Vaasan yliopisto
UNIVERSITY OF VAASA

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Green Bond Premium

Evidence from the Corporate Bond Market

School of Accounting and Finance
Master's Thesis in Finance
Master's Degree Programme in Finance

Vaasa 2020

UNIVERSITY OF VAASA

School of Accounting and Finance

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Title of the Thesis: Green Bond Premium : Evidence from the Corporate Bond Market

Degree: Master of Science in Economics and Business Administration

Programme: Master’s Degree Programme in Finance

Supervisor: Sami Vähämaa

Year: 2020 **Sivumäärä:** 72

ABSTRACT:

This thesis investigates the existence of the green bond premium and its determinants through an analysis of 44 corporate green bonds and their matched non-green bonds listed on the Bloomberg Terminal over the period of 01/01/2016 – 28/02/2020. A Matching method is used to match green bonds with comparable conventional bonds, followed by a two-stage regression procedure.

In the first stage, the study examines the presence of the green bond premium. A panel regression with fixed effects is performed to disentangle yield differential between green bonds and matched conventional peers into two main components: the liquidity difference measured by the difference in the bid-ask spread and the green bond premium. Empirical results indicate that green bonds are traded at lower -0.45 basis points yield compared to their conventional peers, confirming the presence of the green bond premium in the secondary corporate bond market. This result supports the argument that investors are willing to accept a lower return to acquire green bonds over their non-green counterparts. The second stage of the analysis aims to identify the factors influencing the green bond premium. To reach that goal, cross-sectional regressions are run for the estimated bond-specific green premium, with bond characteristics being the explanatory variables. The study discovers that the principal amount at issuance of green bonds negatively impacts the green bond premium. Meanwhile, the thesis could not find any significant influence of external reviews on the green bond premium.

The empirical outcomes signal the high market demand for corporate green bonds. For the bond investors, benefits from enhanced transparency and engagement with the green bond issuers would outweigh the extra cost of acquiring green bonds instead of ordinary bonds. Building on this research, future studies could examine the green bond premium when the market matures with more available data and standardized regulations on green bonds are established.

KEYWORDS: SRI, Green bonds, Bond pricing, Green finance, Matching method

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Abbreviations

Bps	Basis points
CB	Conventional bond
CBI	Climate Bonds Initiative
CSP	Corporate Social Performance
CSR	Corporate Social Responsibility
ESG	Environmental, Social and Governance
GB	Green bond
GBP	Green Bond Principles
SRI	Socially Responsible Investing
YTM	Yield to Maturity

1 Introduction

According to the National Aeronautics and Space Administration (2020), the past five years (2015 – 2019) were the warmest in the record since 1880. The steady rising temperatures, along with extreme natural disasters in many places around the world, indicate that global warming is now an irreversible threat to the worldwide economy. In the purpose of mitigating the climate change risk, it is estimated that around $90 trillion would be needed for facilitating the transition into a low-carbon and more sustainable economy by 2030 (The Global Commission on the Economy and Climate, 2018). That trend has transformed the financial markets as well. In the 21st Conference of the Parties to the United Nations Framework Convention on Climate (COP21) 2015, the Paris Agreement was adopted, emphasizing that the global goal is to limit the rise of the temperature “well below 2 degrees Celsius”. In addition to that, the financial market should follow a direction towards a climate-resilient economy (United Nations, 2015).

During the past decade, new innovative investing solutions have been introduced, aiming at financing the projects that create positive environmental impacts. In this context, green bond, which is defined as “fixed income, liquid financial instruments that are used to raise funds dedicated to climate mitigation, adaptation, and other environment-friendly projects” (World Bank, 2017), has become increasingly popular in the bond market. Since the first issuance of the Climate Awareness Bond by the European Investment Bank (EIB) in 2007, the green bond market has experienced exponential growth in the number of deals and issued amounts. Remarkably, after the adoption of the Paris Agreement 2015, the green bond issuance has been growing by more than 80% in 2016 and 2017. In 2019, the green bond market continued to mark a new global record with a total amount of $257.7 billion green bond issuance, surging by 51% from $170.6 billion in 2018 (CBI, 2020).

Figure 1 illustrates the evolution of green bond issuance over the period 2013 – 2019. Mirroring the global trend, new green bond issuance in Europe reached $116.7 billion in 2019, up by 74% from 2018 and accounted for 45% of worldwide issuance. Asia-Pacific remained the second largest contributor to the market, accounting for a fourth of the global figure with a year-on-year increase in new green bond issuance of 29%. Meanwhile, the North American region witnessed robust growth in 2019 (46%), comprising 23% of the global volume.

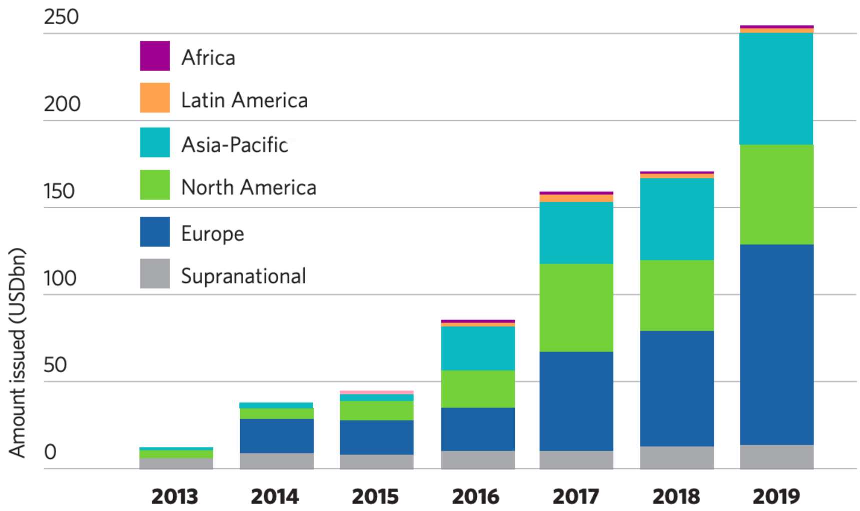

Figure 1. Green bond issuance by region 2013 – 2019 (CBI, 2020)

In the 2018 Green Bond Market Summary, CBI (2019) highlights that while there is a slowdown in the municipal and governmental green bond sector, the market for corporate green bonds is substantially expanding. Notably, this potential market has just existed since 2013, with the first issuance of EDF's green bonds to financing 13 renewable energy projects in France and North America (Electricite De France, 2019). As presented in Figure 2, in 2019, the corporate sector (including financial and non-financial entities) remained a significant player with a total of $114.5 billion green bond issuance, representing approximately 44% of the entire market in terms of new issuance amount (CBI, 2020).

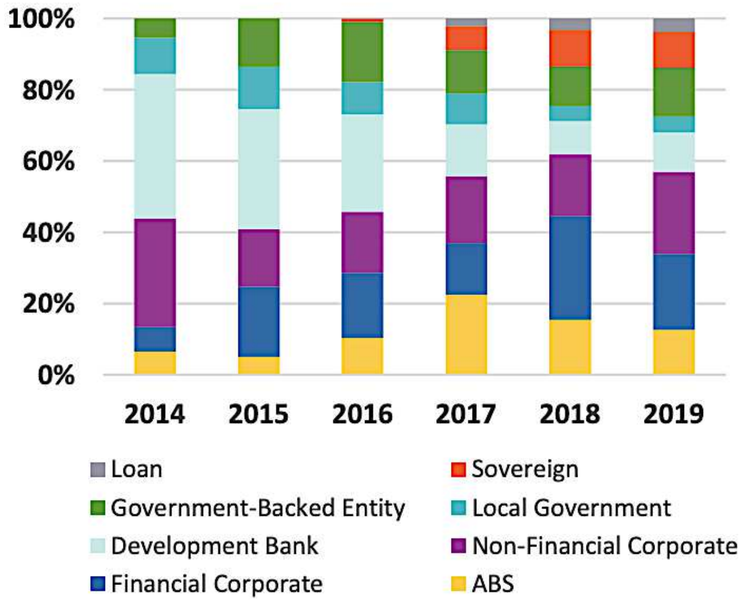

Figure 2. Green bonds issuance by issuer type 2014 – 2019 (CBI, 2020)

Despite the ongoing significance of the topic, there is little evidence of the benefits of corporate green bonds and their implications for investors and corporate issuers. Corporate green bond is a new financial instrument and the market for this type of bond is relatively small in comparison to the entire bond market. Available literature mainly examines the financial performance and the valuation of municipal and supranational bonds. Meanwhile, it is argued that these markets are not comparable due to discrepancies in bond specifications (Flammer, 2018). Therefore, this thesis aims to investigate the performance of corporate green bonds in terms of yield.

