THE GREEN BOND PREMIUM IN THE EUROPEAN MARKET

Lappeenranta–Lahti University of Technology LUT

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ABSTRACT

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This thesis presents green bonds and voluntary regulations, such as green labels, that closely relate to green bonds, as well as analyses the yield differentials of green bonds issued in the European markets. Firstly, in the empirical section of this thesis, a matching method was implemented to find green bonds and conventional bonds that share selected bond characteristics to ensure unbiased comparison, and secondly, analysing the chosen bonds' yields with a fixed effects panel regression to estimate the green bond premium. This thesis was able to identify a green bond premium of -2.0 basis points in the overall sample, as well as premia of other magnitudes in multiple subsamples, including Euro-denominated bonds (-0.2 bps), Eurobonds (-3.5 bps), and bonds issued in the financial sector (-3.7 bps). The results of the final dataset also indicate that the green bond premium is of a greater magnitude for bonds that hold a green label. Relationships between green labels and green bond yields was also analysed but no link was identified.

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Vihreiden joukkovelkakirjojen preemio Euroopan markkinoilla

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Tämä tutkielma esittää vihreät joukkovelkakirjat ja niitä ympäröivät vapaaehtoiset regulaatiot vihreiden tunnisteiden muodossa, sekä analysoi Euroopan markkinoille liikkeelle laskettujen vihreiden joukkovelkakirjojen tuottoja. Empiirisen tutkimuksen ensimmäisessä vaiheessa hyödynnettiin täsmäytysmenettelyä, jonka pyrkimyksenä oli löytää keskenään samanlaisilla erityispiirteillä olevia vihreitä ja tavallisia joukkovelkakirjoja vertailukelpoisuuden varmistamiseksi, ja toisessa vaiheessa kyseisten joukkovelkakirjojen tuottoja analysoitiin kiinteiden vaikutusten regressioanalyysillä tavoitteena tunnistaa mahdollinen vihreä preemio. Tämä tutkielma pystyi identifioimaan Euroopan markkinoilla olevan yleinen -2.0 korkopisteen suuruinen preemio, mutta myös muun suuruisia preemioita aliotoksista, mukaan lukien Euromääräiset joukkovelkakirjat (-0.2 kp), Eurobondit (-3.5 kp), ja joukkovelkakirjat, jotka oli laskettu liikkeelle taloussektorilla (-3.7 kp). Tutkielman tuloksista voi myös päätellä, että vihreä preemio on korkeampi joukkovelkakirjoille, joilla on vihreä tunniste, verrattuna joukkovelkakirjoihin, joilla tunnistetta ei ole. Vihreiden tunnisteiden sekä preemioiden välistä yhteyttä myös tutkittiin, mutta yhteyttä ei näiden väliltä löytynyt.

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At the start of writing this thesis, I naively had copious amounts of optimism about how swiftly I could finish it and graduate, but alas, as some things in life are, writing this thesis was taxing and demanding throughout the entire process, from the initial data gathering up until writing the last few sentences. In the span of several months, all reanalysing, rewriting, and honing took a toll on me, but now I am elated to say that this thesis is finished.

I'm extremely grateful to my thesis supervisor Jan Stoklasa, who offered me endless guidance, support, and advice when I was struggling. I don't think I could have finished my thesis by the end of the summer, a deadline I set myself, without his help.

Also, a big thank you goes my family, friends, and boyfriend, all of whom offered limitless patience and encouraging words to me throughout the entire writing process of this thesis. I would also like to express my gratitude to my two cats, who helped in mitigating my ever-rising levels of stress.

In Helsinki, August 23rd, 2022

Hanna Ahto

ABBREVIATIONS

bp/bps	basis point/basis points
CAB	Climate awareness bond
CB	Conventional bond
CBI	Climate Bonds Initiative
CBS	Climate Bond Standard
EIB	European Investment Bank
EUGBS	European Green Bond Standard
ESG	Environmental, Social, Governance
GB	Green bond
GBP	Green Bond Principles
ICMA	International Capital Market Association
ISIN	International Securities Identification Number
SB	Synthetic bond

Table of contents

Figures

Tables

Appendices

1 Introduction

Sustainability, preservation of nature and environmentalism are important ideologies in today's world and new ways to combat raising climate temperatures and global warming are needed more than ever before. Over the last couple of decades, the finance sector is finally starting to partake in the fight against global warming with green financing (Galaz et al., 2015). Green bonds are one of these green financial instruments, and while they at first glance operate exactly the same as conventional bonds, their "bonus feature" is also their main function – proceeds of green bonds are earmarked solely to environmentally conscious projects, (CBI, 2021b) while the proceeds of conventional bonds can be used as the issuer pleases.

Responsibility, or burden, of resolving global warming or at the very least helping reduce it has been bounced around from governments to corporations to consumers in the past. Nowadays, investors can indirectly partake in the aforementioned fight for a greener future by choosing to invest in environmentally conscious projects. Earlier literature from nearly a decade ago into green bonds have concluded that investors truly value those sustainable projects and, due to limited supply, are willing to pay a higher price or accept lower yields for the green bonds (Barclays, 2015; Ehlers & Packer, 2017). However, this may not be the case moving forward, as evidence in contrary (alongside support), has been presented in more recent studies, leaving the current situation with a lack of consensus (Bachelet et al., 2019; Zerbib, 2019). A common theme in green bond literature is to emphasise the importance of identifying and preventing misrepresentation of where proceeds of green bonds are used, but actual analysis of this topic has been sparce, as classifying and verifying green bonds is a fairly new process.

This thesis aims to investigate the difference between green bonds and all possible near identical conventional bonds' yields in the European markets while taking into consideration the obtained proof that a bond is or is not indeed green. In this chapter the background and motivation for this thesis, research problems and questions, and limitations will be presented.

1.1 Background

In the past decade, investors have shown vast excitement in taking part in resolving global warming in the financial markets, and it is expected to increase in the upcoming years (Febi et al., 2018). Academic literature into green bonds has built up to a rather steady body of studies in the recent years, and scholars have approached the subject of difference between green and conventional bonds in many ways, and in many cases, studies suggest that green bond issuers enjoy a premium, sometimes referred as the "greenium". The green bond premium is the difference in prices between green bonds and conventional bonds, where, when all other bond pricing factors identical, green bonds are priced higher than their conventional counterparts. (Barclays, 2015; Baker et al., 2018) This premium means investors of green bonds are willing to accept lower overall yields for their investment compared to another bond's yields, or from the issuers point of view, it can also mean lower costs of debt. Earlier studies of green bond premia had found more prominent premium but suffered from limited data and inexplicit variable controls (Ehlers & Packer, 2017). The last couple years have witnessed a growth in more elaborate studies that have largely, but delicately confirmed the existence of a green bond premium, though it is believed to be much smaller than initial studies presented (Zerbib, 2019; Hyun et al., 2021). While the general (but still delicate) belief is that a green bond premium of at least some magnitude exists, the notion has also been challenged with researchers providing evidence in support of a green bond discount (Bachelet et al., 2019). Due to still limited amount of data, many studies have focused on bonds of the entire world without narrowing down to a certain region.

The existence of green bond premium and the overall voluntary nature in reporting of green bonds have brought forth the risk of greenwashing, in which an issuer deliberately mispresents their actions as more sustainable and environmentally conscious than what they are in reality. The potentiality of greenwashing is present in the green bond markets, and it can be tackled from the issuer's perspective by obtaining third-party certifications or verifications (labels) for green bonds, but looking at the broader picture, any legal standards or taxonomy on green bonds across all regions remain to be seen. Intentionally mispresenting where the proceeds of a green bond are used can entice investors to invest under false pretences. The importance of labels has been noted in green bond literature (Ehlers & Packer, 2017; Baker et al., 2018; Hyun et al., 2021; Flammer, 2021; Xu et al., 2022), but actual analysis of their influence on green bonds has been minimal, most likely due to the fairly new practice of labelling green bonds resulting in still new, and meagre data.

1.2 Motivation

The pressure to succeed in limiting environmental deterioration grows with each passing year, and it may be naïve to expect corporations, municipalities and, generally speaking, issuers to invest in environmental projects without incentives, like lower costs of debt. Green bond premium in the primary markets would result in lower capital costs for the issuers, but this thesis focuses on the secondary market and views green bond premia from the investor’s point of view, as investing is something that anyone can do and have full control on what they spend their money on.

I think it is important that the presence of a green bond premium (higher priced green bonds, resulting in overall lower yield in comparison to conventional bonds from investors’ point of view) is investigated to better understand the nuances of financial markets related to environmental practices. Does being environmentally conscious with one’s investment decisions always come with a cost of accepting a lower yield compared to yields of another bond? Does an investor have to choose between sustainable projects and profits? Is it possible that green bonds and conventional bonds are truly so identical, that it makes no difference for the investor to invest in green bonds, other than the desire for being green?

Due to their traded capability and security, green bonds are the most commonly used green financial instrument (Zhang et al., 2021), and as such a suitable instrument to choose to be the focus of this thesis. There has been a rapid increase in the issuances of green bonds during the past few years and the amount of data, while still limited, is far richer compared to what it was at the time the first green bond literature was published, giving a perfect opportunity to delve a little deeper into a relevant topic considering the poor environmental state the entire world is in. Green bond issuances in the European markets have also seen vast growth recently: almost half of all issued green bonds were denominated in Euros and also half of all green bonds were issued in the EU in 2020 (European Parliament, 2021), but this region has not received much attention when it has come to green bond premium analysis, which this thesis aims to rectify.

1.3 Research questions

Because financial markets are not homogenous, it is generally important to look into more specific regions, especially if prior research in said regions has been sparce and if there is enough data available for a high-quality analysis. The main objective of this thesis is to analyse more closely the green bonds issued in the European markets from their first issuance, to find whether there is an overall green bond premium, or a discount, in green bonds released in the European markets, and whether, and by how much, labels (among other bond characteristics) affect said green bond premium. The main research question of this thesis is:

Is there an overall green bond premium in the European markets?

And supporting research questions are:

1. *Is the magnitude of green bond premium the same for all green labels?*
2. *Is there a relationship between green labels and green bond premia?*

Majority of recent studies on green bonds lean towards confirming the presence of green bond premium, although the results have seen controversy. Most of the green bond premium analyses have been conducted on world-wide bonds with only a few focusing on more specific regions, and one on only Euro-denominated bonds. (Zerbib, 2019; Bachelet et al., 2019; Barclays, 2015; Hyun et al., 2021; Larcker & Watts, 2020; Gianfrate & Peri, 2019) As the contradictory evidence to green bond premia are still more sparce, the initial expectation on the results of this thesis is that the results follow the conclusions of the majority: green bonds are priced at a premium, thus the yields of green bonds are lower than the yields of comparable conventional bonds in the secondary markets.

It has not always been made evident exactly what green bonds each researcher has included in their studies, differing from only Green Bond Principle aligned bonds to all bonds that have been marked green by the issuer. Most likely this has been due to the newness of the green bond reporting and verification, but nonetheless, the importance of green labels has been noticed and emphasized by many authors. As greenwashing is a rising issue in the green bond markets, and voluntary regulations have been created specifically to minimize its negative effects on the entire market, it provides a great opportunity for this thesis to focus more on the difference in premia of green bonds that hold different green labels and investigate whether the green labels have any relationships with the green bond premium.

1.4 Limitations

Green bonds have only been issued for fewer than two decades and the exponential growth green bond markets have witnessed started a few years ago (EIB, 2021; Jones, 2021), and also, any type of regulations regarding green bonds were first presented not even a decade ago in 2014 (ICMA, 2020b). Based on the youth of the green bond markets, the chosen methodologies used, and the resulting small sample sizes in other researchers' studies, in comparison to all issued green bonds (Zerbib, 2019; Bachelet et al., 2019; Gianfrate & Peri, 2019; Hyun et al., 2021), and for the choice of methodology used in this thesis (closely following Zerbib's (2019) methodology), it is not expected that this thesis either is able to utilise all green bonds issued in the European markets to draw definitive conclusions from. Also, while this thesis aims to provide insight into green bond premia in the European markets for the investor, it will not be able to serve all who invest in bonds, as green bond premium more so affects those who actively trade in bonds, and not so much those investors who buy bonds and hold them until maturity.

1.5 Structure of the thesis

The introduction, up until this point, gave a brief overlook of the entire topic and supplied the motivation, research questions, and limitations this thesis faced. The rest of the thesis is structured as follows: the next chapter focuses on green bonds and relevant topics surrounding them, such as voluntary regulations and reporting practices, explaining what has been studied in prior literature, and how it all relates to the current market situation of green bonds. It is necessary to provide an adequate overview on the entire green bonds' framework, as it is the base for all analyses of this thesis.

Next, the data for the analysis and how it was obtained and refined is presented. The matching method strongly connected to the data refining is also explained in detail starting from the criteria and their definitions. The entire data collection and refining process is intricately connected to the methodology, which is presented after. The methodology presents all the regression models and variables used in the empirical analysis of this thesis to estimate the size and magnitude of the green bond premium. The results of the empirical analysis are presented in the fifth chapter. This thesis ends with further discussions on limitations and conclusions concerning the entire paper.

2 Overview of green bonds

This chapter will introduce relevant topics for this research: green financing in broader terms, and green bonds and their current market situation in more detail. As green bonds are the main focus of this thesis, this chapter will also introduce the problems the green bond markets are facing, namely greenwashing, and viable solutions for these problems: voluntary regulations of green bonds, namely Green Bond Principles (GBP) and Climate Bond Standard (CBS). Lastly, an in-depth literary review on green bond premium is presented.

