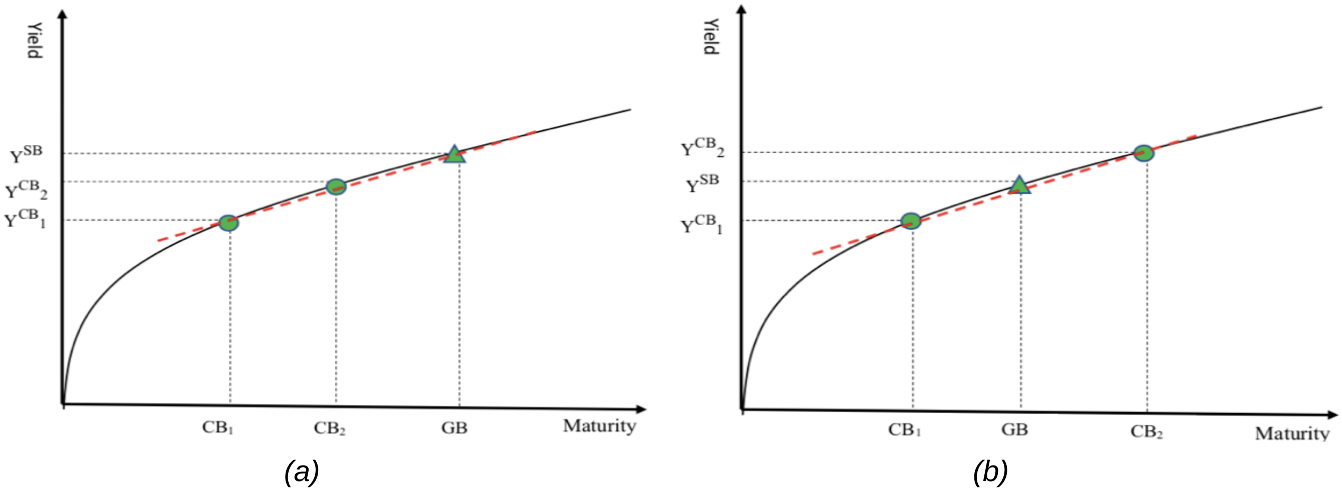

Figure A1: Extrapolation and Interpolation of the synthetic conventional bond yield. This figure shows how the synthetic conventional bond yield is calculated using linear extrapolation (a), and linear interpolation (b).