1.1 Purpose of the study

The purpose of this thesis is to examine the yield differential between green bonds and comparable ordinary ones in the secondary corporate bond market. More precisely, this translates into answering the two following questions: *'Is there a green bond premium?'* and *'Do green bond characteristics drive such a premium?'*

In an attempt to estimate the difference in yield between each corporate green bond and its corresponding conventional bond, the Matching method is applied in this study. This approach is consistent with previous academic research on examining the yield differentials. Through a panel regression with fixed effects of daily yield spreads between two types of bonds after controlling for liquidity difference, the green premium is addressed as an unobserved bond-specific fixed effect in this model (Zerbib, 2019). Next, the determinants of this green premium are identified by an OLS cross-sectional regression model.

This thesis aims to examine a sample of corporate green bonds listed on the Bloomberg Terminal as of December 31, 2019. Each green bond belongs to the list is matched with conventional bonds that are issued by the same issuer and exhibit the nearest maturity and the same other characteristics. Further information about the uses and reporting of green bonds is collected from the CBI database and the corporate website of the bond issuers.

1.2 Hypotheses

Firstly, the study attempts to investigate the existence of the green bond premium. The Economic Theories of Social Norms suggests that investors may accept a financial cost to reduce reputational or ethical risks from disobeying social norms (Elster, 1989). This argument implies that investors may promote pro-environmental preferences by accepting lower returns on their investment portfolios. Additionally, Fama and French (2007) conclude that the taste for assets could influence investment decisions. Furthermore, a majority of existing research on green bond premium proves that green bonds have lower yields than their conventional counterparts. Since green bonds are potentially perceived as less risky, investors are willing to expect a lower yield when investing in green bonds over conventional bonds. Due to the inverse relationship between bond yield and price, it means that green bonds are overpriced in comparison to non-green bonds. Therefore, the following hypothesis would be tested:

H_1: Green bonds are traded with lower yields in comparison to ordinary bonds

Secondly, similar to prior research, this thesis explores the factors influencing the green bond premium. Previous empirical studies suggest that the bond rating, the issue amount and the type of issuer are vital drivers of the green bond premium. For instance, Zerbib (2019) documents that AA- and A-rated green bonds exhibit a higher premium compared to other green bonds. Karpf and Mandel (2017) show that green bonds have a higher premium if the principal amount at issuance increases. Furthermore, Febi et al. (2018) discover that maturity also has a significant effect on the green bond premium. In addition to that, Bachelet et al. (2019) and Li et al. (2019) find that the issuer type and the "green" verification by external parties of green bonds also impact its pricing. Therefore, the following hypothesis is formed:

H_2: The characteristics of a green bond affect its green premium

1.3 Structure of the study

The thesis is structured as follows. Chapter 1 presents a brief introduction to the research topic and hypotheses. Chapter 2 encompasses necessary information about the corporate green bond market and provides the readers with common arguments over the concept of Green Bond. Chapter 3 reviews the previous literature, focusing on the relation between the corporate environmental performance and bond yield, whereby the topic of Green Bond Pricing is thoroughly discussed.

In chapter 4, a description of the dataset and the methodology used in the thesis is explained. Precisely, this part describes the Matching method applied for processing data and the empirical models for hypotheses testing. Chapter 5 summarizes the main results from the empirical tests and compares them with existing research, whereby the research questions are answered. Finally, the managerial implications, the main limitations of the thesis and suggestions for further research are addressed in chapter 6.

2 Corporate green bond

A bond is a fixed-income security that allows the issuer to borrow money from bondholders in exchange for contractual streams of payment over a specified period. The issuers of bonds could be the state and local governments, government-related entities, and corporations (Fabozzi, 2010). Unlike government bonds, corporate bonds are not risk-free even though they generally generate promised flows of income for bondholders. It is because several types of risk associated with the financial situation of issuing firms could affect the actual coupon and principal payments on these bonds (Bodie et al., 2014). Investors, therefore, require higher yields to compensate for higher levels of risk they take when investing in corporate bonds.

In principle, the present value of a bond consists of the annual coupon payments and the final principal discounted by a pre-determined discount rate. Thus, the price of a bond can be computed as follow (Fabozzi, 2010):

$$P_0 = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} + \frac{FV}{(1+r)^n}$$

where: $P_0 =$ bond price

$C_t =$ coupon payment

$FV =$ face value or par value

$r =$ interest rate or (required) yield of investors

$n =$ number of coupon payments

$t =$ time period when the payment is received

When discussing bond valuation, another central concept is yield which implies the actual return that investors earn from investing in a bond. In practice, there are several metrics of bond yields. The most commonly used measure is Yield To Maturity (YTM). It is defined as the interest rate that makes the present value of the future cash flows from a bond equal to its current market price, assuming that the bond is held to maturity. Accordingly, YTM could be calculated by using the above equation with a given bond price. In this case, the most critical factors of a bond are taken into account (current market price, coupon payment, face value, time to maturity), thereby making it easier to compare bonds with different features (Fabozzi, 2010).

A remarkable feature of a bond is the inverse relationship between bond price and yield. When the required yield of a bond decreases, the present value of the cash flows from it is higher, making its price goes up. Also, the bond price goes down when its required yield increases (Fabozzi, 2010). Theoretically speaking, when the expected yield of a bond is higher than the coupon rate, the bond must be sold at a lower price than its face value. Otherwise, rational investors are not willing to invest in an asset that generates a lower return than their expectations. In this case, the bond is sold at a discount. On the contrary, when the required yield of a bond falls below its coupon rate, the bond becomes an attractive asset to invest. The bond price, therefore, rises above its par value. In other words, the bond is sold at a premium (Fabozzi, 2010).

In general, a green bond is a bond whose proceeds are used to fund projects that are meant to deliver environmental or climate-related benefits (G20 Green Finance Study Group, 2016). Therefore, green bonds can be a financing source for a wide variety of industries. Figure 3 provides information on the allocation of the proceeds from issuing green bonds throughout 2017 – 2019. It could be observed that the Energy and Buildings are the most funded sectors, which account for approximately 60% of the funds from green bond issuance (CBI, 2020). The Transport sector follows with around 20% market share. Those figures imply the global efforts to primarily develop low-carbon buildings, environmental-friendly transportation system and renewable energies. The remaining categories, including Waste, Water, Land Use, Industry, Information and Communication Technologies (ICT) and Adaptation and Resilience (Unalloc. A&R), account for roughly 20% of total 2019 issuance.

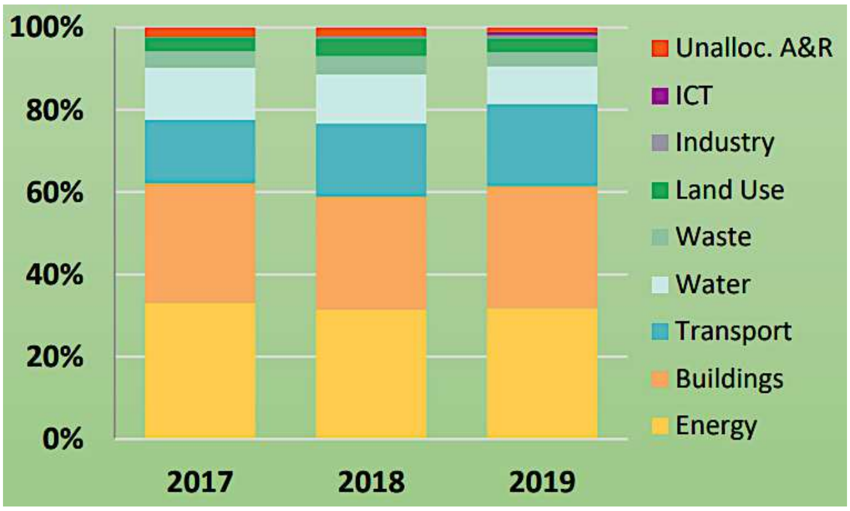

Figure 3. Allocation of the proceeds from green bond issuance by sector 2017 – 2019 (CBI, 2020)

2.1 The Green Bond Principles

Since the green bond is a recent phenomenon, there are still no standardized regulations for this type of securities. In that context, the Green Bond Principles (GBP), the most widely accepted voluntary guidelines, were developed by the International Capital Market Association in 2014. The primary objectives of the GBP are to inform issuers with major concerns involved when issuing credible green bonds and provide investors with the necessary information that needs to be considered when evaluating a green bond investment. In addition to that, the GBP also lays a foundation for the standardization of the green bond regulations.

The GBP recommends a clear process and disclosure for issuers and highlights the importance of transparency, accuracy and integrity in reporting about green bond issuance and use of proceeds. In essence, four core pillars of the GBP are Use of proceeds, Process of Project Evaluation and Selection, Management of Proceeds and Reporting (International Capital Market Association, 2018).

Use of proceeds

The use of proceeds for environmental projects is a typical trait of a green bond. Thus, all the essential information about it should be clearly stated in the legal documentation of the green bond. Specifically, the allocation of the proceeds, environmental benefits and the feasibility of the projects should be measured and communicated with the investors. Furthermore, the uses of proceeds which are eligible for green bonds are defined and categorized into the following non-exhaustive groups (International Capital Market Association, 2018):

- Renewable energy;
- Energy efficiency;
- Pollution prevention and control;
- Sustainable management of land and living natural resources;
- Biodiversity conservation;
- Clean transportation;
- Sustainable water and wastewater management;
- Climate change adaptation;
- Eco-efficient and/or circular economy products, technologies, processes;
- Green buildings.