2.1 Green finance, green bonds

In general speech, the term "green finance" has been used interchangeably with terms such as "sustainable finance", "climate finance", and "social finance". Without looking into too much detail, they all carry the same definition: the act of involving environmental, social and governance (ESG) considerations in decision-making in the financial markets, with an objective to allocate funds to greener, more sustainable, and socially conscious investments. The more discerning definition of green finance still varies depending on who's asked – one defines it as broader than "climate finance", as it addresses other environmental objectives such as natural resource and biodiversity conservation, while climate finance focuses more on reduction of greenhouse gas emissions, but is narrower than "sustainable finance", which takes into consideration all climate, green, and social finance. Green finance can also be described as an umbrella term for financial instruments, such as green banks, village funds, and financial technology, all of which specifically aim to allocate funds to greener investments with different methods. (European Commission, 2021a; ICMA, 2020a; Sachs et al., 2019)

Green and conventional bonds are fixed income securities, designed to be exactly alike one another in all ways including pricing principles. Green bonds can be issued by municipalities, government entities, corporations, and multilateral development banks, to name a few (Flammer, 2020; Clapp & Pillay, 2017). The bond's prices are calculated present values of the bond's cash flows, and they are affected by the required yield, which can fluctuate based on inflation and issuer credit quality, and the bond's time to maturity (Agar, 2005; Fabozzi, 2013). A simple formula for calculating a bond's price is as follows, where P is the price of the bond, C is the bond's coupon payments or future cashflows, y is the yield-to-maturity or the required yield, FV is the face value or par value, t and n are the time period and the total number of periods until maturity, respectively, as adapted from Fabozzi (2013):

$$P = \sum_{t=1}^{n} \frac{C}{(1+y)^t} + \frac{FV}{(1+y)^n} \tag{1}$$

Essentially, the bond is priced higher the lower the required yield is (Agar, 2005; Fabozzi, 2013). The only theoretical difference between green and conventional bonds is that green bonds come attached with environmental benefits, that can be perceived indirectly by investors and issuers alike from the green projects the money was allocated to – such as investing in solar power for facilities – while the use of conventional bonds' funds is not restricted in any way thus is not necessarily used on green projects (Ehlers & Packer, 2017; CBI, 2021d). What this means is, like with all other financial instruments under green finance, the proceeds of green bonds are to be distributed to environmentally beneficial projects and investments only, ensuring that investing in green bonds is synonymous with investing in green, environmentally conscious projects, thus a more sustainable future.

All financial instruments under green finance, and the green bond market itself, are still fairly young. It is commonly agreed that the first green bond, at the time called as "climate awareness bond" (CAB), was issued in 2007 by the European Investment Bank (EIB, 2021). Green bond issuances began moderately, but since 2015, the market has grown ten-fold from cumulative issuances of 104 billion USD in 2015 to over 1 trillion USD worldwide in 2020 (Jones, 2021), and similar growth can be seen in just the European markets as well, as presented in Figure 1.

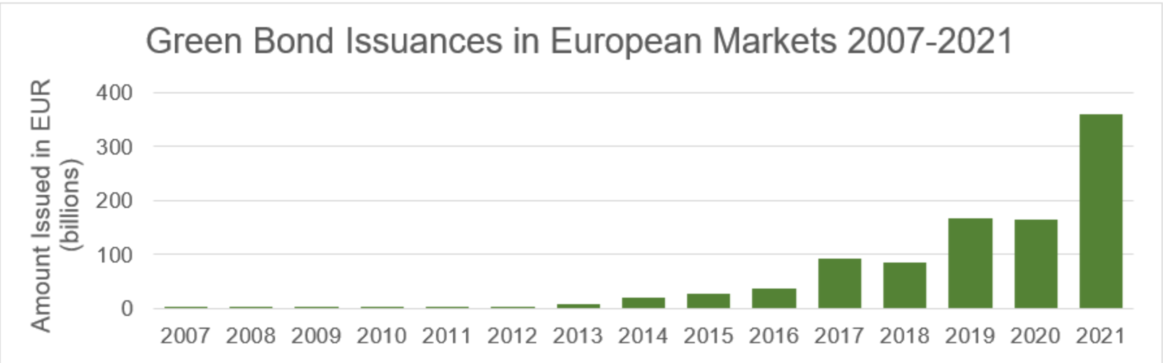

Figure 1 Green Bond Issuances in Billions EUR in European Markets 2007-2021 (Thomson Reuters Eikon, 2022)

It would not be a surprise, and, in fact, it is expected, that the green bond market keeps growing at the current pace, as many other financial innovations have also emerged to sate the “growing hunger” among investors to find a solution for present-day environmental issues (Park, 2018). Not only are more issuers taking part in the green bond markets, but the issue amounts are also on the rise: as an example, The European Commission issued a “NextGenerationEU green bond” worth 12 billion euros in 2021 and even boasted in their press release that the bond was oversubscribed by over 11 times (European Commission, 2021b). Recent reports published by CBI (2020; 2021c) also show that green bonds on average experience larger oversubscriptions than conventional bonds, indicating there is a high demand for green bonds and many eager, willing investors.

Although continuing market growth is expected, some challenges for it have been identified in minimal auditing of proceeds after issuances, and lack of standardized practices in the green bond markets (McInerney & Bunn, 2019). Absence of regulation can create asymmetry of information between issuers, investors, and shareholders, leaving a window for issuers to potentially profit off of their dishonest claims (Park, 2018; Dahl, 2010). Regarding green bond issuances, an issuer may intentionally present misleading information about where the green bond’s proceeds are used – this is called greenwashing. A pattern of larger oversubscriptions for green bonds could potentially entice issuers to take part in greenwashing in an effort to increase their cash flows.

2.1.1 Greenwashing

Companies in general can mislead or intentionally falsely profess that they are acting sustainably or socially responsible in their business practises when, truthfully, they are not. These types of greenwashing behaviours can benefit corporations in forms of improved financial performance, increasing their competitive advantage, or in general help them have a more appealing image to investors and consumers (Sun & Zhang, 2019), which can lead to increased sales, for example. This behaviour can also be present in the green bond markets: the proceeds can be said to go towards a sustainable project but instead are used for something else entirely, or issuers can claim or exaggerate that the environmental impact of the investment is greater than what it truly is, and the difficulty of quantifying that environmental impact makes greenwashing easier for issuers. Greenwashing flourishes in places where anything can be said, nothing is backed with evidence, and no one can be held responsible for lying.

The existence of greenwashing puts more responsibility on environmentally conscious investors to identify instances of greenwashed green bonds, but in many cases auditing the use of proceeds or the environmental impact of the investment at a minimum is time-consuming, costly, and difficult for investors, if not altogether impossible. Greenwashing has the potential to hurt the credibility of the whole market and significantly diminish the funds used from investors who are rightfully strict on what they invest their money on. Investors tend to avoid investing in a company that participates in greenwashing (Gatti et al., 2021), or at least they expect to be compensated with higher yields, if the risk of greenwashing is high (Baldi & Pandimiglio, 2022).

Greenwashing has been identified as a problem by many scholars in academic literature on green bonds and the importance of accurate and truthful green bond reporting has been widely proclaimed as a solution for it (Ehlers & Packer, 2017; Baker et al., 2018; Hyun et al., 2021; Flammer, 2021; Xu et al., 2022). At this point in time, reporting and transparency related to green bonds are entirely voluntary. Having a label that indicates a company is acting sustainably, certified by a third party, has been shown to significantly increase the amount investors spent on mutual funds (Becker et al., 2022), and much like investors are not as likely to invest in greenwashing companies, they are also not likely spend their money in investments when there is uncertainty in ESG information disclosures or third-party ratings (Avramov et al., 2022)

However, the situation in the green bond markets may not be so gloom, as the greenwashing problem has been tackled with many voluntary regulation practices, such as the Green Bond Principles, Climate Bond Standard and EU Green Bond Standard, all of which will be introduced in the next subchapter.

2.1.2 Green labels

The Green Bond Principles (GBP), first introduced in 2014 by a collective of banks from around the world, are a voluntary process guideline for issuing green bonds, highlighting the importance of transparency and disclosure, aiding both issuers and investors in mitigating possible information asymmetry surrounding green bonds (CBI, 2018; ICMA, 2020b). The four core components for alignment with the Green Bond Principles are (ICMA, 2020b):

1 Use of proceeds

Legal documentation should be established on what projects, with clear environmental benefits, the proceeds are used. In case of refinancing and existing project, keeping detailed documentation about the distribution of finances is advised.

2 Process for project evaluation and selection

Issuers are expected to inform investors in a clear way how the chosen green projects benefit the environment, and how they fit in the existing categories for green projects (e.g., renewable energy or clear transportation) and potential risks involved with the projects.

3 Management of proceeds

All green bond proceeds should be tracked by the issuer in a suitable manner, net proceeds should be allocated to green projects periodically and in case of unallocated net proceeds, issuer should inform investors of the intended types of temporary placement for the aforementioned balance.

4 Reporting

Reports with up-to-date information about the use of proceeds, lists of green projects, their descriptions, amounts allocated to these projects – as transparently as these can be reported – and their expected impact on the environment should be conducted annually, or on a timely basis in case of material developments.

On top of these core components, the GBP recommends adhering to Green Bond Frameworks: a legal documentation of the issuer’s alignment to the Green Bond Principles with other relevant information, e.g., certifications of green bonds. Use of external reviews pre and post issuances and publicising them for increased transparency in reporting is also recommended, but not mandatory. It is important to distinguish that the GBP itself does not hold or provide a label for green bonds, it is a “status” obtained for the green bond by having had a third-party verifier certify the bond’s adherence to the Green Bond Principles. Before the Green Bond Principles were introduced, there were no guidelines of any kind on what bonds can be perceived to be green.

Climate Bonds Initiative (CBI) built on top the GBP and formed a Climate Bond Standard (CSB) and expanded the ruleset to include alignment with the targets of the 2015 Paris Agreement to limit global warming to 1.5 degrees Celsius, full compliance with the standards and guidelines of multiple regions, and disclosure of impact reporting of the investment (CBI, 2021a). Climate Bonds Initiative offers an actual green label, CBI

Certification, for all the green bonds that strictly adhere to the standard they have set. It is worth repeating that all reporting regarding green bonds is voluntary, and this is true, but it should not be confused with the practices of obtaining (and keeping) a green label, such as the CBI Certification, where adhering to the standards set includes mandatory annual reporting with public disclosure up until all green bond proceeds have been allocated. Alongside reporting, CBI impel the issuers to obtain a third-party verification for green bonds in order for them to be eligible to obtain CBI Certification.

International Capital Market Association (ICMA, 2021), who are involved in defining the Green Bond Principles, provides a list of potential external reviewers, who could perform the verification of a green bond, but whose compliances to the GBP itself has not been confirmed. Climate Bond Initiative (CBI), however, has filled this role and more: they have verified external reviewers and appointed them “Approved Verifiers”. In the spring of 2022, there were 59 Approved Verifiers, including major corporations such as Deloitte, PwC, and KPMG (CBI, 2022a).

For a green bond, it is possible to obtain a Second Party Opinion (SPO), which focuses more on analysing the environmental impact of the investment project, a Green Bond Rating, where a rating agency analyses the green bond’s alignment with the Green Bond Principles and its green credentials, and Third Party Assurance, which checks the proceed allocation of the green bond investment. All of the documentation mentioned fall under external reviews but obtaining an external review for a green bond does not necessarily mean the bond obtains a green label (CBI, 2022c). A green bond of which issuer-provided information has been checked to be correct and in line with at least the Green Bond Principles (four core components introduced earlier in this subchapter) by an independent third-party reviewer is considered a verified green bond, thus has a green label. An external review, like Second Party Opinion, may possibly not include verifying the bond’s adherence to the GBP, thus obtaining any external review for the green bond does not automatically ensure the bond has a green label.

Certifications by CBI are very black-and-white in the sense that a green bond in question either fills out all the requirements for certification, and thus are eligible for certification, or do not, but third-party verified green bonds only need to uphold the Green Bond Principles. The European Green Bond Standard (EUGBS), a Europe-wide standard that largely emphasizes the same values as the GBP and CBS (allocation of funds, transparency, external reviews), but also adds requirement to align projects with EU Taxonomy. It was first introduced as a proposal in 2019, and despite arguments that it should become a mandatory standard (ECB, 2022), EUGBS is also voluntary, but adhering to the EUGBS gives issuers the right to call their bonds European Green Bonds. (European Commission, 2022)

Overall, a lot has been done to mitigate the risk of greenwashing in the green bond markets, but the work is not yet over. It has become clear that verification, a green label, has the potential to be a useful tool to inform potential investors beyond the issuer's own claim that their issued bonds are indeed green, or at least were at the time the verification was given.

In later parts of this thesis, the general term of "green bonds" are used to mean all green bonds regardless of their obtained certification, verification, or lack thereof, if they have been marked green by the issuer. When necessary to distinguish green bonds of different labels, "labelled" will be used for both CBI certified bonds, and bonds that adhere to the Green Bond Principles. Bonds that hold no verification or certification, but are marked as green by the issuer, are differentiated as "self-labelled" green bonds. All green bonds, labelled and self-labelled, will be included in the analysis of the green bond premium to get a good overall look of the entire green bond market situation.

2.2 Green bond premium in literature

As the green bond markets have grown rapidly in the past decade, so has emerged the interest to study the performance of green financial instruments, such as green bonds. A common theme since the beginning of green bond focused studies is analysing the possible differences in yields of green and conventional bonds. This difference in yields is called a green bond premium (or "greenium"). Green bond premia are typically associated with a minus sign and are presented in basis points (bps; one basis point is equal to 0.01%), as they stand for the yield loss amount between green and conventional bonds. As a reminder, all bonds are priced higher the lower their required yield is (Fabozzi, 2013), so in cases of green bond premium in the secondary markets, an investor is willing to pay a higher price to obtain a green bond thus accept lower overall yields the size of the premium compared to the yields they would have gotten from a conventional bond with near identical bond characteristics; ergo, they pay a premium for the green bond. The opposite of green bond premium is called a green bond discount, when a green bond is actually priced lower than otherwise identical conventional bonds, resulting in higher yields for the investor.