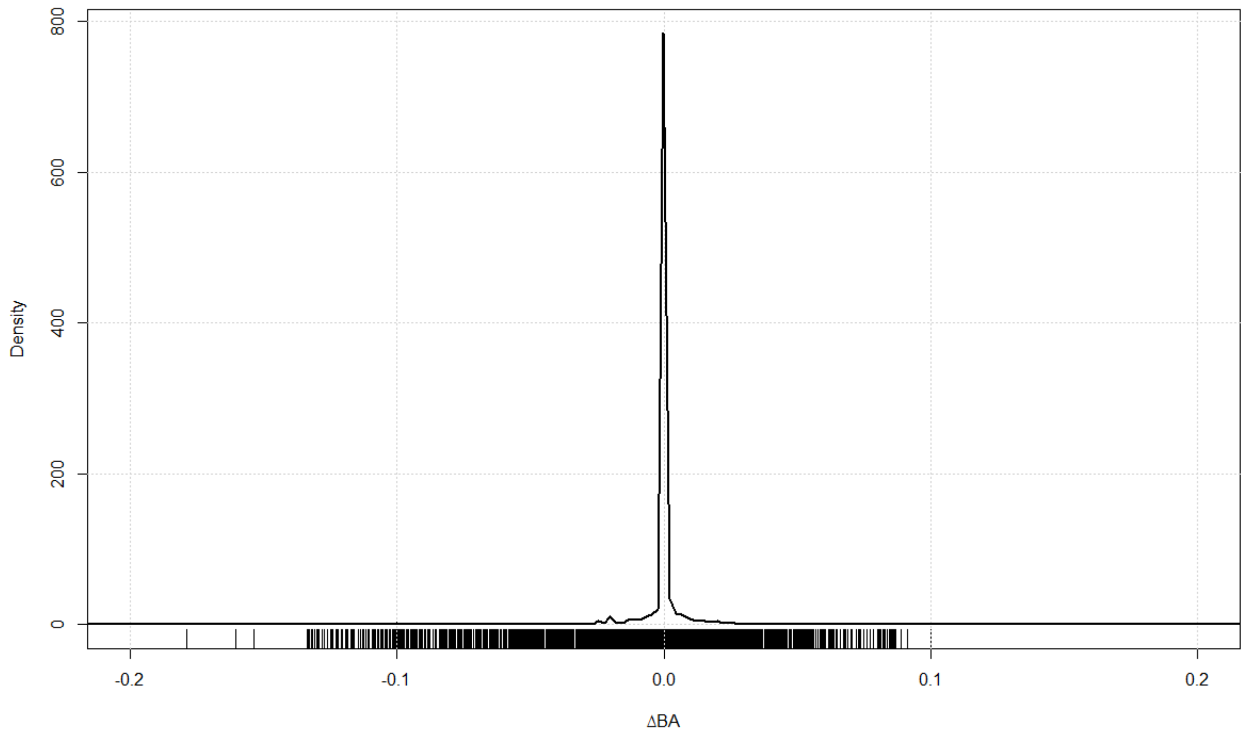

Figure A2: ΔBid-ask density. This figure shows the density of the liquidity proxy ($\Delta BA_{i,t}$)

Matched Bonds	Bonds	Bond Amount (Million)
Swedish Krona:		
AB Stena Metall Finans	1	800
Advanced SolTech Sweden AB (publ)	5	748
Aktiebolaget Stångåstaden	3	1 075
Aligera Holding AB (publ)	1	500
Arise AB (publ)	3	2 100
Atrium Ljungberg AB (publ)	14	6 200
Baseload Capital Sweden AB	1	500
Castellum AB	2	1 000
Fabege AB (publ)	17	6 950
Fastighets AB Balder (publ)	1	1 900
Fastighetsaktiebolaget Förvaltaren	2	600
FastPartner AB (publ)	1	1 000
Hemfosa Fastigheter AB	1	1 300
Hemsö Fastighets AB (publ)	2	1 000
Humlegården Fastigheter AB (publ)	5	2 800
Jernhusen AB	6	2 650
Klövern AB (publ)	1	2 500
Kungsleden AB (publ)	4	3 600
Lunds Kommun	1	750
Midsummer AB (publ)	1	200
Millicom International Cellular S.A.	1	2 000
Nacka Kommun	1	500
Nobina AB (publ)	1	500
Norrköpings kommun	1	600
RE IV Limited	1	600
Rikshem AB	9	2 550
Samhällsbyggnadsbolaget i Norden AB (publ)	1	500
Skanska Financial Services AB	3	1 850
Skåne Läns Landsting	6	3 200
Specialfastigheter Sverige AB	2	1 250
Stockholm Exergi Holding AB (publ)	2	2 500
Stockholms Kooperativa Bostadsförening, Kooperativ Hyresrätts förening	1	300
Sveaskog AB	5	3 100
Svensk FastighetsFinansiering (SFF) AB	13	7 632
Södra Skogsägarna ekonomisk förening	1	1 000
Uppsalahem AB	1	500
Vacse AB (publ)	3	1 700
Vasakronan AB (publ)	33	17 936
Vellinge Kommun	2	450
Volvofinans Bank AB (publ)	1	700
Västerås Stad	2	750
Västra Götalands läns landsting	1	-
Wallenstam AB (publ)	4	1 900
Örebro Kommun	5	2 250
Östersunds Kommun	1	800
Sum SEK	173	93 241
Norwegian Kroner:		
Agder Energi AS	1	750
BKK AS	1	2 000
Clemens Kraftverk AS	2	450
DNB Bank ASA	1	1 000
Eidsiva Energi AS	1	750
Entra ASA	4	3 600
Fantoft Utvikling AS	1	260
Kommunalbanken AS	2	1 350
LM Group Holding A/S	1	475
Lyse AS	1	500
Nord-Trøndelag Elektrisitetsverk AS	3	750
NorgesGruppen ASA	1	400
OBOS Eiendom AS	1	430
Oslo kommune	1	1 500
Scatec Solar ASA	2	1 500
Sogn og Fjordane Energi AS	4	900
Sparebanken Sogn og Fjordane	1	300
Sunndal Sparebank	1	75
Vardar AS	1	300
Vasakronan AB (publ)	3	650
Sum NOK	33	17 940
Danish Kroner:		
Nykredit Realkredit A/S	2	875
Realkredit Danmark A/S	1	815
Sum DKK	3	1 690
EURO		
European Energy A/S	1	140
Nelja Energia AS	1	50
Småkraft AS	1	50
University Properties of Finland Ltd (Suomen Yliopistokiinteistöt Oy)	1	100
Sum EURO	4	340
The Króna (Icelandic crown)		
Orkuveita Reykjavíkur	2	12 931
Reykjavíkurborg	1	6 920
Sum ISK	3	19 851