Process of Project Evaluation and Selection

The GBP suggests the green bond issuers to thoroughly communicate about the environmental objectives of the green projects and identify how they fit within the eligible categories of green projects described above. The benefits of green projects should also be clearly stated and quantified if possible (International Capital Market Association, 2018).

Management of Proceeds

It is advised that the proceeds from green bonds should be periodically adjusted to match the allocation of funds to the eligible green projects. It means that issuers should keep track of the use of the allocated amounts to ensure that capital raised from green bonds is appropriately spent. Moreover, the investors should also be informed about the intended use of the unallocated proceeds (International Capital Market Association, 2018).

Reporting

Information about the green projects, the allocated amount of proceeds and the expected environmental impacts should be communicated to the investors on a timely basis. Besides, the GBP recommends the issuers to use quantitative metrics to monitor the performance and the feasibility of the green projects. A description of those methods, along with the underlying assumptions and key performance indicators, should also be included in the regular reporting (International Capital Market Association, 2018).

In addition to the preceding considerations, the GBP also recommends the green bond issuers to obtain external reviews as supplemental evidence for the transparency, integrity and accuracy of their green bond issuance. The importance and types of independent reviews will be discussed further in this chapter.

2.2 Advantages and disadvantages of green bond issuance

From the issuer’s standpoint, a green bond could be seen as evidence of their sustainability strategy. Through issuing green bonds, firms can communicate with lenders about the integration of ESG factors into their business operations, thereby gaining their reputation as an environmentally-responsible establishment. Furthermore, issuing green bonds could help firms diversify the investor base by attracting more institutional and individual investors who are interested in environmental-related securities (Shishlov et al., 2016).

Through a survey of 86 treasurers from numerous green bond issuing entities, CBI (2020) reveals that 91% of the respondents concurred that green bond issuance accelerates more engagement with the investors via mutual dialogues about the issuance and the reporting process of green bonds. Also, 98% of the respondents supposed that new investors had been attracted thanks to the issuance of green bonds. Another beneficial effect of green bond issuance is the possibility to raise awareness about green finance within the issuing institutions. Also, the green bond issuing and tracking process could improve the internal synergies between finance and sustainability departments in tackling ESG issues (Shishlov et al., 2016).

Conversely, one primary concern of the green bond's issuing entities is the upfront and ongoing costs for labeling, tracking and reporting activities related to the green bond issuance. In fact, the issuance of green bonds requires extra charges for establishing a framework, commissioning external assurance about the eligibility of bonds and other costs for the management and reporting of the use of proceeds. Another challenge faced by the green bond issuers is the reputational and legal risk when they cannot justify the integrity of green bonds (Shishlov et al., 2016). In this case, the green bond issuance could be potentially alleged as "greenwashing", leading to costly legal proceedings. For instance, in 2017, Walmart had to pay $1 million to resolve the greenwashing claims that it sold plastic products that had been wrongly labeled as "biodegradable" or "compostable" (Hardcastle, 2017).

From the lender's perspective, additional information on the use of proceeds from green bonds and enhanced transparency created through stricter reporting could be valuable when appraising the investment strategies and related risks without incurring extra transaction costs. Noticeably, SRI funds and individual investors adopt strict screening standards that allow them to invest merely in firms that are considered to be socially or environmentally responsible. Firms that cannot pass those criteria could help alleviate this problem by issuing green bonds, indicating that the money raised from that is used to fund environmental-related activities. As a result, by investing in such green bonds, SRI funds could further diversify their portfolio while maintaining strict screening criteria (Shishlov et al., 2016).

However, similar to the issuing institutions, the concern over the integrity of green bonds remains the greatest problem since the green bond market is self-regulatory. The lack of consensus on the standards of green bonds and information disclosures is likely to create misunderstanding among market actors, especially when the market is growing in terms of size and scope (Shishlov et al., 2016). If investors do not have sufficient information about the environmental profile of the green bond issuer, they are not able to assess the feasibility of the green projects as well as their associated risks (G20 Green Finance Study Group, 2016). As a result, green bonds could be mispriced by the market.

To conclude, there are several challenges concerning the issuance and investment of green bonds. It is due to the recent emergence of the green bond with the lack of standardized regulations. Nevertheless, in light of the growing concern about green finance, it appears that the benefits outweigh the costs, which could justify the expansion of the green bond market.

2.3 External reviews

As stated earlier, the lack of standard regulations for green bonds results in the so-called "greenwashing" concern. According to KPMG (2015), a green bond is considered as a mean of "greenwashing" when:
- Proceeds from green bonds are used to fund projects that do not aim to generate positive environmental or climate-related impacts;
- Principal business activities of the issuers are unsustainable and create detrimental effects on the ecosystem;
- Proceeds are not appropriately managed to ensure that they are used to fund the intended green projects;

- Issuers are not able to clarify the objectives as well as the actual environmental impacts of green projects.

Therefore, to mitigate the risk of "greenwashing" and enhance the integrity of the green bond market, the GBP recommends green bond issuers to obtain an external review for their green bond issuance. In addition, the GBP also outlines the major criteria that most of the certification of external review schemes follow. Table 1 describes various types of external review green bond issuance.

Table 1. Types of external review of green bonds (Shishlov et al., 2018), (CBI, 2015)

Type	Scope or review services and deliverables	Example of the service providers
Consultancy and 'second opinion'	Providing advice to create the corporate green bond framework for the green bond issuers, or offering a 'second-opinion' about the adherence to the GBP of the green bond issuers. The "greenness" of the eligible projects or assets could also be reviewed.	CICERO, Oekom, Sustainalytics, Vigeo
Certification	Certifying that the green bond and its associated framework adhere to the prevailing standards in terms of transparency and integrity.	CBI
Verification	Giving assurance about the alignment of green bond or the associated framework with internal standards or promises made by the issuers.	Enst&Young, KPMG, PwC
Rating	Offering a rating scale to enable the comparison among different categories of bonds in terms of the level of sustainability.	Moody's, Oekom, S&P, Cicero

Notwithstanding the incurrence of additional costs, the acquisition of an external review brings various benefits to the green bond issuers and investors. The first advantage of the external review is that it signals the integrity of the green bond issuance and management of proceeds, thereby, allowing the green bond issuing entities to attract a more diverse investor base (CBI, 2020). In addition to that, it offers the debt providers with an assurance that the proceeds from green bonds are used and managed properly in compliance with the commonly adopted guidelines. For that reason, the issuers of green bonds could reduce the risk of being perceived as “greenwashing”. Finally, although external reviews do not provide assurance about the credit risks or the expected returns of green bonds, it enables investors to quickly and easily find a credible green bond thanks to its role as a screening of eligible green bonds (CBI, 2020).

3 Literature review

Although the green bond topic is a new area of research, its examination fits into prior literature on Socially Responsible Investing (SRI). The field of SRI is concerned with the integration of Corporate Social Responsibility (CSR) factors into the traditional investment process. Prior research on the area of CSR recognizes considerable financial benefits originating from good CSR practices. In particular, superior Corporate Social Performance (CSP) could have a positive influence on a firm's cost of capital from various perspectives. Renneboog et al. (2008) state that SRI investors are willing to pay a premium for the appreciation of social or ethical values of their investments. Also, SRI funds are expected to underperform conventional funds (Riedl & Smeets, 2017). Accordingly, the main questions arising from this new investment approach are: To what extent do firms and investors benefit from SRI practices? And what is the interest of investors to invest in underperforming assets here?

A large number of academic studies address the above concerns by investigating the effects of CSP on the cost of equity. However, the empirical results are mixed. While Statman and Glushkov (2009) find no significant difference in returns between socially responsible portfolios and their ordinary counterparts, Brammer et al. (2006) find a negative impact of CSP on stock prices. Interestingly, Krüger (2015) documents that the market reacts negatively to both positive and negative news about firms' CSP even though adverse investor reaction to good CSP announcement is much weaker. The author further explains that positive news about CSP implies that firms have had some issues with CSR in the past. Conversely, numerous researchers propose that CSP positively impacts the cost of equity (Konar & Cohen, 2001; Kempf & Osthoff, 2007; Ghoul et al., 2011).

Another strand of literature studies investor preferences through the performance of "sin" stocks and bonds. By extensive analysis of the stock market for 1962 – 2006, Hong and Kacperczyk (2009) provide evidence that stocks from sinful industries (tobacco, alcohol, gaming) expose to higher risks, hence, resulting in higher expected returns.

Ghoul et al. (2011) reach a similar conclusion when observing a sample of 12,915 U.S. firms from 1992 to 2005. In contrast, Fabozzi et al. (2019) analyze a sample of 546 unique “sin” bonds and 9,118 ordinary bonds and conclude that “sin” bonds are overvalued. The possible explanation for this result is that the pressure of transparency is more influential in the equity market than in the debt market. Thus, bondholders of “sin” bonds tend to pay a premium to invest in firms that are expected to generate higher returns (Fabozzi et al., 2019).