Estimating the green bond premium have often been done by comparing green bonds to similar conventional bonds in some way or form. A common way as a first step for later analysis is to compile a dataset of green and conventional bonds by employing a matching method model for finding near identical conventional bonds to green bonds based on the bonds' characteristics (Zerbib, 2019; Bachelet et al., 2019). Typically, these matching methods include several bond characteristics such as ratings, maturities, and issue dates, but the chosen criteria are not exactly the same in every study that uses it, while they do maintain a noticeable pattern of similarity to one another. Main differences are usually in one or two chosen bond characteristics that differs from the other authors, as often even the matching criterion ranges are similar. Sometimes, the matching method is implemented but the criteria for matching are not told (Febi et al., 2018). Based on the data used, the matching method can be conducted in a different way, used to identify securities from the same municipality, issued at the same day, that have similar terms, coupons, and maturities as pairs (Larcker & Watts, 2020). Another type of method to find similar conventional bonds include, for example, propensity score near-neighbour matching (Hyun et al., 2021). Aside from matching green bonds to conventional bonds, green bond premia have also been estimated using global credit indexes (Barclays, 2015).

In the very early stages of green bond issuances, scholars used simple side-by-side comparisons to estimate the green bond premium (Ehlers & Packer, 2017), but later on, with the continuously expanding data available, have adapted to use a variety of regression analyses. OLS panel regressions, sometimes utilizing a dummy variable to specify the greenness of the bond, have been used to analyse both the yield differential between green bonds and synthetic bonds with determinants varying from study to study (Barclays, 2015; Bachelet et al., 2019). While some determinants are more commonly seen, like maturities and a liquidity proxy, other variables change frequently depending on the author. More recently, fixed effects panel regressions have seen some use by different authors (Zerbib, 2019; Febi et al., 2018; Bachelet et al., 2019). There is still an ongoing discussion between scholars on what variables and characteristics have an effect on green bond yields and green bond premia, which is evident from the variety of regression and estimation models chosen to analyse the same issue. This relates to a widespread problem in all empirical finance research as asset prices depend on factors that are unobservable (Gormley & Matsa, 2014).

As the first version of the Green Bond Principles was introduced in 2014 (ICMA, 2020b), studies published shortly after this are early research in this topic. These early research had consistently found a rather large green bond premium (Barclays, 2015; Ehlers & Packer, 2017), and while these earlier findings have been confirmed in more recent studies albeit with smaller premia (Baker et al., 2018; Zerbib, 2019; Hyun et al., 2021), contradicting evidence have also been presented (Karpf & Mandel, 2018; Bachelet et al., 2019).

Barclays (2015) found a -16.7 basis point (bp) premium in the secondary market of green bonds marked green by the issuer. They found that the green bond premium actually increased each quarter in their analysis timespan when analysing multiple cross-sectional samples of their data, offering as possible explanations the vast differences in the supply and demand quantities, oversubscriptions of green bonds, and the cautious assessment, not based on evidence, that green investors accept lower yields of green bonds if the “yield” is received in other ways, such as in the form of “psychological benefits” from investing environmentally.

Ehlers & Packer (2017) claim their results are consistent with the results of Barclays (2015), and they did find an average premium of -18 bps in the primary market using a simple comparison of green and conventional bonds with a small sample size of U.S. and Euro green bonds, but they did not provide any evidence for a premium in the secondary market. Baker et al. (2018), who analyse the yields of U.S. corporate and municipal green bonds with a pooled fixed effects model found a premium of -7.6bp in the primary markets. However, Larcker & Watts (2020) argue that the model Baker et al. (2018) used was insufficient and used in a situation where a better option for controlling the factors that affect bond yield was available, leading to biased results in favour of green bond premium. Larcker & Watts (2020) do not find evidence of a green bond premium in their study of self-labelled bonds in the municipal market.

Many early studies abode with lacking data and vague specifications, which was noticed by Zerbib (2019), who also criticized in broad terms earlier studies’ variable controls. Thus, he implemented the use of the matching method that was mentioned earlier in this chapter. Zerbib (2019) also applied strict maturity and liquidity controls to a larger sample of 110 green bonds and found an average premium of -1.8 bps in the secondary market, a number which is significantly closer to zero than earlier studies, but the sign of the premium is still negative. Contrarily, Bachelet et al. (2019) who largely followed the matching method of Zerbib (2019), after conducting an analysis on 89 green bonds found a discount (the opposite of a premium) as high as +5.9 bps. However, despite finding a rather high green bond discount in their overall sample, they did find evidence of a premium for green bonds issued by a government institution.

Karpf & Mandel (2018), who also used a larger sample size and strict variable controls, found a green bond discount of +7.8 bps in the secondary market in their research of US municipal green bonds in line with the Green Bond Principles. Their method of choice was the Oaxaca-Blinder decomposition method. One green bond premium analysis in the European markets on 121 green bonds was conducted by Gianfrate & Peri (2019), who found evidence of green bond premium in both the primary and secondary markets of up to -13 bps using a propensity score matching method. They emphasize that green bonds can be an effective way for issuers to build funds for green projects.

Hyun, Park & Tian (2021) expand on prior studies by analysing the pricing differences of a large sample of labelled and unlabelled green bonds instead of yield differences between green and conventional bonds, finding that when common pricings are similar, labelled green bonds, such as CBI Certified and GBP Aligned bonds, have up to -36 bps lower bond yields compared to conventional bonds. This finding is in accordance with many early research results, but the high premium stands out from the rest of the recent studies, where found premia have been generally more subtle, or even on the positive side.

The impact green bond issuances have on equity markets have also been researched recently, with many scholars noting a significant increase in stock prices around green bond announcements (Tang & Zhang, 2020; Wang et al., 2020; Flammer, 2021). Despite the similarities in results concerning increases in stock prices, Tang & Zhang (2020) and Wang et al. (2020) found evidence that corporate green bonds were issued at a small premium, while Flammer (2021) did not find evidence of either.

Due to limited amount of available financial data, the studies mentioned in this chapter focus mostly on green bonds that have been issued all over the world with no region restrictions (Zerbib, 2019; Bachelet et al., 2019; Hyun et al., 2021) or green bonds that have been issued only the United States (Larcker & Watts, 2020; Karpf & Mandel, 2018; Baker et al., 2018), or in Europe (Gianfrate & Peri, 2019), and the amount of bonds in each study's sample size is commonly less than 125 (Zerbib, 2019; Bachelet et al., 2019; Gianfrate & Peri, 2019; Ehlers & Packer, 2017) and occasionally more than that (Larcker & Watts, 2020; Karpf & Mandel, 2018). Despite the exponential growth of green bond issuances over the past few years (CBI, 2021c), it is evident from the low sample sizes included in a vast amount of analyses on green bonds premium that only a small portion of the issued green bonds were actually included, thus the achieved results indicating green bond premium or discount may not accurately represent the entirety of the green bond markets of the selected region, but a smaller subsection of it.

Although there is no clear consensus in the academic literature of the existence of a green bond premium, the majority of earlier studies skewed in that direction. These earlier findings have certainly not been undisputedly rejected or disproven by more recent studies – studies have confirmed green bond premia albeit of a much smaller calibre, and sometimes shown evidence of discounts. Nonetheless, the general body of studies seem to indicate that, at the moment, there still is a green bond premium and that labelled green bonds have highlighted benefits among all bonds for the issuers, but not the investors if only yields and no other benefits are considered. Verified and certified green bonds raise the climate standards of the markets, mitigate information asymmetry, and continue to offer security to investors, ensuring that their funds are used in environmental projects they value, and hopefully, in the future, at no added cost (or loss of potential yields) to the investor.

It is important to expand the knowledge of green bonds' yields in markets that have received less attention in the present literature and to look into what kind of effect, if any, labels have on green bond prices and yields. The goal of this thesis is to build upon what is already known about green bond premia and utilise that knowledge to the green bonds issued in the European markets. To ensure that the results of this thesis are comparable to at least two studies in green bond literature, the methods of Zerbib (2019) will be closely followed. It is expected that the results of the empirical analysis will not be able to represent the entirety of green bonds issued in Europe as Zerbib's (2019) matching method and the steps taken to obtain the green bond premium will most likely greatly limit the amount of green bonds actually included in the empirical analysis, though the results can still hopefully provide substantial results for more specific subsections of the European markets. The decision to follow Zerbib's (2019) methodology was made due to the research being fairly contemporary, and for the fact his methodology has been used as a basis in later research by other scholars as well (Bachelet et al., 2019; Hyun et al., 2021). The drop in included green bonds for the empirical analysis could have been avoided by choosing an alternate method of analysing green bonds, for example by utilising global credit indexes in the analysis like Barclays (2015) did but ensuring the results of this thesis could be nearly directly compared to more than one research had graver importance.

3 Data

The data gathering and refining process for this thesis is explained in this chapter. The data for the empirical analysis was gathered entirely from Thomson Reuters Eikon database, which holds vast amount of information regarding all sorts of bonds, as well as their historical financial data. At the later stages of the data gathering process the Climate Bonds Initiative database for certified green bonds was also consulted, to verify the certifications of bonds marked with such certification on Eikon (CBI, 2022b).

The data collection was started by obtaining an initial dataset of every green bond released up until December 31st, 2021, in the European markets from the Thomson Reuters Eikon Database. The basic green bond filter in Thomson Reuters Eikon does not discriminate green bonds that do not hold a green label or a verification, but includes all green bonds that, at the very least, have been marked green by the issuer. This first dataset contained of 3588 individual green bonds. Out of the 3588 green bonds 2206 were Eurobonds – bonds that are denominated in a different currency than that of the country where it was issued. The filtering system of the Thomson Reuters Eikon was trusted with regards that these Eurobonds were issued in the European markets, and due to no other available country of issue data, no further examination was made into the countries where the Eurobonds were issued due to the sheer amount of them. The remaining 1382 bonds were issued in 26 different European countries, with the four biggest contributors being Sweden (31%), Germany (30%), Norway (12%), and France (11%), together contributing 84% of all the green bonds issued.

Following the obtainment of the initial database, the construction of the matching method model presented by Zerbib (2019) was started. It has been a common sight in more recent studies to follow this matching methods model (Zerbib, 2019; Bachelet et al., 2019), which will be presented in more detail later this chapter, and it has been proven to be effective in finding and identifying two or more comparable conventional bonds for each green bond in the dataset. The benefit of the matching method is that it allows the researcher to focus on the effects of the one factor of interest deliberately left out of the matching process. (Zerbib, 2019) This thesis aims to identify the presence of green bond premium (or discount) in the European markets. Zerbib (2019) states that the bond yield difference between green and conventional bonds is the cumulative effect of the liquidity differential and the green bond premium, which is why in the context of this thesis, in order to determine the presence of a green bond premium, the factor of interest is liquidity.

According to Choudhry (2004), the yield of a bond is affected by three factors: the bond's term to maturity, credit quality, and liquidity. Using this matching method ensures that all chosen bonds have the same characteristics, based on the selection done by the author, and were exposed to the same market changes, leading there to be no difference in yields due to credit or market risk. Any default risk has also been eliminated by only analysing bonds from the same issuer. This type of matching method for bonds has been used in other financial studies to evaluate the cost of liquidity (Helwege et al., 2014), and will also be applied in this thesis to increase the comparability of the results to other studies that implemented the same method.

The criteria for bond characteristics of green bonds and two closest matching conventional bonds from the same issuer are presented in the Table 1 (adapted from Zerbib, 2019 and Bachelet et al., 2019). Table 1 also presents all the characteristics that were retrieved for each bond to complement the initial dataset. As Zerbib (2019) explains, the liquidity of the bond can be assessed from the bonds issue amount or issue date; thus, a double constraint is set up to only include conventional bonds that are issued no more than 6 years earlier or later than the issue date of green bond and have an issue amount no less than 25% or no more than 400% than the issue amount of the green bond. Controlling the issue dates and amounts in this stage helps to control for any residual liquidity bias later in estimation of the green bond premium, which is the possible difference in yields between green and conventional bonds when all other factors are identical. Limiting the maturity length of conventional bonds to +-2 years of the green bond increases the estimation accuracy of the synthetic bond yield, which will be presented in more detail in later parts of this thesis.

The search for identical conventional bonds for each green bond was implemented step-by-step for all 3588 green bonds in the initial dataset. Unfortunately, the remote access to Thomson Reuters Eikon was uncooperative throughout the entire search process, and the database could not be connected to any analytics tool, which made identifying those conventional bonds unnecessarily difficult, but the difficulty ultimately only lengthened the data gathering process without affecting the quality of the end result. The compiling of the dataset was started by setting up search functions for each individual green bond based on the criteria and specified limits presented in Table 1. The search function presented a list of International Securities Identification Numbers (ISIN) for all the conventional bonds that exactly match the criteria set. These ISIN's were used throughout the entire empirical analysis part to identify the bonds. In case any of the characteristics used in the matching method were missing for a green bond, or if the search for an identical conventional bond based on the green bond's criteria did not provide two or more conventional bond ISIN's, the green bond was removed from the dataset. Two conventional bonds are needed for each green bond to calculate the synthetic bond's yields and bid-ask spreads in later parts of this chapter.