Figure A3: Listed green bonds in the Nordics. This figure presents a list of the total listed green bond market in the Nordic market. Source: Stamdata, Authors' calculations

		Daily			Weekly			Monthly			
		Mean(P_i)	Median(P_i)	P_i=0	Mean(P_i)	Median(P_i)	P_i=0	Mean(P_i)	Median(P_i)	P_i=0	# GB
		-0,0040	-0,0018	0,1451	-0,0040	-0,0027	0,1657	-0,0042	-0,0022	0,2429	77
Industry Group	Consumer Services	-0,0140	-0,0140		-0,0133	-0,0133		-0,0132	-0,0132		1
	Industry	0,0120	0,0120		0,0132	0,0132		0,0112	0,0112		1
	Public Sector	0,0006	0,0005	0,8438	0,0010	0,0004	0,8438	0,0010	0,0012	0,8438	8
	Pulp, Paper and Forestry	-0,0486	-0,0486		-0,0418	-0,0418		-0,0464	-0,0464		1
	Transporation	-0,0188	-0,0059		-0,0186	-0,0059		-0,0222	-0,0107		3
	Utilities	-0,0004	0,0493		-0,0002	0,0467		-0,0015	0,0462		3
	Real Estate	-0,0057	-0,0019	0,1197	-0,0059	-0,0059	0,1291	-0,0041	-0,0020	0,2242	58
	Bank	0,0628	0,0628		0,0621	0,0621		0,0634	0,0634		2
Currency	NOK	0,0240	0,0240		0,0245	0,0252		0,0233	0,0255		6
	SEK	-0,0064	-00019	0,0598*	-0,0065	-0,0033	0,0698*	-0,0051	-0,0039	0,1158	71
HY/IG	High Yield	0,0244	0,0486		0,0247	0,4647		0,0252	0,0451		5
	Investment Grade	-0,0060	-0,0021	0,0327**	-0,0060	-0,0034	0,0392**	-0,0048	-0,0040	0,0712*	72
Risk Type	Municipality	0,0033	0,0033		-0,0037	-0,0037		0,0047	0,0047		1
	Senior Secured	0,0043	0,0043		0,0051	0,0051		0,0041	0,0041		2
	Senior Unsecured	-0,0048	-0,0022	0,1176	-0,0049	-0,0035	0,1282	-0,0036	-0,0046	0,1971	67
	Government Guaranteed	0,0003	0,0005		0,0006	0,0004		0,0005	0,0012		7
Fixed/FRN	Fixed	-0,0009	-0,0012	0,3294	0,0000	0,0012	0,3931	0,0016	0,0015	0,6434	23
	FRN	-0,0018	-0,0023	0,2704	-0,0058	-0,0034	0,2704	-0,0048	-0,0040	0,2557	54
Issue amount (m SEK)	0-250	0,0023	-0,0018	0,6112	0,0008	-0,0020	0,6112	0,0038	-0,0040	0,6112	17
	251-500	-0,0112	-0,0055	0,0449**	-0,0107	-0,0057	0,0626*	-0,0091	-0,0045	0,1142	30
	501-750	0,0000	-0,0006	0,5614	-0,0001	-0,0057	0,5614	0,0002	-0,0060	0,7197	15
	>751	-0,0007	0,0033	0,7197	-0,0002	0,0037	0,6387	-0,0011	0,0047	0,7615	15