Recent academic works have attempted to relate CSP to the cost of debt. According to Ge and Liu (2015), CSP is positively correlated with corporate bond ratings and superior CSP allows firms to issue bonds with lower spreads. Oikonomou et al. (2014) reach the same conclusion when examining the U.S. corporate debt market. Likewise, a study conducted by Ghouma et al. (2018) reveals that enhanced corporate governance enables Canadian firms to decrease bond yield spreads. From the bank lending perspective, Goss and Roberts (2011) observe a sample of 3,996 loans to U.S. firms to investigate the impact of CSR on bank loan interest rates. The findings suggest that CSR strength does not reduce the cost of borrowing. Nevertheless, firms that have CSR problems are charged with higher interest rates from banks. La Rosa et al. (2018) report a similar finding when investigating listed European firms from 2005 to 2012. Moreover, the authors document that CSP is positively associated with debt rating and lenders appreciate companies with strong CSP.

In contrast to the studies mentioned above, Menz (2010) researches the European corporate bond market and finds that there is a weak positive linkage between CSP and bond spreads. Similarly, through an analysis of 1,641 observations over a period from 2005 to 2009, Magnanelli and Izzo (2017) conclude that CSP increases the cost of debt. The authors argue that CSR ratings may not add more values to investors as credit ratings already include some of the environmental, social and governance factors. Moreover, investors may not take CSR considerations into account when making investment decisions because they do not see an apparently positive impact of CSR practices on the risk-return characteristics of their investments.

Although no consensus has been achieved with regard to the impact of CSP on the firm's financing, most of the available literature suggests that CSP positively influences firms' cost of debt. In particular, in the wake of sustainability finance, environmental practices play a crucial role in sustainable business operations. Besides, the green bond is considered a favorable financial instrument that offers several important benefits for corporates and investors. For that reason, the published research relating to environmental considerations and green bond performance will be discussed further in the following parts of this chapter. The first section explores the relationship between corporate environmental performance and the cost of debt. In the second section, essential empirical studies on the performance of green bonds are analyzed.

3.1 Environmental performance and cost of debt

The linkage between environmental management and the firm's financing has been studied extensively. In the earlier studies on this area, it is indicated that good environmental management lowers the cost of debt. Sharfman and Fernando (2008), Schneider (2011), Bauer and Hann (2014) suggest that bond yield is negatively associated with environmental performance. Nevertheless, this relationship fades as bond rating improves (Schneider, 2011). On the contrary, Chava (2014) documents that good environmental practices do not reduce the cost of capital. Meanwhile, firms with environmental issues have significantly higher costs of debt (Chava, 2014). This claim is consistent with Bauer and Hann (2014) who argue that firms that create environmental problems are more likely to default on their debts due to a higher possibility to suffer from reputational losses, legal and regulatory risks. In contrast, companies that actively generate environmental benefits through their products, services and business operations could mitigate the above-mentioned risks and improve profitability. As a consequence, investors and lenders appreciate corporate environmental responsibility.

Another stream of literature on the relationship between environmental considerations and the cost of debt investigates bank lending behavior. For instance, by studying bank loan spreads of 2,679 unique firms from 1992 to 2007, Chava (2014) reveals that banks charge lower interest rates to eco-friendly firms, while companies with environmental problems bear relatively higher interest rates. The author explains that bank lenders could be potentially accountable for environmental harm caused by their borrowers. Another possible reason is that banks may face a reputational risk when they lend money to environmentally-damaging projects. Therefore, banks tend to care more about the environmental profile of their debtors.

Regarding the impact of environmental practices on the bond ratings, while Bauer and Hann (2014) show a weak link between superior environmental management and higher credit ratings, Chabowski et al. (2019) study 310 unique firms in the U.S. from 1987 to 2015 and claim that companies exposing to polluting activities have low bond ratings. One possible reason behind these outcomes is that activities to reduce detrimental impacts on the environment may increase firms' financial positions, including returns on assets and Tobin's Q (Bauer & Hann, 2014). Conversely, companies that have poor environmental performance are likely to have weak corporate governance or internal control. Since profitability, firm value, corporate governance practices and internal control are the crucial elements in the credit rating process, it is suggested that environmental efficiency and bond ratings are positively associated (Chabowski et al., 2019).

Taken together, despite the contradictory pieces of evidence, a majority of prior literature seems to propose that environmental strengths have a positive impact on the cost of debt of companies partially through enhanced credit qualities. On the other hand, as previously analyzed, environmental concerns pose litigation, regulatory as well as reputational risks to companies' stakeholders, therefore, leading to a higher cost of debt.

3.2 Green bond performance

Earlier studies on green bonds focus on understanding the benefits of issuing green bonds. By conducting an event study, Flammer (2018) finds that the financial market reacts positively to the announcements on green bonds issuance. To be more specific, the average cumulative abnormal return (CAR) on the shares of firms that issue green bonds in the two-day window [-1, 0] is 0.67% and significant at 5% level. Additionally, she suggests that the issuance of green bonds improves firms' profitability in the long run, thanks to the effectiveness of the green projects.

By applying a market model with the domestic market and MSCI market indices, Baulkaran (2019) investigates a sample of 54 public-traded firms issuing green bonds worldwide and shows that the average CAR on the stocks of the issuing companies in the announcement day is -0.17%. However, this result is not statistically significant. The author proposes that there might be chances of leakage of information. Thus, the CAR on announcement day is insignificant. On a [-10, 10] event window, the study reports an average CAR of 1.48% (when using the domestic market index) and 1.42% (when using the MSCI market index). Likewise, Tang and Zhang (2018) claim that corporate green bond issuance seems to be beneficial to shareholders. More specifically, on [-10, 10] and [-5, 10] event window, the average CAR on the stocks of the green bond issuers is approximately 1%. Nevertheless, the authors find weak evidence on the market reaction to financial institutions issuing green bonds.

Empirical studies targeting green bond performance in the primary market, where green bonds are issued, have been limited so far. It is mainly due to the fact that the green bond market is still at an early stage of development. Ehlers and Packer (2017) were among the first studies to examine the valuation of green bonds through the concept of green bond premium. According to the authors, the green bond premium exists when investors are willing to pay a higher price or accept a lower yield to invest in green bonds over conventional ones. Through a comparative analysis of yield spreads at issuance between 21 green bonds and their “brown” counterparts, they report an average negative premium of 18 basis points (bps).

Similarly, by employing six different matching approaches, Gianfrate and Peri (2019) examine 121 pairs of green and ordinary bonds and document a negative premium of 18.5 bps. This finding is closely consistent with the previous article from Ehlers and Packer (2017). The key takeaway is that the “greenness” specification negatively impacts bond yield and this effect is stronger in the primary market. The article further explores that the cost of achieving a green label or verification from an external party for the “greenness” of bonds is far lower than the above-estimated premium. This finding implies that the financial gain achieved from issuing green bonds outweigh the extra costs incurring during the green labeling process.

Furthermore, Baker et al. (2018) conduct an intensive analysis that considers the potential role of green verification. The results highlight that green bonds have lower after-tax yields than those of ordinary bonds (by 5.5 to 7.6 bps) and this gap is even wider when the “greenness” of bonds is assured by the CBI. Following the econometric model developed by Baker et al. (2018), Fatica et al. (2019) regress bond’s offering yield at issuance on the “greenness” and other bond characteristics over a sample of 266,724 bonds from Dealogic DCM over the period 2007 – 2018. They find that only green supranational and non-financial green bonds are issued at a premium compared to normal bonds. Particularly, the negative impact of the “greenness” on the yields of supranational bonds is approximately four times larger than its effect on non-financial bonds’ yields. By contrast, the authors find no statistically significant yield gap for bonds issued by financial institutions. They suggest that investors prefer supranational and non-financial green bonds to financial ones because of higher transparency in the uses of proceeds in governmental and non-financial organizations.

While the previously discussed research appears to agree on the existence of a negative green bond premium in the primary market, CBI (2018) shows mixed results when investigating the yield curves of 60 new-issued green bonds from January 2016 to June 2018. The report indicates that 31 out of 60 green bonds are traded at higher yields than the non-green bonds, although the magnitude of this pattern is smaller than expected. On the other hand, 29 out of 60 green bonds have similar or lower yields compared to those of conventional bonds, implying that there is little evidence about the green bond premium.

Another line of research focuses on discovering the green bond premium in the secondary market where green bonds are traded after issuance. Barclays (2015) regresses the cost of debt measured by the option-adjusted spread (OAS) on numerous bond-specific and green dummy variables and reports a negative premium of 17 bps. Using a different approach, Zerbib (2019) matches green bonds to conventional bonds of the same issuer to construct a dataset of 1,065 bonds complying with the GBP. The author thereby finds a statistically significant but moderate premium of -2 bps. Remarkably, this premium varies across different market segments. For instance, the green bond premium is close to zero for AAA government-related bonds, while the negative effect of green label on green bond yield is greater for financial and low-rated bonds (with a negative premium of 2.5 – 2.7 bps). Although the result does not indicate any substantial discrepancy in pricing between green bonds and comparable ordinary bonds, the study highlights that institutions may have a chance to expand their bondholder base by issuing green bonds.