Table 1 The matching method for green bonds and conventional bonds

Bond characteristic	Criteria
Bond structure	Identical
Coupon type	Identical
Collateral	Identical
Currency	Identical
Rating	Identical
Seniority	Identical
Issuer	Identical
Issue amount	no less than 25% of the green bond issue amount and no more than 400%
Issue date	no more than 6 years earlier or later than issue date of green bond
Maturity	no more than 2 years shorter or longer than maturity of green bond

While every other characteristic of the conventional bonds had to match exactly or be within the set limits to that of the green bond, a slight relaxation was implemented to the matching criterion on ratings. For each bond, a rating from all the big three credit rating agencies (Standard & Poor's, Moody's, and Fitch Ratings) was obtained, and out of these three ratings, the highest rating was chosen instead of the average of all available ratings per bond, like Zerbib (2019) had done. This slight relaxation was implemented because calculating the average ratings for thousands and thousands of bonds simultaneously proved to be too heavy for the spreadsheet software that was used and trying to calculate the averages in smaller increments proved to be unhelpful.

This highest rating of the bond was further refined by rounding it to only include the letter grade with no signs, in other words, including all ratings of AA+, AA, and AA- under AA; A+, A, and A- under A, and so on with all the remaining ratings, in accordance with Zerbib (2019). The resulting rounded highest rating then had to be identical for both the green bond and the conventional bond. If any step in the matching process overall left fewer than two matching conventional bonds corresponding to the green bond, the green bond was removed from the dataset. At the end of the matching process the dataset held 945 green bonds, and for each green bond, at least two conventional bonds of all the same characteristics. If one green bond had more than two identical conventional bonds, the two with the closest maturities to the green bond were chosen for the dataset in accordance with Zerbib's (2019) methodology and the rest of the identical conventional bonds were discarded, meaning in the end, there were 945 groups of three related bonds.

The initial dataset contained 3588 green bonds issued in the European markets prior to December 31st, 2021. The matching method resulted in 2643 green bonds, 73.7% of the sample, being excluded from the empirical analysis. The most restricting criterion in the matching method was that the issuer of both green and conventional bonds had to be the same – ensuring that both bonds were issued by the same issuer cuts all differences in credit risk that two bonds of different issuers may have faced. Moreover, the strict criteria altogether, and having to find two identical conventional bonds for each green bonds from the same issuer essentially means that all issuers who have not issued "enough" (i.e., at least three nearly identical bonds, out of which one is marked as green, and the rest are not) multiple bonds in a relatively short time span are entirely excluded from the analysis. The resulting sample at this point of the data refining process is already representing only a portion of larger issuers' green bonds in the European markets, and issuers that potentially had to make the decision to issue a green bond instead of a conventional bond, not to mention one of each, are not included.

The goal of this thesis is to identify whether there is a green bond premium in the European markets, if the premium is different for each green label, and also the effect any green label the bond holds has on the premium. For this purpose, the verification and certification information were obtained for each green bond. Alas, the verification and certification data for green bonds in Thomson Reuters Eikon was not as rich as could be hoped and was in fact quite garbled: there were many instances of missing or contradictory values. Some bonds that were in one column stated to adhere to the Green Bond Principles did not have a verifier, or any other information besides that on file, and one bond adhering to both the Green Bond Principles and the EU Green Bond Standards was still marked as "self-labelled" in another place. The difficulty of obtaining relevant and up-to-date information on green bonds while having access to a major database like Eikon epitomizes the need for regulations and registries for green bonds. All the verification and certification information that was present in Thomson Reuters Eikon was assembled to reflect the most accurate state of greenness possible for each bond, containing three categories:

1 CBI Certified Green bonds

This category contains only those green bonds that have been certified by the Climate Bonds Initiative, as was identified in Thomson Reuters Eikon. The issuers have fulfilled all the requirements that the CBI has set under the Climate Bonds Standard in order to obtain the certification, including providing adequate annual reporting on their bonds, containing how the proceeds have been allocated. CBI certified green bonds have the most "prestigious" status among all green bonds.

2 GBP Aligned Green bonds

Green bonds that have followed either the Green Bond Principles set by ICMA, or the EU Green Bond Standard proposed by the European Commission are in this category. The bonds adhering to the EUGBS were included in this category and not in one by themselves due to them being only four (4) in the entire sample. The EUGBS in itself also contains the principles of the GBP. The bonds following the GBP were identified by Thomson Reuters Eikon.

3 Self-Labelled Green bonds

The remaining green bonds in the dataset, which do not fit into either of the categories above, are included in this category. Most bonds in this category have only been labelled as green by the issuer and there is no evidence of any type of adherence to any green standard. It was briefly mentioned earlier that it is possible for issuers to obtain a Second Party Opinion (SPO) or an Assurance from a third party to evaluate certain aspects of the green bond. As neither of the two external reviews mentioned necessarily verify the green bonds obedience of the GBP, they are not included in the second category but are instead included here.

Then, to further expand the dataset, a query was made to obtain ask yield, ask, and bid data for all green and conventional bonds. Related to conventional bonds, ask yield data is used for estimating the synthetic bond yield (explained in more detail in the next subchapter), and closing percent bid and ask data are used for calculating the synthetic bonds' bid-ask spreads, used as liquidity proxy in the fixed effects within regression to estimate the green bond premium. Unfortunately, for a large portion of the green bonds Thomson Reuters Eikon did not contain any ask yield, bid, or ask data, which resulted in the green bond's exclusion of the dataset. A total of 655 out of 945 green bonds contained all necessary aforementioned financial data. If any of the two related conventional bonds to the green bond were missing any of the previously mentioned data, all three bonds were removed from the dataset, as future calculations on the bonds cannot be performed. Similarly, if any bond's ask yield, bid, or ask data had fewer than 30 day-observation values total also resulted in all related three bonds being excluded from the dataset to increase the accuracy of the synthetic bond yields and bid-ask spreads. At the end of the matching process, the entire matching process was double checked, that all bond the characteristics were identical or within the set ranges.

It was not clearly specified in Zerbib's (2019) study if any alternative conventional bonds, with third, fourth and higher closest maturities to the green bond (that were still within the set ranges specified in Table 1) were used in the sample, in cases when the one or both of the two conventional chosen bonds had to be excluded from the analysis, for example if financial data was not available for them. As it was not plainly stated whether alternatives were used, the aforementioned data was gathered only for the two conventional bonds with the closest maturities to the green bond and not for any of the additional identical conventional bonds that were identified in the beginning of the data collection process, potentially resulting in needless exclusions of green bonds out of the dataset for the analysis. Essentially, discarding the additional conventional bonds resulted in a smaller sample size in comparison to what it could have been had alternatives been used.

After the obtaining of ask yield, ask, and bid data the dataset contained 224 green bonds, which is significantly less than the 945 green bonds that were in the dataset after the implementation of the matching method, and it is around a third of the 655 green bonds that had financial data. Despite this low amount of green bonds still included in the dataset, it was still around twice the amount of bonds included in the study of which methodology this thesis follows (Zerbib (2019): 110 green bonds), and in the studies which results are primarily used for comparison in the later parts of this thesis (Bachelet et al. (2019): 89, Gianfrate & Peri (2019): 121 green bonds) - for this reason the sample size was considered sizeable enough and the data refining process was continued.

3.1 Synthetic bond

The matching method explained in the earlier subchapter resulted in each green bond to have two corresponding conventional bonds that have exactly the same characteristics, with possible minor differences in maturities, issue amounts and issue dates, though still within the ranges set in Table 1. In order to eliminate the possible maturity bias of the two conventional bonds, a synthetic bond, with exactly the same maturity as the green bond, is created by linear interpolation (or extrapolation) of the two conventional bond's ask yields at the green bond's maturity date. The synthetic bond will have the same properties as the green bond except for the difference in liquidity. (Zerbib, 2019) In the equation calculations the maturity of conventional bond 1 was always earlier than that of conventional bond 2. The equation is as follows:

$$\text{Ask yield}^{SB} = \frac{\text{Ask yield}^{CB2} - \text{Ask yield}^{CB1}}{\text{Maturity}^{CB2} - \text{Maturity}^{CB1}} \times (\text{Maturity}_{GB} - \text{Maturity}_{CB1}) + \text{Ask yield}^{CB1} \quad (2)$$

The yield spread between the green bond and synthetic bond is the difference between the bonds' ask yields i on day t:

$$\Delta\text{Yield spread differential}_{i,t} = \text{ask yield}_{i,t}^{GB} - \text{ask yield}_{i,t}^{SB} \quad (3)$$

For majority part of the data, the interpolation worked adequately and provided believable approximations for the synthetic bond ask yields when compared to the minimum and maximum ask yields values of the two conventional bonds. For a few bonds, the interpolation formula estimated invalid synthetic bond yields, due to the identical maturity times of the two conventional bonds. And in couple cases, where the maturities of the two conventional bonds were far apart, and there were minimal day-observations, the interpolation resulted in vastly too high or too low estimates for the extrapolated values (e.g., multiple times either the min or max values of the actual ask yields of the conventional bonds, that can be viewed in Table 2) for the synthetic bond yield, which also resulted in the pertinent green bonds exclusion from the sample.

Table 2 Descriptive statistics of the bonds in the sample

	Sample					
	Min	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max**
Ask yield of GB	-2.263	0.021	0.443	0.443	1.110	9.831
Ask yield of CB 1	-1.654	-0.152	0.255	0.255	0.869	9.164
Ask yield of CB 2	-2.000	-0.012	0.412	0.412	1.087	9.967
Ask yield of SB	-2.397	0.038	0.452	0.453	1.211	11.462

Table 2 presents the distributions of the central elements of the data collection of this thesis: ask yields of the green bonds (GB), both conventional bonds (CB 1 and CB 2), and the created synthetic bond (SB). Although some differences in the distributions could be expected, the distributions of the synthetic bonds' ask yields are actually similar to those of the two conventional bonds.

3.2 Bid-ask spread as liquidity proxy

Zerbib (2019) asserts that the green bond premium is the unobserved specific effect of the regression of the yield differential on the liquidity differential between green and conventional bonds, he explains that using closing percent quoted bid-ask spread as a proxy for the liquidity is the only viable option as the fixed effects panel regression model can only be used with a variable that varies over time. For this reason, other often used liquidity proxies such as issue amounts and issue dates are not used in the empirical analysis part of this thesis, but, of course, were used in the matching method as a range criterion for the bond characteristics. The fixed effects panel regression model is then used to estimate the green bond premium. The first step of the green bond premium estimation, however, is to control for residual liquidity with the following steps presented in formulas (4), (5), and (6).

A bid-ask spread of a bond is the difference of its bid and ask prices. There is more than one way to calculate the bid-ask spreads, but Chung & Zhang (2014), show that a simple bid-ask spread calculation can do an adequate job as a liquidity proxy, further endorsed by Langedijk et al. (2018), who show evidence it performs the best compared to other low-frequency (meaning computed from daily data) liquidity proxies. Using closing percent quoted bid and ask prices, the bid-ask spreads were calculated with the following formula for all bonds in the sample:

$$Bid\text{-}ask\ spread_{i,t} = \frac{ask_{i,t} - bid_{i,t}}{\left(\frac{ask_{i,t} + bid_{i,t}}{2}\right)} \tag{4}$$

In order to create a bid-ask spread for the synthetic bond, the distance-weighted average of the two conventional bonds' bid-ask spreads was calculated. Zerbib (2019) defines $d_1 = |\text{Green bond maturity} - \text{Conventional bond A maturity}|$ and $d_2 = |\text{Green bond maturity} - \text{Conventional bond B maturity}|$, and the synthetic bond's bid-ask spread as:

$$Bid\text{-}ask\ spread_{i,t}^{SB} = \frac{d_2}{d_1 + d_2} bid\text{-}ask\ spread_{i,t}^{CB1} + \frac{d_1}{d_1 + d_2} bid\text{-}ask\ spread_{i,t}^{CB2} \tag{5}$$

The liquidity proxy, which is used as an independent variable in the fixed effects panel regression later, was obtained from the differential of the bid-ask spreads of green bonds and synthetic bonds i on days t, like shown in formula (6):

$$\Delta Bid\text{-}ask\ spread\ differential_{i,t} = bid\text{-}ask\ spread_{i,t}^{GB} - bid\text{-}ask\ spread_{i,t}^{SB} \qquad (6)$$

Distributions of the bid-ask spread differential is presented in Table 3. The mean is near exactly zero, and the standard deviation of the variable is incredibly low, preliminarily suggesting that the matching method criteria for the liquidity measures, i.e., issue amounts and issue dates, sufficiently controlled for the liquidity in the beginning of the data refinement process.

Table 3 Distribution of the liquidity proxy

$\Delta Bid\text{-}ask\ spread\ differential_{i,t}$ (%)						
Min	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max**	**Std. Dev.**
-0.025	-0.000	0.000	0.000	0.002	0.026	0.003

After the entire dataset was processed, the final sample contained 194 green bonds and 388 conventional bonds with a total of 66299 bond-day observations ranging from July 4th, 2014, the earliest date of any financial information for the bonds in the dataset, until December 31st, 2021. Out of the green bonds remaining, 54% were Eurobonds and 46% were issued in twelve different European countries, with only Germany, Norway, Switzerland, Sweden, and France having more than one issuance. The dataset includes bonds issued by agencies (banks), governments, and corporations and the green bonds represent all ratings included in the sample, apart from one, quite evenly, so there should not be any bias in the overall results towards high- or low-end rated green bonds. Rating categories AAA, AA, A, BBB, and NR all contain at least 28 bonds, and there are only two BB-rated bonds in the sample.