Note: *p<0.1; **p<0.05; ***p<0.01

Figure A4: Green bond premium in different subsamples. Figure A4 shows the mean and median green bond premium for the different subsamples and for different observation intervals. The table also presents the level of significance at which the null H0: $P_i = 0$ is rejected. Additionally, the number of green bonds in each subsample is presented.

ISIN	Company	Company
SE0009779457	Atrium Ljungberg AB (publ)	Svensk FastighetsFinansiering (SFF) AB
NO0010720972	Bkk AS	Svensk FastighetsFinansiering (SFF) AB
SE0009161607	Castellum AB	Svensk FastighetsFinansiering (SFF) AB
SE0009161615	Castellum AB	Svensk FastighetsFinansiering (SFF) AB
SE0010297275	Fabege AB (publ)	Vasakronan AB (publ)
SE0010414425	Fabege AB (publ)	Vasakronan AB (publ)
SE0010947135	Fabege AB (publ)	Vasakronan AB (publ)
SE0011869825	Fastighets AB Balder (publ)	Vasakronan AB (publ)
SE0011974351	FastPartner AB (publ)	Vasakronan AB (publ)
SE0008406235	Hemsö Fastighets AB (publ)	Vasakronan AB (publ)
SE0008406243	Hemsö Fastighets AB (publ)	Vasakronan AB (publ)
SE0010599290	Jernhusen AB	Vasakronan AB (publ)
SE0010599407	Jernhusen AB	Vasakronan AB (publ)
SE0011643154	Jernhusen AB	Vasakronan AB (publ)
SE0011063163	Klövern AB (publ)	Vasakronan AB (publ)
SE0010599100	Kungsleden AB (publ)	Vasakronan AB (publ)
SE0010832873	Kungsleden AB (publ)	Vasakronan AB (publ)
SE0011869692	Kungsleden AB (publ)	Vasakronan AB (publ)
SE0009947500	Lunds Kommun	Vasakronan AB (publ)
NO0010790769	Lyse AS	Vasakronan AB (publ)
NO0010843121	NorgesGruppen ASA	Vasakronan AB (publ)
SE0009190069	Norrköpings kommun	Vasakronan AB (publ)
NO0010752702	Oslo kommune	Vasakronan AB (publ)
SE0005991510	Rikshem AB	Vasakronan AB (publ)
SE0006510681	Rikshem AB	Vasakronan AB (publ)
SE0007073895	Rikshem AB	Vasakronan AB (publ)
SE0008294805	Rikshem AB	Vasakronan AB (publ)
SE0009345622	Rikshem AB	Vasakronan AB (publ)
SE0009345630	Rikshem AB	Vasakronan AB (publ)
SE0010468900	Rikshem AB	Vasakronan AB (publ)
SE0010469031	Rikshem AB	Vasakronan AB (publ)
SE0012256741	Samhällsbyggnadsbolaget i Norden AB (publ)	Volvofinans Bank AB (publ)
SE0005878022	Skanska Financial Services AB	Västerås Stad
SE0010600262	Specialfastigheter Sverige AB	Wallenstam AB (publ)
SE0010600270	Specialfastigheter Sverige AB	Wallenstam AB (publ)
SE0007075122	Stockholm Exergi Holding AB (publ)	Örebro kommun
NO0010842321	Sunndal Sparebank	Örebro kommun
NO0010842321	Sunndal Sparebank	Örebro kommun
SE0008092787	Sveaskog AB	Östersunds Kommun

Figure A5: Matched sample of green bonds. The list presents the company name and ISIN number of the green bonds used in this analysis.