When comparing the yield spreads of 548 U.S municipal green bonds and 667 ordinary bonds from 2015 to 2018, Partridge and Medda (2020) report a statistically significant premium of -3.7 bps. Furthermore, the researchers conduct an index benchmarking analysis by constructing green-labeled bond indices then comparing their performance with that of the S&P investment-grade municipal index over the period 2015 – 2018. The study finds that the green-labeled bond index outperformed the S&P investment-grade municipal index with a higher Compound Annual Growth Rate (2.86% versus 2.45%) and lower volatility (0.73% versus 1.82%). This result is in line with the prior yield analysis, which implies that green bonds are traded at a premium in comparison to their conventional counterparts.

In contrast to the articles mentioned above, Karpf and Mandel (2017) analyze the premium of 1,880 U.S. municipal green bonds and discover that they are traded at a discount of 7.8 bps during the period from 2010 to 2016 compared to their ordinary counterparts, although the green bond premium exists from 2015 onward. They suggest that the result could be biased due to some unobservable factors such as the lack of awareness or the skepticism of the market participants on green financing, which need to be explored further in future literature. In addition to that, Baker et al. (2018) argue that this result may be incorrect as many municipal green bonds in the U.S. market are taxable. Since investors’ income are more likely to be taxed, they often require higher yields when investing in bonds (Atwood, 2003).

By using various methods of collecting and analyzing data, empirical studies present mixed evidence about the existence of green bond premiums in both primary and secondary markets. It leaves room for future research on this emerging field of study, especially in the tendency of rising concerns about climate change and green financing. Focusing on the secondary corporate green bond market, this thesis intends to examine the green bond premium further and to provide some insights about the determinants of this new concept.

4 Data and methodology

This chapter outlines the data selection process and the research methodology applied in the thesis. Specifically, the first sub-section explains the construction of the dataset. The second sub-section documents the empirical method used to examine the presence of green bond premium and its determinants, followed by the summary statistics of the prepared dataset.

4.1 Data

This thesis intends to examine all the corporate green bonds and their comparable ordinary bonds listed on Bloomberg Terminal by February 28th, 2020. The preparation of the dataset starts by constructing a list of corporate green bonds. For that purpose, bonds whose Asset class named *Corporates* and the Use of proceeds described as *Green bond/loan* are selected. This list consists of 2,366 green bonds with various coupon types, different ratings from different industries and are denominated in a variety of currencies.

In the next step, all the green bonds with floating coupon rates and zero-coupon bonds are removed because they are priced differently from fixed coupon bonds. The process continues with the Matching procedure. Each green bond is matched with a pair of ordinary bonds from the same issuer based on the specific conditions, as presented in Table 2. The goal of this method is to enhance the comparability between green bonds and ordinary bonds, thereby greatly reducing the effects of common unobservable factors and liquidity bias (Zerbib, 2019). Referring to Zerbib (2019) and Bachelet et al. (2019), the following criteria are set to identify comparable non-green bonds:

Table 2. Matching criteria (Bachelet et al., 2019)

Characteristic	Criteria
Issued amount	Less than four times and greater than one-quarter of the corresponding green bond's issued amount
Coupon rate	Maximum 0.25% higher or 0.25% lower than the corresponding green bond's coupon rate
Maturity date	Maximum 2 years earlier or 2 years later than the corresponding green bond's maturity date
Issuance date	Maximum 7 years earlier or 7 years later than the corresponding green bond's issuance date
Currency	Same
Issuer	Same
Rating	Same
Coupon type	Same
Interest frequency	Same
Seniority	Same
Collateral type	Same

After eliminating all bonds that have incomplete data, bond-specific information and daily yields and prices from January 1st, 2016 to February 28th, 2020 are retrieved from Bloomberg Terminal and Thompson Reuters Eikon. For bond characteristics, the following information is obtained: (1) *International Securities Identification Number (ISIN)*; (2) *Bloomberg Barclays Classification (BCLASS) level 2*; (3) *Issuer name*; (4) *Currency*; (5) *Maturity date*; (6) *Issued amount in local currency*; (7) *Issued amount in USD*; (8) *Coupon frequency*; (9) *S&P Rating*; (10) *Moody's Rating*; (11) *Collateral type*; (12) *Seniority*; (13) *Maturity type;* (14) *Coupon type*.

For daily bond yields and prices, the following data is downloaded: (1) *Ask yield*; (3) *Bid price*; (4) *Ask price*. Additional information about the external reviews or certifications of bonds is collected manually from the CBI database as well as from the corporate website of the green bond issuers. As a result, the dataset consists of 44 bond triplets. After integrating time-series data, bonds with missing data are removed. Finally, the sample comprises 17,162 bond-day observations.

4.2 Research methodology

Several empirical studies on yield difference between various types of fixed-income securities employ an OLS panel regression as the main research methodology. In particular, when examining the existence of the green bond premium, many researchers disentangle yield spreads into bond characteristic components and the "greenness" feature denoted by a dummy variable. One striking advantage of this approach is its simplicity. It enables researchers to run panel regressions without conducting additional steps for data processing.

However, this method has several drawbacks. Firstly, no consensus has been reached upon the main determinants of yield differential between green bonds and their conventional counterparts. Moreover, there are no agreed theories to explain how bond-specific factors or the "greenness" of bond could influence such a yield gap while the presence of the green bond premium is still an ongoing debate. Finally, the inclusion of the "green" dummy variable into an OLS specification could pose a multicollinearity problem. For example, green bonds typically require issuers to meet a high level of transparency in reporting and communication, which could already be factored in the credit rating.

To alleviate the problems posed by the above methodology, a large body of literature employ the model-free technique or the Matching method. To be specific, this method involves matching a pair of investment assets with the same characteristics except for one feature which is the leading property of interest. It appears to be the preferred methodology for recent research on the green bond premium thanks to several advantages over the classical panel regression. Firstly, it mostly eliminates unobserved effects emerging from bond structure differences between green bonds and conventional bonds of the same issuer. Since most of the bond-specific factors driving bond yields are identical, the yield differential can be decomposed into two components: liquidity difference and green premium. Secondly, this technique could reduce the multicollinearity problem caused by the "green" dummy variable.

From the above reasonings, this thesis employs the Matching method to examine the green bond premium. After matching green bonds with comparable conventional bonds, a panel regression analysis is conducted to decompose the yield difference of green bonds and matched ordinary ones into liquidity difference and green bond premium. Lastly, OLS cross-sectional regressions are run to address the main factors driving such a premium. The description of the variables and model specifications will be discussed in the following parts of this sub-section.

The methodology applied in this study is strictly consistent with Zerbib (2019). Nevertheless, while developing on the mentioned research, this research takes into account the effect of external review or certification on the green bond premium. Furthermore, compared to Zerbib (2019) who explores the green bond market until December 31st, 2017, this study provides more recent empirical evidence about green bond premium over a more extended period.

4.2.1 Estimating the green bond premium

The first stage of the analysis aims at investigating the presence of the green bond premium by capturing the unobserved effect driving the yield differential between green bonds and ordinary bonds. To reach that objective, liquidity control variable, maturity control and a variable to measure the above-mentioned differential are introduced. After that, through a panel regression with fixed effects, the pricing gap between two kinds of bonds is disintegrated into a liquidity component and an unobserved factor indicating the green bond premium.

Maturity control:

Due to the limitedness of the data, matching the maturity date between green and non-green bonds cannot be done. Therefore, a maturity control is introduced to reduce the maturity bias. In order to do that, every two conventional bonds in a bond triplet are linearly interpolated or extrapolated at the corresponding green bond's maturity date (Zerbib, 2019). By doing so, for each bond triplet, a synthetic ordinary bond is created with the same maturity as that of the green bond. Practically, the following formula identifies the yield of the synthetic conventional bond:

$$Yield^{CB} = \frac{Yield^{CB2} - Yield^{CB1}}{Maturity^{CB2} - Maturity^{CB1}}(Maturity^{GB} - Maturity^{CB1}) + Yield^{CB1}$$

where $Yield^{CB}$ is the yield of the synthetic conventional bond. $Yield^{CB1}$ and $Yield^{CB2}$ are the yield of conventional bond 1 and 2 in each bond triplet. $Maturity^{GB}$, $Maturity^{CB1}$ and $Maturity^{CB2}$ are time to maturity of the green bond, conventional bond 1 and 2 in each matched bond set, respectively.

Figures 4 and 5 illustrate the examples of the interpolation and extrapolation process. In Figure 4, the green bond has a yield of 1.742%, with 7.47 years to maturity. Conventional bond 1 and 2 are issued by the same issuer with the maturity of 7.36 and 7.87 years, respectively. The yields of those conventional bonds are 1.753% and 1.752%. By applying the above formula, a synthetic conventional bond is generated, with a yield of 1.7528% and a maturity of 7.47 years. For the bond set presented in Figure 5, the same computation is done to create a new synthetic conventional bond that has the same maturity as that of the corresponding green bond.