The three categories, into which all the green bonds were divided, contained 13 bonds certified by the CBI, 161 GBP aligned bonds, and 20 bonds that were categorized as self-labelled. A more detailed accounting of the sample distribution between categories, split also by currency and rating, can be viewed in Appendix 1. Table 4 shows the average maturities of the green bonds in years and average issue amounts in millions EUR, categorized by the aforementioned green label category, rating, and currency.

Table 4 Average maturities and Issue amounts in the sample

			AUD	CHF	EUR	GBP	HKD	IDR	NOK	SEK	USD
CBI Certified	AAA	Maturity			6.99						
		Iss. am.			949						
	AA	Maturity			15.81						
		Iss. am.			921						
	A	Maturity			10						4.33
		Iss. am.			1312						543
GBP Aligned	AAA	Maturity	10	3.70	14.33	6.20		5.16	5.57	8.13	10
		Iss. am.	28	221	1710	2067		36	96	290	947
	AA	Maturity	4.99	7.79	8.42	11.85	5			5.67	5
		Iss. am.	22	172	1170	14595	90			49	568
	A	Maturity		10.52	7.30		9.57		6	3.50	5.60
		Iss. am.		124	500		62		122	95	491
	BBB	Maturity			7.85					3.33	4
		Iss. am.			594					56	284
	BB	Maturity			7.62						
		Iss. am.			461						
	NR	Maturity		7.96	7.50		6		6.19	3.71	4
		Iss. am.		286	50		77		59	32	473
Self-labelled	AAA	Maturity			5.08						
		Iss. am.			750						
	AA	Maturity			11.26					6	
		Iss. am.			297					57	
	A	Maturity			9.05				5	3	5
		Iss. am.			310				24	48	322
	BBB	Maturity			7.17						
		Iss. am.			543						
	NR	Maturity		3.75	6					5	
		Iss. am.		167	75					38	

The 194 green bonds left in the dataset accounts for only 5.4 % of all green bonds issued in the European markets, and out of all countries in Europe, only five (Germany, Norway, Switzerland, Sweden, and France) are represented with more than one green bond (not considering Eurobonds). It is evident that the dataset does not provide sufficient representation of the European market as a whole, thus any results from the later analysis cannot be construed as such, but merely used as guidelines or estimations, and even that with caution. Nevertheless, the dataset contains more green bonds than in several other green bond literature (Gianfrate & Peri, 2019; Zerbib, 2019; Bachelet et al., 2019), that were able to provide significant results, so I am confident that the dataset can provide insight into green bond premia for more specific parts of Europe, i.e. roughly speaking Scandinavia, Central Europe and Eurobonds.

4 Methodology

The methods used in the empirical parts of this thesis are explained in this chapter. To answer the research questions of this thesis, firstly, the green bond premium is estimated with the fixed effects panel regression model and secondly, the determinants of the green bond, and possible effects the green labels have on the green bond, are analysed with an OLS regression to identify any possible relationships between the green bond premium and green labels. The results of the methods introduced in this chapter are presented in the following chapter.

4.1 Estimating the green bond premium

Like was introduced earlier in this thesis, Zerbib (2019) states that the green bond premium is the time-invariant unobserved effect in the fixed effects panel regression of the yield spread differential on liquidity. After confirming the presence of an unobserved heterogeneous effect in their data, and because fixed effects panel regression avoids omitted variables bias when used on matching bonds with near identical characteristics apart from their liquidity, Zerbib (2019) opts to use the model to estimate the green bond premium. Gormley & Matsa (2014) also advise using a fixed effects estimator in the presence of unobserved heterogeneity, by showing that a fixed effects model produces the most consistent estimates against other methods, that aim to control for it by either demeaning the dependent variable with respect to the group before estimating the model with OLS or which use the group's mean of the dependent variable as a control in an OLS specification. The fixed effects panel regression route is therefore chosen for the analysis in the empirical part of the thesis.

The variables calculated in the previous chapter, $\Delta Yield\ spread\ differential_{i,t}$ and $\Delta Bid\text{-}ask\ spread\ differential_{i,t}$ are used in the fixed effects panel regression model. The green bond premium is the fixed effect (p_i) in the FE-model of the daily yield spread between green bonds and synthetic bonds' regression on the daily bid-ask spread differential used as a liquidity proxy, where $\epsilon_{i,t}$ is the error term (Zerbib, 2019):

$$\Delta Yield\ spread\ differential_{i,t} = p_i + \beta \Delta Bid\text{-}ask\ spread\ differential_{i,t} + \epsilon_{i,t} \qquad (7)$$

The fixed effects panel regression is done on the entire sample containing all 194 bonds. Several tests to observe the presence of unobserved heterogeneous effect, heteroskedasticity and serial correlation are performed on the model. Tests for unobserved effects will help differentiate whether the fixed effects model was the correct choice in model selection for the analysis. Tests for heteroskedasticity will indicate whether the residuals of the model are equal or not over time and serial correlation tests tell if there is a pattern between past and present observations of the variables. The efficiency of the fixed effects model is also tested with a Hausman test, which determines whether a fixed effects model or a random effects model is more fitting for the data. Lastly, the estimated green bond premia, which are the fixed effects of the panel regression, are extracted from the model.

4.2 Determinants of the green bond premium

The matching method ensured that the green bonds share identical characteristics with their corresponding pairs of conventional bonds, but, of course, the green bonds do not have identical characteristics among themselves. Following the fixed effects panel regression to obtain the estimated green bond premium, an OLS regression is compiled to take a closer look at the determinants of the premium to see what kind of influence, if any, the bonds characteristics have on it. The considered variables are the bonds' rating, currency, sector, maturity, issue amount, and the bond's green label, all of which are presented in Table 5. Green label, rating, currency, and sector are all treated as categorical variables in the OLS regression.

The initial model specification for the regression analysis is shown below:

$$p_i = \alpha_i + \beta_1 Rating_i + \beta_2 Currency_i + \beta_3 Sector_i + \beta_4 Issue\ Amount_i + \beta_5 Maturity_i + \beta_6 Green\ label_i \quad (8)$$

Table 5 Description of the variables

Variable	Description
Rating	The rating of the green bond. The ratings of the bonds in the dataset include *AAA*, *AA*, *A*, *BBB*, *BB*, and *NR*. Categorical variable.
Currency	The currency in which the bond was issued. The currencies of the bonds in the dataset include *AUD*, *CHF*, *EUR*, *GBP*, *HKD*, *IDR*, *NOK*, *SEK*, and *USD*. Categorical variable.
Sector	The sector of the bond as defined by Refinitiv Business Classification (TRBC). Sectors in the sample include *Basic Materials, Consumer Cyclicals, Energy, Financials, Government Activity, Industrials, Real Estate, Technology,* and *Utilities.* Categorical variable.
Issue amount	Issue amount of the green bond presented in billions EUR.
Maturity	Maturity of the bond on 31st of December 2021, measured in years.
Green label	Label of the green bond. Possible classifications for the green bonds include *CBI Certified Green Bonds, GBP Aligned Green Bonds,* and *Self-Labelled Green Bonds.* Categorical variable.

The OLS regression is run on the entire sample, but also on a smaller sample from which all rating, currency, and sector based subcategories containing fewer than 3 green bonds were removed to improve the overall quality of the analysis. Tests to determine heteroscedasticity and multicollinearity are performed on all used specifications of the model. Heteroscedasticity increases the coefficient estimate's variances and can be present in financial data. Two other model specifications are also constructed, first one excludes the green label, meaning the certification of the bond, to analyse the relationships of the typically seen bond characteristics on the green bond premium, and the second one excludes the Sector, as majority of the data is packed in the financial sector, leaving other variables with fewer values.

A more detailed description of the possible green labels a bond may hold was given in Chapter 3, but as a brief reminder: *CBI Certified Green Bonds* have been certified by Climate Bonds Initiative, *GBP Aligned Green Bonds* adhere at least to the four code principles of Green Bond Principles, and *Self-Labelled Green Bonds* do not, at the current knowledge, hold any verification or certification but are claimed to be green by the issuer.

5 Results

The results of the empirical analysis of this thesis are divided into two sections in this chapter to follow the step-by-step progression of the analysis that was conducted: firstly, the size and magnitude of the green bond premium will be presented, and secondly, the determinants of the green bond premium and their significance will be introduced. All tests and robustness checks performed on the analysis will also be discussed in this chapter. The findings and results will also be compared to prior literature on green bond premia.

5.1 Green bond premium

The empirical part of this thesis was begun by running the fixed effects panel regression on the entire dataset with an objective to identify the time-invariant unobserved effect for each bond, which is the green bond premium, specified by Zerbib (2019). Several tests are conducted on the panel regression: Wooldridge test confirms there is unobserved effect in the model, and F test and Breusch-Pagan Lagrange Multiplier test indicate that there are both fixed and random effects present in the dataset. In similar situations, where both random and fixed effects are present, a Hausman test is used to compare the fixed and random effects models to determine which of the models is more robust. In this case, the Hausman test confirmed under 1% significance level that the fixed effects model is a more suitable for the analysis of this thesis. Additionally, Breusch-Godfrey/Wooldridge, Durbin-Watson and Wooldridge tests indicate serial correlation, and Breusch-Pagan test concludes the presence of heteroscedasticity. These test results are taken into consideration by adding Newey-West and Beck-Katz robust estimations of the standard errors to control for serial correlation and heteroscedasticity. More details about the conducted tests and their results can be viewed in Appendix 2.

Table 6 Fixed effects within-regression

	Dependent variable: $\Delta Yield\ spread_{i,t}$		
	Fixed effects within-regression	**Newey–West robust std. err.**	**Beck–Katz robust std. err.**
$\Delta\text{Bid-ask spread}_{i,t}$	-11.737*** (0.323)	-11.737*** (0.905)	-11.737*** (2.268)
Observations	66299		
R^2	0.019		
Adjusted R^2	0.017		

Note: Standard errors are reported in parentheses
*** p < 0.001; ** p < 0.01; * p < 0.05

Table 6 presents the results of the fixed effects panel regression on $\Delta Yield\ spread_{i,t} = \alpha_i + \beta \Delta Bid\text{-}ask\ spread_{i,t} + \epsilon_{i,t}$. The explanatory R^2-value of the FE-model is low, only 1.9%, though it is still similar to Zerbib's (2019) results of 1.3%. Despite the low explanatory value, the bid-ask spread differential used as a liquidity proxy is statistically significant on 1% significance level for all estimators of the standard errors: a 1 basis point increase in the bid-ask spread differential results in a -11.7 bps decrease in the yield spread differential. Significance of the liquidity proxy in the fixed effects panel regression model indicates that the preliminary estimation of the effectiveness of the matching method may have been inaccurate, as the matching method process did not entirely control for the liquidity and left some residual liquidity to be controlled.

As was expressed in the methodology part of this thesis, Zerbib (2019) states that the green bond premium is the time-invariant unobserved effect in the fixed effects panel regression of the yield spread differential on liquidity. The estimated green bond premia and discounts are presented in Table 7. They range from a minimum of -60.7 basis points (bps) to a maximum of 232.1 bps, with a median of -1.1 bps and mean of -2.0 bps, showing that the extreme ranges of the estimated green bond premium differ from one another quite substantially. Most interestingly, the mean of the entire sample is barely, but still notably, negative, indicating that green bonds in general have marginally lower yields compared to the yields of comparable conventional bonds. 116 green bonds out of 194, or 60%, are estimated to have a negative premium.

Table 7 Distribution of the estimated green bond premium

α_i (%)					
Min	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max**
-0.607	-0.070	-0.011	-0.020	0.024	2.321

The distributions of the estimated premium are presented visually in the Kernel Density plot in Figure 2. The mean is indicated by the red solid line, 1st and 3rd quantiles are indicated with a blue dashed line. The solid green line of the green bond premium shows an extremely narrow positive skewness while it otherwise is quite symmetrical around the mean, apart from the maximum, outlier-like, discount of one green bond shown on the right-side of the plot. For comparison's sake, the next-in-line highest maximum value of green bond discounts is 55.0 bps. Majority of the green bond premia and discounts are packed around both sides of zero. All 194 bonds are included in the density plot, and its bandwidth is 0.03.

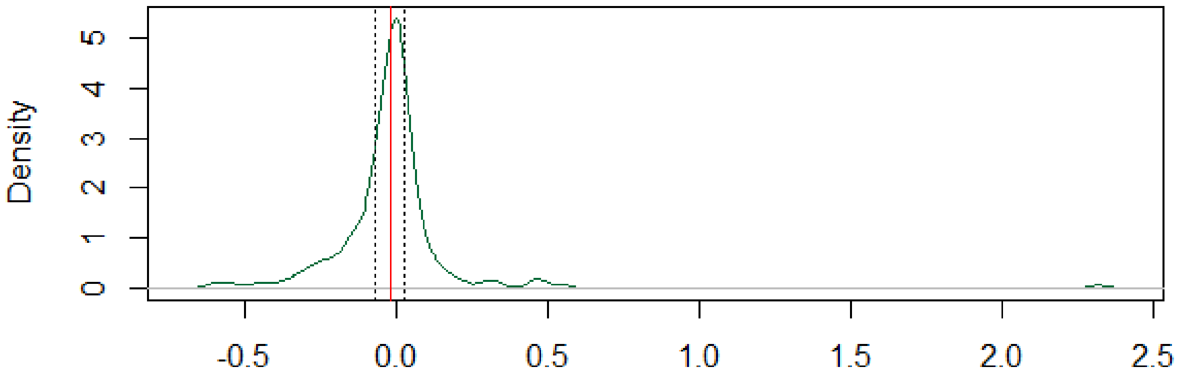

Figure 2 Distribution of the estimated premia and discounts

The sample is then divided into multiple subsamples based on their characteristics, taking into consideration only one characteristic at a time: rating, currency, sector, as well as the green bond's label, and whether they are Eurobonds or not. The sector for each bond is defined by Refinitiv Business Classification (TRBC). A Shapiro-Wilk normality test was conducted on all subsamples with more than 10 bonds; non-normality was found in majority of the subsamples, and normality in the population was present in subsamples of Hong Kong Dollar and Swiss Franc currencies, and Real Estate and Utilities sectors. A more detailed account on the results of the Shapiro-Wilk normality test for each subsample can be viewed in Appendix 3. As majority of the subsamples are not normally distributed, a Wilcoxon signed-rank test is used, as is suggested by Zerbib (2019), to test whether the premium or discount of the subsample, meaning the mean, significantly differs from 0. For the remainder of the subsamples presenting with normally distributed data, instead of the

Wilcoxon signed-rank test, a single sample t-test was chosen to review whether the mean significantly differs from 0. These tests are conducted essentially to see if the premium or discount of the subsample is statistically significant.

Table 8 presents the number of green bonds, mean and medians of the premium in each subsample, and the results of the premium significance testing (Wilcoxon signed-rank test or single sample t-test). Values of smaller subsamples are differentiated with a grey font colour, and no green bond premium significance testing was run on them due to small sample size, hence for them, column $p_i \neq 0$ is empty – for other subsamples, the column shows the possible significance of the green bond premium. The mean of the entire sample, -2.0 bps, is shown to be significantly different from zero, providing evidence that, on average, green bonds in the sample are priced slightly higher compared to conventional bonds, therefore very gently supporting the first and main hypothesis of this thesis, that there is a green bond premium in the European markets. Of course, this is if general conclusions are to be made from the small sample size of green bonds, compared to all green bonds that were issued in the European markets. The methodologies used in this thesis are equivalent to those of Zerbib (2019) and Bachelet et al. (2019), but the results of the empirical analysis on the entire sample are only in line with the findings of Zerbib (2019), who found a green bond premium of -1.8 bps in their entire sample of 110 green bonds, while Bachelet et al. (2019) found a discount of up to 4.3 with a sample size of 89. Taken into consideration the actual bonds that were included in the sample and what kind of selection they represent, a better deduction from the analysis would be that the green bonds issued by larger governments and corporations centralized in northern and central Europe are indicated to have a small but significant green bond premium.

All subsamples from the original 194 green bonds containing more than a hundred green bonds are shown to have a green bond premium – Euro-denominated bonds have a significant green bond premium of -0.2 bps, bonds issued in the Financials-sector have a premium of -3.7 bps, GBP Aligned green bonds, meaning bonds that follow at least the four core principles of the GBP, show a premium of -0.9 bps and Eurobonds bonds have a premium of -3.5 bps. The presented green bond premia should in this case, too, be taken with a grain of salt, as they do not represent the entirety of the European markets.

Table 8 Distribution of the estimated green bond premia per subsample

		Mean	Median	$p_i \neq 0$	# GB
Entire sample		-0.020	-0.011	***	194
Rating	AAA	0.040	-0.009		37
	AA	0.004	0.002		43
	A	-0.050	-0.016	*	56
	BBB	-0.074	-0.070	**	28
	BB	0.172	0.172		2
	NR	-0.034	-0.009		28
Currency	Australian Dollar	-0.038	-0.038		2
	British Pound	-0.008	-0.001		3
	Euro	-0.002	-0.012	*	113
	Hong Kong Dollar	-0.024	-0.016		10
	Indonesian Rupiah	-0.352	-0.352		1
	Norwegian Krone	-0.046	0.003		17
	Swedish Krona	0.025	0.006		17
	Swiss Franc	-0.025	-0.019		16
	US Dollar	-0.148	-0.059	.	15
Sector	Basic Materials	-0.137	-0.137		1
	Consumer Cyclicals	0.083	-0.095		3
	Energy	-0.147	-0.147		1
	Financials	-0.037	-0.016	***	132
	Government Activity	0.122	0.006		19
	Industrials	0.041	0.006		12
	Real Estate	-0.097	-0.042	.	13
	Technology	-0.008	0.027		3
	Utilities	-0.052	-0.031		10
Green Bond Label	CBI Certified Green bond	-0.034	-0.006		13
	GBP Aligned Green bond	-0.009	-0.009	*	161
	Self-Labelled Green bond	-0.095	-0.064	**	20
Country of Issue	Eurobond	-0.035	-0.026	***	104
	Non-Eurobond	-0.003	-0.002		90

Note: *** p < 0.001; ** p < 0.01; * p < 0.05; . < 0.1

While many of the smaller subsamples (containing 10 or more bonds) are not significantly different from zero, thus no definite conclusions can be drawn from them, their means are more or less evenly divided between indicating a green bond premium and a discount. Higher rated bonds suggest a green bond discount and lower rated and not rated bonds a green bond premium. Self-labelled green bonds show a green bond premium of -9.5 bps that is significant under a 1% confidence level and GBP Aligned bonds show a premium of -0.9 bps. The difference is not major, but it is there, suggesting that the second hypothesis of this thesis is also true, there is indeed a difference in premia for green bonds with different green labels, at least when GBP Aligned and Self-labelled green bonds' yields are considered. GBP Aligned green bonds is also substantially the largest subgroup among the green bonds in the sample and also represent the largest amount of green bonds in European markets in general, though the existence of a green bond premium for all GBP Aligned green bonds in the European markets cannot be guaranteed based on this thesis' analysis. Still, these results softly indicate that labelled green bonds, both certified by CBI and those that follow the Green Bond Principles, actually result in higher yields for the investor compared to green bonds that have no labels, and it is worth the effort to seek out green bonds that leave no doubt about them being greenwashed.

5.2 Determinants of green bond premium

In order to understand which bond characteristics may have an effect on the green bond premium, a linear regression is performed on multiple variations of the main function that was presented earlier in this thesis. Function (8) represents the third model specification (c), which includes all chosen variables and in specifications (a) and (b) the green bonds label and the sector, respectively, are excluded.

$$p_i = \alpha_i + \beta_1 Rating_i + \beta_2 Currency_i + \beta_3 Sector_i + \beta_4 Issue\ Amount_i + \beta_5 Maturity_i + \beta_6 Green\ label_i \tag{8}$$

Initial Breusch-Pagan tests indicate heteroscedasticity in all model specifications, so White robust standard errors are included in the reporting, as otherwise the results may have incorrect standard errors. Generalized Variance Inflation Factor (GVIF) is close to 1 for all variables in all specifications, meaning evidence of multicollinearity is not present. All three model specifications were performed on the entire sample of 194 bonds, for which the results can be viewed in Appendix 4, and from the suggestion of Zerbib (2019), all subsamples which include 3 or fewer bonds are excluded to avoid artificially high R^2s, leaving 180 green bonds. The excluded subsamples are presented in grey font in Table 8. The results of the OLS regressions can be viewed in Table 9. The reference modalities are

AA for rating, Euro for currency, Financials for the sector and CBI Certified bonds for the label of the green bond.

Table 9 OLS regression

	Dependent variable: p_i					
	OLS regression with White robust standard errors					
	(a)		(b)		(c)	
Constant	-0.110	(0.085)	-0.125	(0.113)	-0.112	(0.097)
Issue Amount	-0.053*	(0.027)	-0.037*	(0.021)	-0.055*	(0.027)
Maturity	0.017	(0.015)	0.019	(0.016)	0.017	(0.015)
AAA	0.058	(0.042)	0.047	(0.044)	0.044	(0.042)
AA	-0.010	(0.039)	0.005	(0.033)	-0.023	(0.040)
BBB	-0.026	(0.040)	-0.059	(0.039)	-0.043	(0.040)
NR	0.025	(0.048)	0.000	(0.048)	0.021	(0.049)
Hong Kong Dollar	-0.020	(0.074)	-0.044	(0.079)	-0.041	(0.076)
Norwegian Krone	-0.059	(0.063)	-0.020	(0.063)	-0.073	(0.066)
Swedish Krona	0.048	(0.051)	0.085	(0.056)	0.054	(0.051)
Swiss Franc	-0.059	(0.043)	-0.047	(0.038)	-0.065	(0.046)
US Dollar	-0.073	(0.074)	-0.068	(0.073)	-0.072	(0.071)
Government Activity	0.166.	(0.099)			0.173.	(0.099)
Industrials	0.071	(0.056)			0.081	(0.052)
Real Estate	-0.062	(0.058)			-0.050	(0.061)
Utilities	-0.003	(0.044)			0.001	(0.046)
GBP Aligned Green bond			0.023	(0.046)	0.025	(0.044)
Self-Labelled Green bond			-0.069	(0.054)	-0.076	(0.055)
Observations	180		180		180	
R^2	0.268		0.221		0.252	
Adjusted R^2	0.192		0.160		0.183	

Note: *** p < 0.001; ** p < 0.01; * p < 0.05; . < 0.1

All specifications indicate that the issue amount has a significant negative relationship with green bond premium, suggesting that for lower issue amounts green bond premium is higher. Considering the impact ratings have on the premia, although the results are insignificant and thus it is advised to interpret the results with caution, the premium seems to be of a greater magnitude for lower rated bonds compared to higher rated bonds, akin to the results of Zerbib (2019), who identified green bond premia differ based on the bond's rating, though not rated bonds seem to exhibit a green bond discount.

Not one of the currencies in the sample seems to have a significant relationship with the green bond premium in any specification, but in the European markets it appears, though is not proven, that Euro and SEK-denominated bonds enjoy higher yields compared to green bonds issued in other currencies. Both specifications that utilise the Sector variable, (a) and (c), find that Government Activity has a significant positive relationship with the green bond premium.

Most interestingly, there seems to be no significant impact on the green bond premium either way whether the bond holds a green label or not, leaving the third and final hypothesis of this thesis unconfirmed. These results are in contrast with findings of Hyun et al. (2021) and Bachelet et al. (2019), who show in their respective studies that labelled green bonds are traded at a higher premium in comparison to unlabelled bonds. It is interesting to note that both specifications which include the green label, (b) and (c), show different signs for GBP Aligned and Self-labelled green bonds.

Gianfrate & Peri (2019) also studied green bonds in the European region, although with another method (propensity score matching), so the results of this thesis are not entirely comparable with their results and should be viewed and compared with a critical touch. The timespan of their green bond analysis is multiple years narrower than that of this thesis and due to more limited amount of data at the time they, too, faced issues with finding comparable conventional bonds to green bonds potentially at the expense of the quality of the sample. Nonetheless, there are no major differences in the green bond premium that Gianfrate & Peri (2019) identified in comparison to this thesis, though they are a tad higher.

It is worth reminding that the green bond premium represents the mean of all the bonds in the sample throughout the entire timespan. In the end, sadly, it cannot be said with confidence that this thesis confirms the presence of an overall green bond premium in the European markets, as the green bonds included in the sample represent only a small portion of all the green bonds issued in Europe, but the results do indicate that more specific subsections of the European markets, meaning green bonds issued by larger issuers from certain countries (Germany, Norway, Switzerland, Sweden, and France), and Eurobonds have a green bond premium. The results gently suggest that that investors are willing to pay a marginally higher price for green bonds, thus accept overall lower yields. Green bond markets are expected to keep growing exponentially, highlighting the need for further regulations, registries and possibly laws, to further alleviate the concerns of investors regarding greenwashing in the green bond markets.

5.3 Limitations

This thesis faced some limitations mostly related to data collection and refining processes. The sample obtained for this thesis was quite substantial compared to other research conducted on similar topic, but nonetheless, the short supply of financial information on both green and conventional bonds vastly dropped the amount of bonds included in the sample. The matching method was able to find at least two identical conventional bonds to 194 green bonds (which is more green bonds than in many recent literature, like Zerbib (2019) and Bachelet et al. (2019)) but compared to the number of green bonds issued in the European markets (3588), it only amounted to 5.4% of all green bonds issued.

The relaxation of the ratings in the matching method process could potentially affect the two conventional bonds that were chosen as pairs to the green bond, and, in hindsight, instead of changing the way the rating was chosen for each bond included in the dataset, the calculation of the average ratings could have been done in another software that may have handled the data better without crashing constantly. In later analysis, the rating of the green bonds was also used as a categorical variable instead of an ordinal one, so there's a possibility that some insight into the relationship between ratings and green bond premia was left missing.

The criterion and the ranges chosen for the matching method altogether could have been stricter, meaning for example the criterion for issue date ranges for the conventional bond could have been set shorter than more or less than 6 years from the issuance of the green bond, but it would have resulted in fewer bonds included in the sample, which most likely would not have increased the accuracy of the results (Zerbib, 2019). While the financial (ask yield, ask, bid) data is considered reliable, information on green labels, such as evidence of verifications, certifications or other external reviews proved to be somewhat miscellaneous in nature, leaving a slight possibility that the labels for the green bonds in the sample could be misclassified, which would impact the results of this entire thesis.

Due to some level of obscurity of the data collection description in Zerbib's (2019) research, a possible oversight in the data collection process was to disregard the "surplus" identical conventional bonds from the dataset in the event when one green bond had more than just exactly two of them – the consequence of this is that the sample did not include all green bonds it could have, which is why the matching process presented in Chapter 3 was conducted again to find all potential alternatives for the 655 green bonds with financial data. As an example, out of the 224 green bonds included in the original dataset, 11 of the excluded green bonds had more than two identical conventional bonds, but none of the alternative conventional bonds were fit as substitutes due to not having enough data available.

Ultimately, an additional 23 green bonds (1 CBI Certified, 19 GBP Aligned, and 3 Self-Labelled green bonds) with the two matching conventional bonds were identified, resulting in a total of 217 green bonds in the new dataset, an increase of 11.9% in the final sample size. 9 green bonds (39.1%) were Eurobonds and 14 (60.9%) from five different countries, with France, Germany, and Switzerland having more than one green bond. These three countries were among the five most represented counties of green bond issuances in the original sample, as was mentioned in Chapter 3. The additional bonds also held a wide range of ratings – the new bonds expanded the existing subcategories of the original sample.