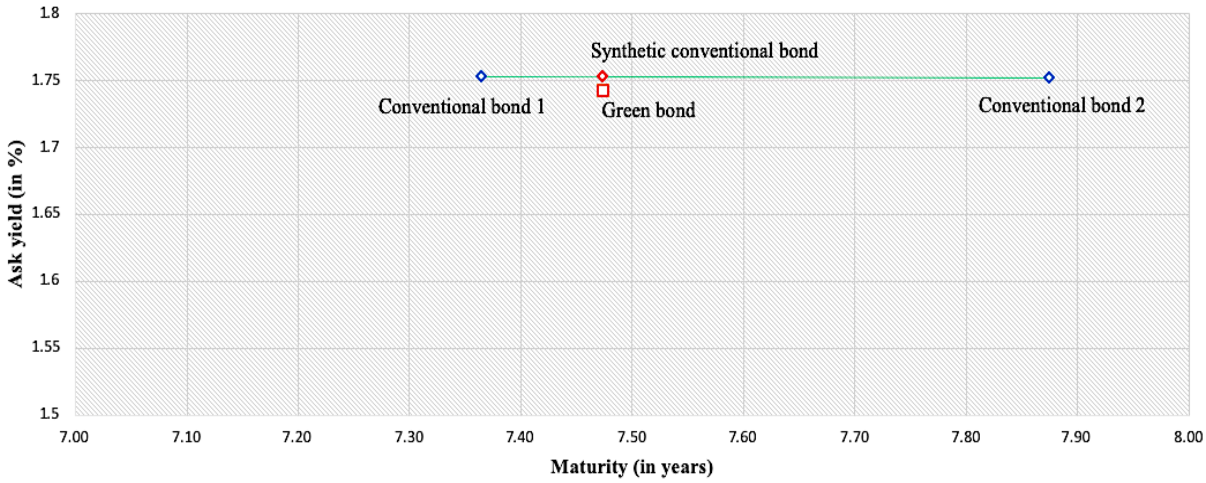

Figure 4. Example of linear interpolation of the yields of two conventional bonds at the maturity date of the corresponding green bond

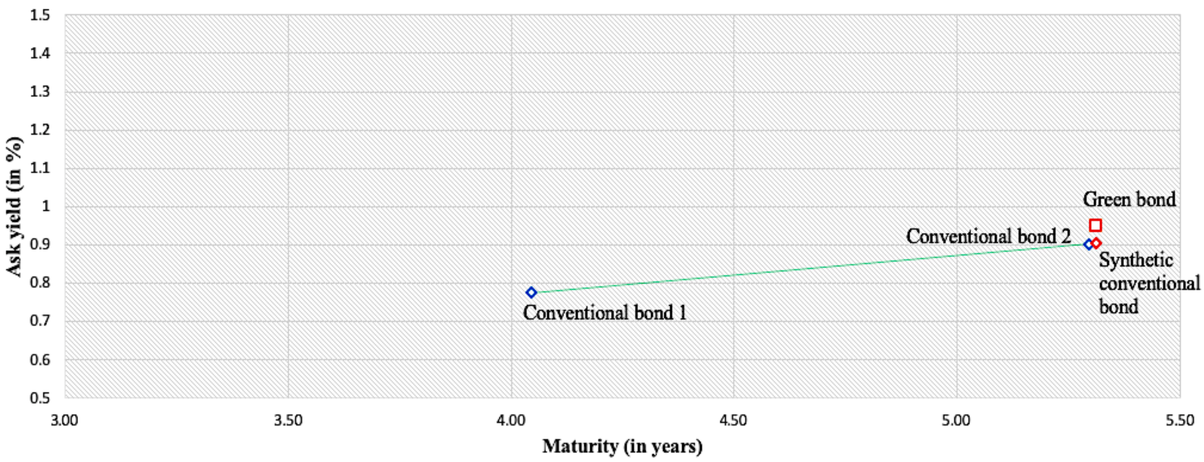

Figure 5. Example of linear extrapolation of the yields of two conventional bonds at the maturity date of the corresponding green bond

Liquidity control:

Many empirical studies find that liquidity factors could have an impact on yield difference between two types of corporate bonds (Chen et al., 2007; Dastidar & Phelps, 2011; Bao et al., 2011; Bongaerts et al., 2017). Although the Matching approach significantly reduces the liquidity bias, there is still liquidity difference because green and non-green bonds cannot be matched perfectly. For that reason, it is essential to control for the residual liquidity between green bonds and synthetic ordinary bonds. Previous literature on green bond premium develops various proxies for liquidity control. For example, Barclays (2015) uses the issuance date while Baker et al. (2018) employ the issue amount as a liquidity proxy.

Zerbib (2019) verifies that after matching green bonds with comparable synthetic ones, the bid-ask spread is an appropriate proxy to limit liquidity and maturity bias. The author further argues that other proxies that require intraday yields or daily trading volume data cannot be used due to the availability of the data. Besides, Fong et al. (2017) suggest that the bid-ask spread is the most effective method to measure liquidity for low-frequency bond data. Therefore, this paper uses bid-ask spread, which is the difference between the bid and ask price, as a liquidity control variable. Following Zerbib (2019), the bid-ask spread of the synthetic conventional bond is estimated as follows:

$$BA_{i,t}^{CB} = \frac{d_2}{d_1 + d_2} BA_{i,t}^{CB1} + \frac{d_1}{d_1 + d_2} BA_{i,t}^{CB2}$$

where:

$$d_1 = |Maturity_{GB} - Maturity_{CB1}|$$
$$d_2 = |Maturity_{GB} - Maturity_{CB2}|$$

$BA_{i,t}^{CB1}$ and $BA_{i,t}^{CB2}$ denote the bid-ask spread of conventional bond 1 and 2 in each bond triplet while $BA_{i,t}^{CB}$ measures the bid-ask spread of the synthetic conventional bond. Accordingly, the liquidity control variable is calculated as:

$$\Delta BA_{i,t} = BA_{i,t}^{GB} - BA_{i,t}^{CB}$$

with $\Delta BA_{i,t}$ denoting the difference in bid-ask spread of green bond *i* and its identical synthetic conventional bond on day *t*.

Dependent variable:

Because the objective of the analysis is to understand how investors would value green bonds differently from ordinary bonds, the difference in ask yield between a green bond and its corresponding synthetic non-green bond is used as the dependent variable. Furthermore, ask yield is used in the available green bond pricing literature, namely Zerbib (2019), Bachelet et al. (2019). Therefore, applying the same approach would make it easier to compare the results with previous studies. The variable is calculated by the following formula:

$$\Delta Yield_{i,t} = Yield_{i,t}^{GB} - Yield_{i,t}^{CB}$$

where $Yield_{i,t}^{GB}$ denotes the yield of green bond *i* on day *t*, $Yield_{i,t}^{CB}$ is the yield of the synthetic conventional bond created from two non-green bonds corresponding to green bond *i* on day *t*. $\Delta Yield_{i,t}$ is the yield difference of green bond *i* and its identical synthetic conventional bond on day *t*.

Consequently, hypothesis H_1 in the thesis is tested with the following setting:

$$\Delta Yield_{i,t} = \alpha_i + \beta_1 \Delta BA_{i,t} + \varepsilon_{i,t} \text{ (1)}$$

where $\Delta Yield_{i,t}$ is the yield difference between green bond *i* and its identical synthetic conventional bond on day t. α_i reflects the unobserved cross-sectional fixed effects in the panel regression. $\Delta BA_{i,t}$ is the difference in bid-ask spread of green bond *i* and its identical synthetic conventional bond on day *t,* with $\varepsilon_{i,t}$ being the error term.

Following Zerbib (2019), the green bond premium (α_i) is the unexplained bond-specific fixed effects in the model (1). When α_i is statistically significantly negative, the green bond *i* is traded at a lower yield compared to its matched conventional bond after controlling for liquidity difference. It indicates that investors pay a premium to acquire the green bond *i* over its identical non-green twin. Conversely, if α_i is statistically significantly positive, the green bond *i* is valued lower than its conventional counterpart's price.

4.2.2 Identifying the determinants of the green bond premium

In the next stage of the analysis, to test hypothesis H_2, a cross-sectional regression is conducted. The main characteristics of bonds and the green-bond verification from an external party are considered as potential drivers of green bond premium. Table 3 gives information on the definitions of the explanatory variables. Specifically, the econometric estimation is addressed as follows:

$$\alpha_{i\,Yield} = \beta_0 + \beta_1 \log(Issued\ Amount_i) + \beta_2 Maturity_i + \beta_3 External\ Review_i + \gamma_1' Rating_{ij} + \gamma_2' Sector_{ij} + \gamma_4' Currency_{ij} + u_i \quad (2)$$

with u_i being the error term.