5.3.1 Revised dataset

To see the potential differences that the additional 23 groups of three bonds have on the results presented in Chapter 5, the green bond premium was estimated on the new dataset, exactly following the methodology presented in Chapter 4. The results for the robustness checks and the fixed effects panel regression model can be viewed in Appendix 5. The FE-model provided quite different results in comparison to the analysis on the smaller dataset, indicating that a 1 basis point increase in the bid-ask spread differential would decrease the yield spread differential by only -8.3 bps instead of -11.7 bps, like with the smaller sample.

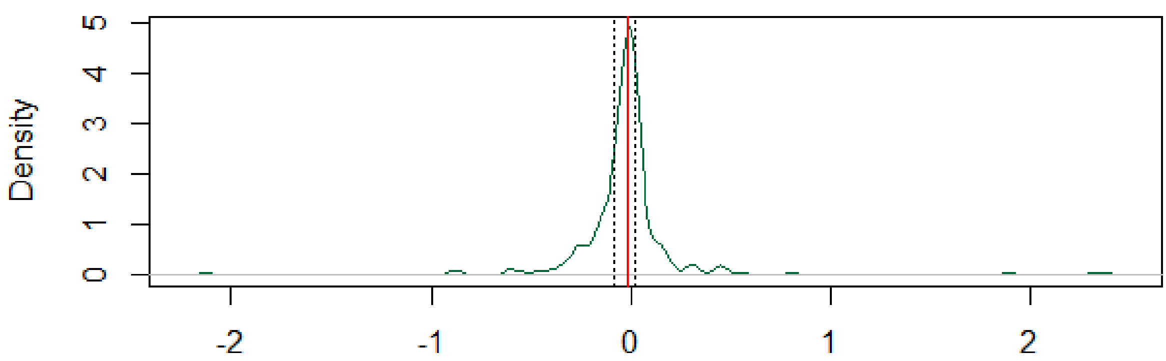

Figure 3 Distribution of the estimated premia and discounts, revised dataset

The distributions of the estimated green bond premia and discounts of the revised dataset are presented in the Kernel Density plot in Figure 3. The red solid line in the figure indicates the mean of the entire sample, and the two blue dashed lines indicate 1st and 3rd quantiles, as in Figure 2. The distributions of the premia and discounts are very similar between both samples.

The distributions of the entire revised dataset can be viewed in Table 10. While the overall mean of the revised dataset is still negative, indicating a green bond premium, it is smaller in magnitude, -1.2 bps, compared to the original dataset with 194 green bonds, -2.0 bps. Most of the subsamples' premia signs remained the same with the revised dataset, with minor changes to the magnitudes (excluding Government Activity and Non-Eurobonds). Self-Labelled green bonds now indicate a premium of a much smaller magnitude, -2.1 bps (-9.5 bps in the original sample), which is more in line with the results of the resent studies.

Most notably the Euro-denominated green bonds are indicated to have a statistically significant discount (+1.1 bps) in the revised dataset instead of a premium (-0.2 bps) like with the original sample. This result would suggest that Euro-denominated green bonds are actually priced lower than their conventional counterparts. To examine this swing of signs more closely, a histogram of the green bond premium distributions of both the original and the revised samples were constructed and is presented in the Figure 4 below. The bonds included in the original sample are in grey and the bonds added in the revised dataset are presented in green.

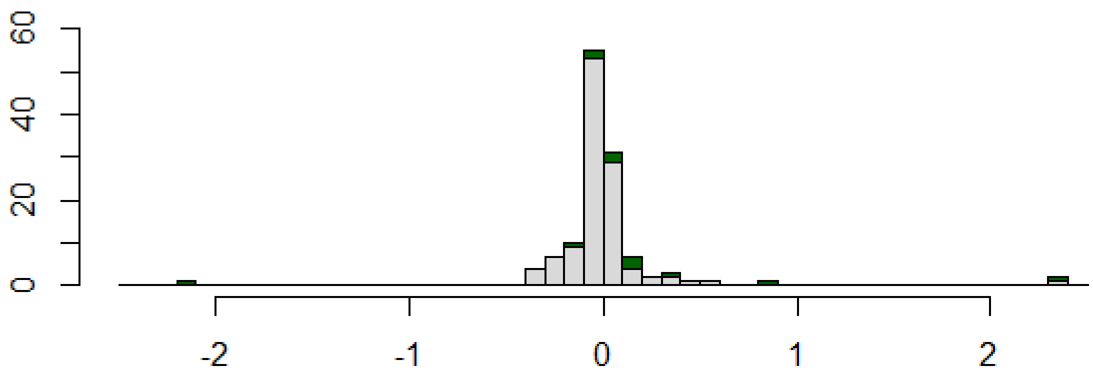

Figure 4 Histogram of Euro-denominated green bond premia and discounts in the final sample, separated by colour (original sample in grey, revised sample in green)

Table 10 Distribution of the estimated green bond premia per subsample in revised dataset

		Mean	Median	$p_i \neq 0$	# GB
Entire sample		-0.012	-0.013	**	217
Rating	AAA	0.017	-0.009		42
	AA	0.114	0.003		49
	A	-0.086	-0.015	*	64
	BBB	-0.078	-0.078	***	29
	BB	0.172	0.172		2
	NR	-0.051	-0.016	*	31
Currency	Australian Dollar	-0.330	-0.070		3
	British Pound	-0.009	0.001		3
	Euro	0.011	-0.013	*	125
	Hong Kong Dollar	-0.025	-0.014		10
	Indonesian Rupiah	-0.354	-0.354		1
	Norwegian Krone	-0.051	-0.005		17
	Swedish Krona	0.028	0.008		18
	Swiss Franc	-0.092	-0.042	**	21
	US Dollar	-0.009	-0.024		19
Sector	Basic Materials	-0.139	-0.139		1
	Consumer Cyclicals	0.082	-0.097		3
	Energy	-0.149	-0.149		1
	Financials	-0.016	-0.016	**	145
	Government Activity	-0.046	-0.005		22
	Healthcare	2.385	2.385		1
	Industrials	0.064	0.014		14
	Real Estate	-0.121	-0.051		16
	Technology	-0.012	0.025		3
	Utilities	-0.056	-0.029		11
Green Bond Label	CBI Certified Green bond	-0.051	-0.008		14
	GBP Aligned Green bond	-0.009	-0.011	*	180
	Self-Labelled Green bond	-0.021	-0.074	*	23
Country of Issue	Eurobond	-0.040	-0.030	***	113
	Non-Eurobond	0.018	-0.006		104

Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

It is seeming in Figure 4, that while the green bonds premia of the newly added bonds in the revised dataset present values of all ranges in the premium distribution – including both high and low ends – discounts seem to be more frequent and are larger in magnitude, which could be the cause of the overall Euro-denominated sample mean turning positive, meaning a change from a green bond premium into a green bond discount.

All in all, the aforementioned limitations did not compromise the most important results of this thesis, instead this thesis merely answered a broad main research question with a more specific answer. I was able to provide insight into green bond premia and provide evidence that the premium is of different for each green label, but unfortunately failed to provide additional value around it, as no relationship of any kind was found between the green bond premium and the green labels. The related analysis ended up not providing significant results, possibly due to the data on certifications and verifications being inadequate to sufficiently differentiate different types of green bond labels (apart from CBI Certified) from one another. Green labels altogether have only been around for less than a decade, which affected the quality of the data available.

6 Conclusions

Global warming and climate change are as relevant topics as ever, happening constantly, in the background. It is a fairly recent development that the financial markets have started to offer ways to help change the world to a better place one green project at a time, but luckily, the practice has already cemented itself in the minds of investors. The rapid expansion of the green bond market, and many showings of oversubscription levels for green bonds, has shown that there is sincere desire among investors to participate in allocating funds to projects that have the potential to push back global warming.

The main goal of this thesis was to analyse the European green bond market from the investor's perspective to see, whether the estimates of green bond premia from the world also held true in European region. The main research question was:

Is there an overall green bond premium in the European markets?

And the answer is: yes, there is, at least in more specific, centralized parts of it. General conclusions for the entirety of the European markets based on the results of this thesis would be too bold of a statement to make. I was able to provide evidence of an overall green bond premium of -2.0 basis points, -0.02%, in the larger green bond markets within Europe (Germany, Norway, Switzerland, Sweden, and France). Multiple subsamples as well exhibited a significant green bond premium of various levels between -9.5 bps and -0.9 bps, though always negative. The findings of this thesis are consistent with Zerbib (2019), who found a green bond premium of -1.8 bps in their sample of worldwide green bonds. A subsample of only Euro-denominated bonds issued in the European markets hold a green bond premium of -0.2 bps, an amount ten times smaller than the premium of the entire sample. In addition, I was able to show that Self-labelled green bonds have the highest premium among the green labels, but that GBP Aligned bonds are also priced at a premium, in response to the first supporting research question, "*Is the magnitude of green bond premium the same for all green labels?*

Throughout this thesis the importance of green bond's transparency and regulation, in the form of green labels, has been emphasized, but unfortunately no link or clear evidence was found between the green labels and green bonds, thus resulting in the second supporting research question, "*Is there a relationship between green labels and green bond premia?"* to be left open, as it would be presumptuous to provide an answer without attestation. Other research in this topic have found a link between green bond premia and green labels

(Bachelet et al., 2019; Hyun et al., 2021). It is possible that the limitations of the data and the time constraints in the writing of this thesis did not allow for the analysis to have more depth and present significant results.

The relevance of the subject of this thesis though cannot be diminished – green bond market grows with each passing day and is attracting new investors, both in Europe and all over the world. This thesis contributes to the overall understanding of green bond yields in the European markets and provides insight to the differences of the expected yields in finer subsamples. Green bonds are still traded at a slight but prominent premium, and that is the price investors have to pay at the moment if they wish to contribute to any green investment. Hopefully, the results of this thesis will not discourage the most profit-seeking investors away but instead encourage them to seek investment opportunities in the form of green bonds, especially when they have the option to invest in Euro-denominated green bonds which have next to the same yields as conventional bonds (or even offer higher yields). Despite the minimal premium, green labels still offer valuable information to investors and just by existing help regulate the markets against possible wrongdoers.

It may take a few years still, but for future research, it would be remarkably interesting to analyse the maturity of the European green bond market through the growth of European Green Bonds, a green label for bonds that follow the European Green Bond Standard (EUGBS). The process of labelling European bonds is still so young, but the assumption is that within a decade the level of labels and other regulatory actions have improved not only in the European markets but all over the world. As the green market keeps growing, utilising stricter matching criteria could be possible to obtain more reliable and comparable results, or alternatively, utilising other types of methodology not including a matching method, which would include all green bonds issued in a region, instead of just a small portion of them. Incorporating other external reviews in the analysis could also be beneficial and help expand the knowledge on the relationships between green labels and green bond premia.

References

Agar, C., 2005. *Capital investment & financing: a practical guide to financial evaluation*. Oxford; Boston: Elsevier Butterworth-Heinemann.

Avramov, D., Cheng, S., Lioui, A. & Tarelli, A., 2022. Sustainable investing with ESG rating uncertainty. *Journal of Financial Economics*, 145(2), pp.642-64.

Bachelet, M.J., Becchetti, L. & Manfredonia, S., 2019. The Green Bonds Premium Puzzle: The Role of Issuer Characteristics and Third-Party Verification. *Sustainability*, 11(4), p.1098.

Baker, M., Bergstresser, D., Serafeim, G. & Wurgler, J., 2018. *Financing the Response to Climate Change: the Pricing and Ownership of U.S. Green Bonds*.

Baldi, F. & Pandimiglio, A., 2022. The role of ESG scoring and greenwashing risk in explaining the yields of green bonds: A conceptual framework and an econometric analysis. *Global Finance Journal*, 52, p.100711.

Barclays, 2015. *The Cost of Being Green*. [Online] Available at: https://www.environmental-finance.com/assets/files/US_Credit_Focus_The_Cost_of_Being_Green.pdf [Accessed 15 October 2021].

Becker, M.G., Martin, F. & Walter, A., 2022. The power of ESG transparency: The effect of the new SFDR sustainability labels on mutual funds and individual investors. *Finance Research Letters*, 47, p.102708.

CBI, 2018. *Green Bond Principles & Climate Bonds Standard*. [Online] Available at: https://www.climatebonds.net/market/best-practice-guidelines [Accessed 20 September 2021].

CBI, 2020. *GREEN BOND PRICING IN THE PRIMARY MARKET: January - June 2020*. [Online] Available at: https://www.climatebonds.net/files/reports/cbi-pricing-h1-2020-21092020.pdf [Accessed 15 May 2022].

CBI, 2021a. *Certification under the Climate Bonds Standard*. [Online] Available at: https://www.climatebonds.net/certification [Accessed 2021 November 11].

CBI, 2021b. *Explaining green bonds*. [Online] Available at: https://www.climatebonds.net/market/explaining-green-bonds [Accessed 11 October 2021].

CBI, 2021c. *GREEN BOND PRICING IN THE PRIMARY MARKET: July - December 2021*. [Online] Available at: https://www.climatebonds.net/files/reports/cbi_pricing_h2_2021_02g.pdf [Accessed 15 May 2022].

CBI, 2021d. *Climate Bonds Taxonomy*. [Online] Available at: https://www.climatebonds.net/files/files/Taxonomy/CBI_Taxonomy_Tables-08A%20%281%29.pdf [Accessed 4 September 2022].

CBI, 2022a. *Approved Verifiers under the Climate Bonds Standard*. [Online] Available at: https://www.climatebonds.net/certification/approved-verifiers [Accessed 15 March 2022].

CBI, 2022b. *Certified Bonds*. [Online] Available at: https://www.climatebonds.net/certification/certified-bonds [Accessed 15 January 2022].

CBI, 2022c. *External Review*. [Online] Available at: https://www.climatebonds.net/market/second-opinion [Accessed 20 May 2022].

Choudhry, M., 2004. *Advanced fixed income analysis*. Amsterdam London: Elsevier Butterworth-Heinemann.

Chung, K.H. & Zhang, H., 2014. A simple approximation of intraday spreads using daily data. *Journal of Financial Markets*, 17, pp.94-120.

Clapp, C. & Pillay, K., 2017. *Climate finance: theory and practice*. New Jersey London Singapore Beijing Shanghai Hong Kong Taipei Chennai Tokyo: World Scientific.

Dahl, R., 2010. Green Washing: Do You Know What You're Buying? *Environmental Health Perspectives*, 118(6).

ECB, 2022. *Opinion of the European Central Bank*. [Online] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021AB0030&from=EN [Accessed 06 June 2022].

Ehlers, T. & Packer, F., 2017. Green Bond Finance and Certification. *BIS Quarterly Review*, pp.89-104.

EIB, 2021. *Climate Awareness Bonds*. [Online] Available at: https://www.eib.org/en/investor_relations/cab/index.htm [Accessed 23 September 2021].

European Commission, 2021a. *Overview of sustainable finance*. [Online] Available at: https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/overview-sustainable-finance_fi [Accessed 15 December 2021].

European Commission, 2021b. *NextGenerationEU: European Commission successfully issues first green bond to finance the sustainable recovery*. [Online] Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_21_5207 [Accessed 2 May 2022].

European Commission, 2022. *European green bond standard*. [Online] Available at: https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/european-green-bond-standard_en [Accessed 03 June 2022].

European Parliament, 2021. *European green bonds*. [Online] Available at: https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/698870/EPRS_BRI(2022)698870_EN.pdf [Accessed 20 June 2022].

Fabozzi, F.J., 2013. *Bond markets, analysis, and strategies*. 8th ed. Boston Columbus Indianapolis: Pearson.

Febi, W., Schäfer, D., Stephan, A. & Sun, C., 2018. The impact of liquidity risk on the yield spread of green bonds. *Finance Research Letters*, 27, pp.53-59.

Flammer, C., 2020. *Environmental and energy policy and the economy*. Chicago London: The University of Chicago Press.

Flammer, C., 2021. Corporate green bonds. *Journal of Financial Economics*, 142(2), pp.499-516.

Galaz, V. et al., 2015. Why Ecologists Should Care about Financial Markets. *Trends in Ecology & Evolution*, (30), pp.571-80.

Gatti, L., Pizzetti, M. & Seele, P., 2021. Green lies and their effect on intention to invest. *Journal of Business Research*, 127, pp.228-40.

Gianfrate, G. & Peri, M., 2019. The green advantage: Exploring the convenience of issuing green bonds. *Journal of Cleaner Production*, 219, pp.127-35.

Gormley, T.A. & Matsa, D.A., 2014. Common Errors: How to (and Not to) Control for Unobserved Heterogeneity. *Review of Financial Studies*, 27(2), pp.617-61.

Helwege, J., Huang, J.-Z. & Wang, Y., 2014. Liquidity effects in corporate bond spreads. *Journal of Banking & Finance*, 45, pp.105-16.

Hyun, S., Park, D. & Tian, S., 2021. Pricing of Green Labeling: A Comparison of Labeled and Unlabeled Green Bonds. *Finance Research Letters*, 41.

ICMA, 2020a. *Sustainable Finance: High-level definitions*. Zurich: International Capital Market Association.

ICMA, 2020b. *The Governance Framework of the Principles*. [Online] Available at: https://www.icmagroup.org/assets/documents/Regulatory/Green-Bonds/GBP-SBP-GovernanceFinal5-May-2020-110520.pdf [Accessed 30 September 2021].

ICMA, 2021. *External Reviews*. [Online] Available at: https://www.icmagroup.org/sustainable-finance/external-reviews/ [Accessed 11 November 2021].

Jones, L., 2021. *Record $269.5bn green issuance for 2020: Late surge sees pandemic year pip 2019 total by $3bn*. [Online] Available at: https://www.climatebonds.net/2021/01/record-2695bn-green-issuance-2020-late-surge-sees-pandemic-year-pip-2019-total-3bn [Accessed 24 September 2021].

Karpf, A. & Mandel, A., 2018. The changing value of the 'green' label on the US municipal bond market. *Nature Climate Change*, 8(2), pp.161-65.

Langedijk, S., Monokroussos, G. & Papanagiotou, E., 2018. Benchmarking liquidity proxies: The case of EU sovereign bonds. *International Review of Economics & Finance*, 56, pp.321-29.

Larcker, D.F. & Watts, E.M., 2020. Where's the greenium? *Journal of Accounting and Economics*, 69(2-3).

McInerney, C. & Bunn, D.W., 2019. Expansion of the investor base for the energy transition. *Energy Policy*, 129, pp.1240-44.

Park, S.K., 2018. Investors As Regulators: Green Bonds and the Governance Challenges of the Sustainable Finance Revolution. *Stanford Journal of International Law*, 54(1).

Sachs, J.D., Woo, W.T., Yoshino, N. & Farhad, T.-H., 2019. Importance of Green Finance for Achieving Sustainable Development Goals and Energy Security. In *Handbook of Green Finance*. 1st ed. Singapore: Springer. pp.3-12.

Sun, Z. & Zhang, W., 2019. Do government regulations prevent greenwashing? An evolutionary game analysis of heterogeneous enterprises. *Journal of Cleaner Production*, 231, pp.1489-502.

Tang, D.Y. & Zhang, Y., 2020. Do shareholders benefit from green bonds? *Journal of Corporate Finance*, 61, pp.1-18.

Thomson Reuters Eikon, 2022. *Green bonds data*.

Wang, J. et al., 2020. The market reaction to green bond issuance: Evidence from China. *Pacific-Basin Finance Journal*, 60.

Xu, G., Lu, N. & Tong, Y., 2022. Greenwashing and credit spread: Evidence from the Chinese green bond market. *Finance Research Letters*, 48, p.102927.

Zerbib, O.D., 2019. The effect of pro-environmental preferences on bond prices: Evidence from green bonds. *Journal of Banking & Finance*, 98, pp.39-60.

Zhang, R., Li, Y. & Liu, Y., 2021. Green Bond Issuance and Corporate Cost of Capital. *Pacific-Basin Finance Journal*, (69), pp.1-22.

Appendix 1. Green bond amounts, categorised by certification, currency, and rating

Label	Currency	Rating	Amount of bonds
CBI Certified	Euro	AAA	3
		AA	3
		A	4
	US Dollar	A	3
GBP Aligned	Australian Dollar	AAA	1
		AA	1
	British Pound	AAA	2
		AA	1
	Euro	AAA	16
		AA	23
		A	24
		BBB	20
		BB	2
		NR	6
	Hong Kong Dollar	AA	1
		A	7
		NR	2
	Indonesian Rupiah	AAA	1
	Norwegian Krone	AAA	4
		A	1
		NR	11
	Swedish Krona	AAA	3
		AA	3
		A	1
		BBB	3
		NR	3
	Swiss Franc	AAA	5
		AA	7
		A	2
		NR	1
	US Dollar	AAA	1
		AA	1
		A	5
		BBB	2
		NR	1
Self-labelled	Euro	AAA	1
		AA	2
		A	5
		BBB	3
		NR	1
	Norwegian Krone	A	1
	Swedish Krona	AA	1
		A	1
		NR	2
	Swiss Franc	NR	1
	US Dollar	A	2
Total amount of green bonds			194

Appendix 2. Robustness tests for fixed effects panel regression

$\Delta\text{Yield spread differential}_{i,t} = p_i + \beta\Delta\text{Bid-ask spread differential}_{i,t} + \epsilon_{i,t}$

Test	**Hypothesis**	**p-value**	**Conclusion**
Wooldridge	no unobserved effects	0.000	unobserved effects are present
F test	no individual effects	0.000	individual effects present
Breusch-Pagan LM	no individual effects	0.000	individual effects present
Hausman	random effects model is more robust	0.000	fixed effects model is more robust
Breusch-Godfrey	no serial correlation	0.000	serial correlation
Durbin-Watson	no serial correlation	0.000	serial correlation
Wooldridge	no serial correlation	0.000	serial correlation
Breusch-Pagan	homoskedasticity	0.000	heteroskedasticity

Appendix 3. Shapiro-Wilk normality test results

		p-value	Conclusion
Entire sample		0.000	non-normally distributed
Rating	AAA	0.000	non-normally distributed
	AA	0.000	non-normally distributed
	A	0.000	non-normally distributed
	BBB	0.006	non-normally distributed
	BB		
	NR	0.000	non-normally distributed
Currency	Australian Dollar		
	British Pound		
	Euro	0.000	non-normally distributed
	Hong Kong Dollar	0.123	normally distributed
	Indonesian Rupiah		
	Norwegian Krone	0.004	non-normally distributed
	Swedish Krona	0.000	non-normally distributed
	Swiss Franc	0.406	normally distributed
	US Dollar	0.015	non-normally distributed
Sector	Basic Materials		
	Consumer Cyclicals		
	Energy		
	Financials	0.000	non-normally distributed
	Government Activity	0.000	non-normally distributed
	Industrials	0.000	non-normally distributed
	Real Estate	0.129	normally distributed
	Technology		
	Utilities	0.295	normally distributed
Green Bond Label	CBI Certified Green Bond	0.003	non-normally distributed
	GBP Aligned Green bond	0.000	non-normally distributed
	Self-Labelled Green Bond	0.000	non-normally distributed
Country of Issue	Eurobond	0.000	non-normally distributed
	Non-Eurobond	0.000	non-normally distributed

Note: empty values are due to sample size smaller than 10

Appendix 4. OLS regression of the entire sample

	Dependent variable: p_i					
	OLS regression with White robust standard errors					
	(a)		(b)		(c)	
Constant	-0.222**	(0.080)	-0.120	(0.069)	-0.239	(0.098)
Issue Amount	-0.039	(0.021)	-0.026	(0.015)	-0.040	(0.021)
Maturity	0.018	(0.015)	0.019	(0.016)	0.018	(0.015)
AAA	0.046	(0.038)	0.044	(0.041)	0.033	(0.039)
AA	0.001	(0.037)	0.018	(0.030)	-0.012	(0.038)
BBB	-0.015	(0.040)	-0.048	(0.037)	-0.032	(0.040)
BB	0.282	(0.256)	0.174	(0.256)	0.281	(0.256)
NR	0.031	(0.049)	0.008	(0.048)	0.026	(0.049)
British Pound	0.125	(0.083)	0.094	(0.076)	0.132	(0.084)
Euro	-0.036	(0.074)	-0.018	(0.069)	-0.028	(0.072)
Hong Kong Dollar	-0.048	(0.109)	-0.051	(0.108)	-0.060	(0.111)
Indonesian Rupiah	-0.386***	(0.062)	-0.380***	(0.063)	-0.385***	(0.062)
Norwegian Krone	-0.080	(0.079)	-0.030	(0.070)	-0.086	(0.081)
Swedish Krona	0.021	(0.073)	0.070	(0.053)	0.035	(0.071)
Swiss Franc	-0.100	(0.102)	-0.073	(0.090)	-0.098	(0.101)
US Dollar	-0.106	(0.068)	-0.082	(0.063)	-0.096	(0.066)
Consumer Cyclicals	0.05	(0.044)			0.034	(0.042)
Energy	0.082	(0.079)			0.179	(0.100)
Financials	0.136*	(0.058)			0.139	(0.058)
Government Activity	0.296*	(0.140)			0.307	(0.140)
Industrials	0.201**	(0.073)			0.213	(0.072)
Real Estate	0.07	(0.075)			0.085	(0.079)
Technology	0.168*	(0.096)			0.163	(0.098)
Utilities	0.124	(0.051)			0.131	(0.054)
GBP Aligned Green bond			0.023	(0.046)	0.027	(0.045)
Self-Labelled Green bond			-0.061	(0.055)	-0.070	(0.056)

Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

Appendix 5. Robustness tests and results for FE-model on dataset with 217 green bonds

$\Delta\text{Yield spread differential}_{i,t} = p_i + \beta\Delta\text{Bid-ask spread differential}_{i,t} + \epsilon_{i,t}$

Test	**Hypothesis**	**p-value**	**Conclusion**
Wooldridge	no unobserved effects	0.000	unobserved effects are present
F test	no individual effects	0.000	individual effects present
Breusch-Pagan LM	no individual effects	0.000	individual effects present
Hausman	random effects model is more robust	0.000	fixed effects model is more robust
Breusch-Godfrey	no serial correlation	0.000	serial correlation
Durbin-Watson	no serial correlation	0.000	serial correlation
Wooldridge	no serial correlation	0.000	serial correlation
Breusch-Pagan	homoskedasticity	0.000	heteroskedasticity

	Dependent variable: $\Delta Yield\ spread_{i,t}$		
	Fixed effects within-regression	**Newey–West robust std. err.**	**Beck–Katz robust std. err.**
$\Delta\text{Bid-ask spread}_{i,t}$	-8.309***	-8.309***	-8.309***
	(0.270)	(1.056)	(1.391)
Observations	69927		
R^2	0.013		
Adjusted R^2	0.010		

Note: Standard errors are reported in parentheses

*** p < 0.001; ** p < 0.01; * p < 0.05