Table 3. Variables legend

Variable name	Description
Rating	Bond's S&P rating. In case S&P rating is unavailable, Moody's rating is used and converted into S&P rating. The groups of ratings are AA, A, BBB, B, NR (non-rated). Scale variable which takes: 1 if rating is NR, 2 if rating is BBB, 3 if rating is A, 4 if rating is AA. One B-rated bond is excluded to avoid the artificially high R^2 problem.
Sector	Bloomberg classification level 2 (BCLASS Level 2) is used, which provides 3 categories namely Financial Institutions, Industrials and Utility. Scale variable which takes: 1 if sector is Financial Institutions, 2 if sector is Industrial, 3 if sector is Utility.
Currency	The currency of the bond at issuance, comprising AUD, CNY, EUR, HKD, INR, MYR, NOK, SEK, THB, TWD, USD. Scale variable which takes: 1 if currency is USD, 2 if currency is AUD, 3 if currency is CNY, 4 if currency is EUR, 5 if currency is SEK, 6 if currency is THB. The bonds denominated in other currencies are removed to avoid

	the artificially high R^2 problem. The definitions of these currencies are presented in Appendix 1.
Issued Amount	Issued amount in USD as of February 28th, 2020.
Maturity	Bond's time to maturity in years, as of February 28th, 2020.
External Review	Dummy variable which takes 1 if the green bond receives a verification or review from an independent party, 0 otherwise.

4.3 Descriptive statistics

The final unbalanced panel dataset consists of 44 matched triplets of bonds with 17,162 bond-day observations. Due to the strict Matching criteria between green bonds and their comparable ordinary bonds, the number of bonds tested is greatly reduced, resulting in a relatively small sample compared to that of the benchmarked research. However, several empirical studies using the Matching approach have similar sample sizes. For instance, Goldreich et al. (2005) examine the yield differential of 55 matched pairs of on-the-run and off-the-run US Treasury bonds while Kreander et al. (2005) analyze the performance of 30 pairs of ethical and non-ethical European funds.

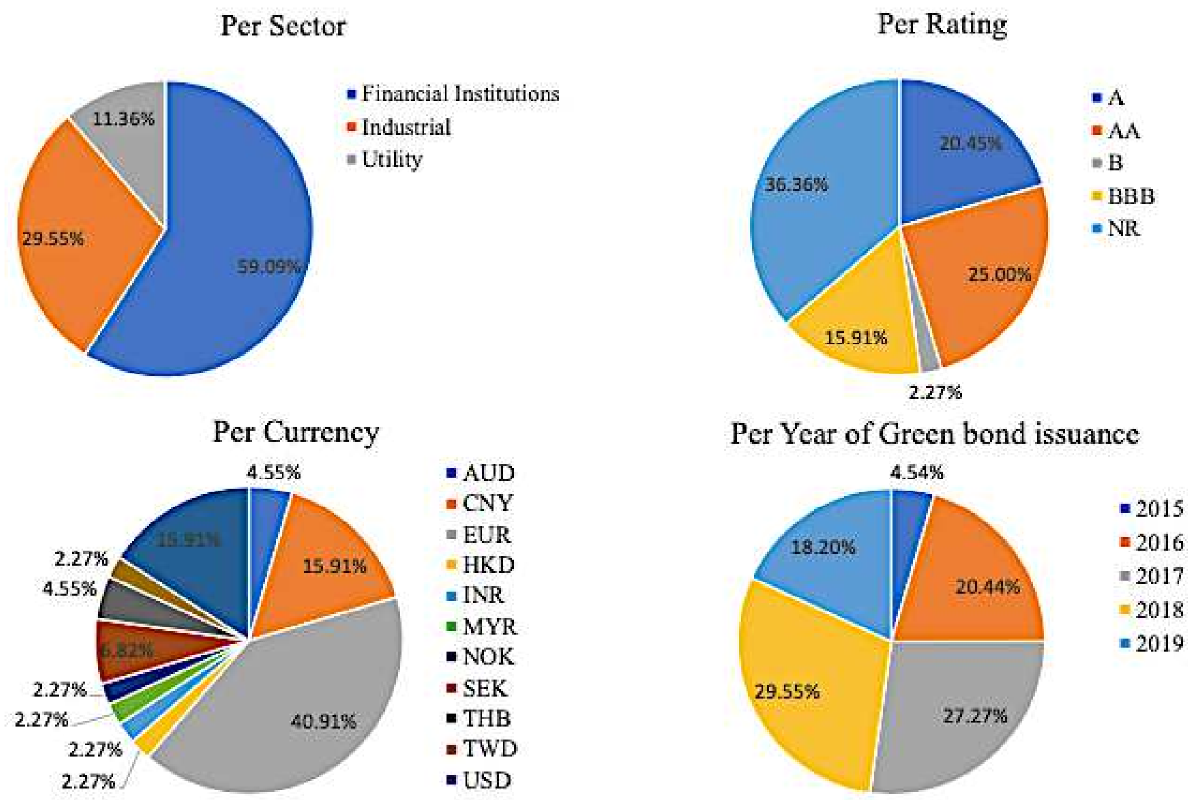

Figure 6. Green bond distribution by sector, rating, currency and year of issuance.

Figure 6 depicts the composition of the sample by sector, rating, currency denomination and year of green bond issuance. Per sector, the Financials contribute 59% to the total number of bonds, followed by the Industrial and Utility sectors with 29% and 11%, respectively. When looking at the ratings of the bonds, a large proportion of non-rated bonds (36%) could be observed. This figure is expected since most of the bonds from Asia and Nordic countries are not rated by S&P and Moody's. Besides, A- and AA-rated bonds account for nearly half of the entire sample. The composition of the sample by currency reflects the global pattern that Europe is the dominant green bond issuer, followed by Asia and America. Finally, 95% of the green bonds are issued after 2015, confirming the rising awareness about green finance after the adoption of the Paris Agreement.

Table 4. Summary statistics of the sample categorized by sector and rating

		Obser-vations	Mean	SD	Min	Max
Financial Institutions						
A	ΔYield (%)	2,896	-0.031	0.094	-0.609	0.235
	ΔBA (bps)	2,896	-0.088	0.185	-1.051	0.244
	Maturity of GB (years)	2,896	5.505	0.768	5.003	7.016
	Coupon rate of GB (%)	2,896	0.811	0.262	0.300	1.125
AA	ΔYield (%)	3,614	0.035	0.559	-2.991	3.835
	ΔBA (bps)	3,614	0.019	0.111	-0.453	0.630
	Maturity of GB (years)	3,614	5.225	0.668	5.003	7.005
	Coupon rate of GB (%)	3,614	1.414	1.445	0.250	3.625
BBB	ΔYield (%)	989	0.024	0.104	-0.130	0.345
	ΔBA (bps)	989	-0.031	0.077	-0.427	0.146
	Maturity of GB (years)	989	5.004	0.002	5.003	5.005
	Coupon rate of GB (%)	989	0.958	0.260	0.750	1.250
NR	ΔYield (%)	2,110	-0.022	0.131	-1.711	1.981
	ΔBA (bps)	2,110	-0.026	0.093	-0.801	0.251
	Maturity of GB (years)	2,110	4.146	1.069	3.003	5.003
	Coupon rate of GB (%)	2,110	4.595	2.154	1.875	8.550
Industrial						
AA	ΔYield (%)	1,206	-0.029	0.083	-0.455	0.364
	ΔBA (bps)	1,206	-0.082	0.034	-0.204	0.002
	Maturity of GB (years)	1,206	8.505	2.121	7.005	10.005
	Coupon rate of GB (%)	1,206	2.925	0.106	2.850	3.000
B	ΔYield (%)	366	0.790	1.841	-4.141	4.686
	ΔBA (bps)	366	-0.020	0.032	-0.045	0.243
	Maturity of GB (years)	366	8.299	0.000	8.299	8.299
	Coupon rate of GB (%)	366	5.875	0.000	5.875	5.875

BBB	ΔYield (%)	1,317	-0.101	0.174	-0.970	0.648
	ΔBA (bps)	1,317	-0.007	0.060	-0.506	0.089
	Maturity of GB (years)	1,317	5.003	0.000	5.003	5.003
	Coupon rate of GB (%)	1,317	2.875	0.000	2.875	2.875
NR	ΔYield (%)	2,385	0.023	0.092	-0.525	0.335
	ΔBA (bps)	2,385	0.160	3.305	-0.513	80.518
	Maturity of GB (years)	2,385	5.504	2.929	3.003	10.008
	Coupon rate of GB (%)	2,385	2.564	1.185	0.950	3.860
Utility						
A	ΔYield (%)	967	-0.049	0.113	-0.608	0.325
	ΔBA (bps)	967	0.035	0.097	-0.284	0.475
	Maturity of GB (years)	967	8.505	2.121	7.005	10.005
	Coupon rate of GB (%)	967	1.858	1.389	0.875	2.840
BBB	ΔYield (%)	1,220	0.001	0.109	-0.275	0.547
	ΔBA (bps)	1,220	-0.064	0.088	-0.141	0.813
	Maturity of GB (years)	1,220	6.045	1.362	5.082	7.008
	Coupon rate of GB (%)	1,220	2.188	0.442	1.875	2.500
NR	ΔYield (%)	92	0.005	0.043	-0.021	0.289
	ΔBA (bps)	92	0.096	0.056	-0.277	0.106
	Maturity of GB (years)	92	5.723	0.000	5.723	5.723
	Coupon rate of GB (%)	92	4.870	0.000	4.870	4.870
Entire sample						
A	ΔYield (%)	3,863	-0.036	0.100	-0.609	0.325
	ΔBA (bps)	3,863	-0.057	0.176	-1.051	0.475
	Maturity of GB (years)	3,863	6.172	1.660	5.003	10.005
	Coupon rate of GB (%)	3,863	1.043	0.711	0.300	2.840
AA	ΔYield (%)	4,820	0.019	0.486	-2.991	3.835
	ΔBA (bps)	4,820	-0.006	0.107	-0.453	0.630
	Maturity of GB (years)	4,820	5.822	1.602	5.003	10.005
	Coupon rate of GB (%)	4,820	1.689	1.430	0.250	3.625

B	ΔYield (%)	366	0.790	1.841	-4.141	4.686
	ΔBA (bps)	366	-0.020	0.000	-0.045	0.243
	Maturity of GB (years)	366	8.299	0.000	8.299	8.299
	Coupon rate of GB (%)	366	5.875	0.000	5.875	5.875
BBB	ΔYield (%)	3,526	-0.031	0.147	-0.970	0.648
	ΔBA (bps)	3,526	-0.033	0.079	-0.506	0.813
	Maturity of GB (years)	3,526	5.301	0.753	5.003	7.008
	Coupon rate of GB (%)	3,526	1.857	0.917	0.750	2.875
NR	ΔYield (%)	4,587	0.002	0.113	-1.711	1.981
	ΔBA (bps)	4,587	0.073	2.386	-0.801	80.518
	Maturity of GB (years)	4,587	4.923	2.229	3.003	10.008
	Coupon rate of GB (%)	4,587	3.597	1.911	0.950	8.550

Table 4 reports the summary statistics of the sample. Overall, there is a considerable variation in yield differential *(ΔYield*) across different sectors and rating classes. For instance, the average yield difference of BBB bonds in the Financial sector is 2.4 bps while bonds with similar rating in the Industrial sector has an average yield spread of roughly -10.1 bps. It means that Financial BBB-rated green bonds have lower prices in comparison with their conventional peers. On the contrary, Industrial BBB-rated green bonds are priced higher than their non-green counterparts. Also, the large standard deviations within some sub-classes indicate that investors have disparate views when evaluating green bonds.

Besides, as displayed in Table 4, the residual liquidity measured by the difference in the bid-ask spread (*ΔBA*) is relatively small, with the average values ranging from -0.06 bps to 0.07 bps. These figures imply that the Matching procedure significantly reduced the liquidity bias between green and non-green bonds. A large fluctuation within some subcategories could be observed through high standard deviations, once again highlighting the contradictory perspectives of the market about the pricing and the prospects of green bonds.

When looking at the maturity of the sub-samples, Financial green bonds are reported to have a lower maturity with an average of 5 years, while this number for Industrial and Utility green bonds is roughly 6.8 years. It could be seen that the maturity of green bonds changes vastly across different sectors and rating groups. Another component worth mentioning is the coupon rate. Similar to other indicators, the coupon rate also varies greatly, with a mean spanning from 0.811% to 5.875%. Since the sample used in this study is an unbalanced panel and the distribution of bonds by sector, rating, currency are different, no further conclusions on the relationship between the movement of the above indicators could be drawn.

5 Empirical results

The empirical results presented in this chapter are organized into two parts. The first one concerns the evaluation of the sign and the magnitude of the green premium. The second step is to assess the impact of bond-specific characteristics on such a premium. Accordingly, key findings are discussed and compared with empirical results from previous studies on the green bond premium.

5.1 Green bond premium

As stated in the previous chapter, to identify the presence of the green bond premium, panel regression with fixed effects is run on the following equation:

$$\Delta Yield_{i,t} = \alpha_i + \beta_1 \Delta BA_{i,t} + \varepsilon_{i,t} \qquad (1)$$

Referring to Zerbib (2019), the green bond premium is defined as an unobserved bond-specific and time-invariant effect. Therefore, α_i in equation (1) is the green bond premium corresponding to each specific bond triplet. The panel regression is conducted on the assumption that errors are homoscedastic and have a zero mean value. The Durbin Watson statistic indicates that there is an autocorrelation detected in the residuals. The Breusch-Pagan test is run, reporting that the variance of the error terms remains constant across observations. Furthermore, the results of the Normality test confirms that the residual values are not normally distributed. Lastly, unit root tests are conducted to check the stationarity of the residuals. Of which, a majority of the tests report that the residual series is stationary. The results of the above tests are presented in Appendix 2.

Table 5 shows the outputs of the regression from equation (1). Accordingly, the R^2 equals to 18.14%. The coefficient for the liquidity control variable (ΔBA) is estimated to -0.8232 and statistically significant at a 1% significance level. This figure indicates that a 1% increase in residual liquidity (captured by the difference in bid-ask spread) between a green bond and its identical synthetic conventional twin results in a 0.82% decrease in the yield spread between two mentioned types of bonds. Practically, the yield differential of a green bond and its identical non-green peer is negatively associated with the deteriorating liquidity of that green bond.

Table 5. Identifying the green bond premium

	Dependent variable: $\Delta Yield_{i,t}$
ΔBA	-0.8232***
	(0.2271)
Constant	0.0085**
	(0.0028)
Observations	17,162
R^2	0.1814
Adjusted R^2	0.1793

Note: Standard errors are reported in parentheses.
*p < 0.1; **p < 0.05; ***p < 0.01.

Next, a Hausman test is performed to compare the robustness of the fixed-effects and the random-effects models. The purpose of this step is to see which model is more appropriate for testing hypothesis H_1. The outcome suggests that a random-effects model should be run alternatively. Therefore, the author re-estimates specification (1) using a random-effects panel regression. The discrepancy between the two models is that the unobserved bond-specific effects are assumed not to be correlated with the control variable in the random-effects model.

As shown in Table 6, despite the extremely weak R^2 (0.1%), the results confirm the statistically significant and negative association between the liquidity difference and yield differential of green bonds and their matched conventional twins. Following the regression, several robustness checks are performed to examine the heteroskedasticity, autocorrelation, normality and stationary concerns. The outputs of those tests are presented in Appendix 3.

Table 6. Results of the panel regression with random effects

	Dependent variable: $\Delta Yield_{i,t}$
ΔBA	-0.8191***
	(0.2270)
Constant	0.0049
	(0.0265)
Observations	17,162
R^2	0.0008
Adjusted R^2	0.0007

Note: Standard errors are reported in parentheses.
*p < 0.1; **p < 0.05; ***p < 0.01.

Furthermore, to observe how the above-discovered relationship evolves over time, year fixed effects are added into equation (1). Accordingly, the following estimation is considered:

$$\Delta Yield_{i,t} = \alpha_i + \beta_1 \Delta BA_{i,t} + \beta_2 Year_t + \varepsilon_{i,t} \qquad (3)$$

where $Year_t$ is a scale variable which denotes the year of the observation.

The outcomes of the conducted regression for the above specification are displayed in Table 7. It is noted that a one-year increase in *Year* leads to an increase of 0.57 bps in the yield differential between two kinds of bonds (*ΔYield*). However, this result is not statistically significant. On the other hand, liquidity difference (ΔBA) is proved to have a negative influence on *ΔYield* with a coefficient of -0.8223. It is statistically significant at a 1% level of confidence and closely consistent with the finding from the regression of model

(1). To check the robustness of the results, various robustness tests are performed, with the results shown in Appendix 4.

Table 7. Regression results of model (3)

	Dependent variable: $\Delta Yield_{i,t}$
ΔBA	-0.8223***
	(0.2270)
Year	0.0057
	(0.0038)
Constant	-0.0063
	(0.0102)
Observations	17,162
R^2	0.1815
Adjusted R^2	0.1794

Note: Standard errors are reported in parentheses.
*p < 0.1; **p < 0.05; ***p < 0.01.

Following Zerbib (2019), the green premium for each bond triplet in the sample can be documented by obtaining the fixed effects in the panel regression of equation (1), as presented in Appendix 5. The distribution of the estimated green bond premia is illustrated in Table 8 and Figure 7. A large fluctuation of green bond premia could be observed, varying from -34.13 bps to 78.14 bps with a mean and median of -0.45 and -1.34 bps, respectively. Remarkably, a total of 75% of the estimated green premia is negative, showing that compared to their non-green peers, most of the green bonds are overpriced by the investors.

Table 8. Distribution of the estimated green bond premia

Green bond premium: $\hat{\alpha}_i$					
Min	1st Quartile	Median	Mean	3rd Quartile	Max
-0.3413	-0.0457	-0.0134	-0.0045	-0.0010	0.7814

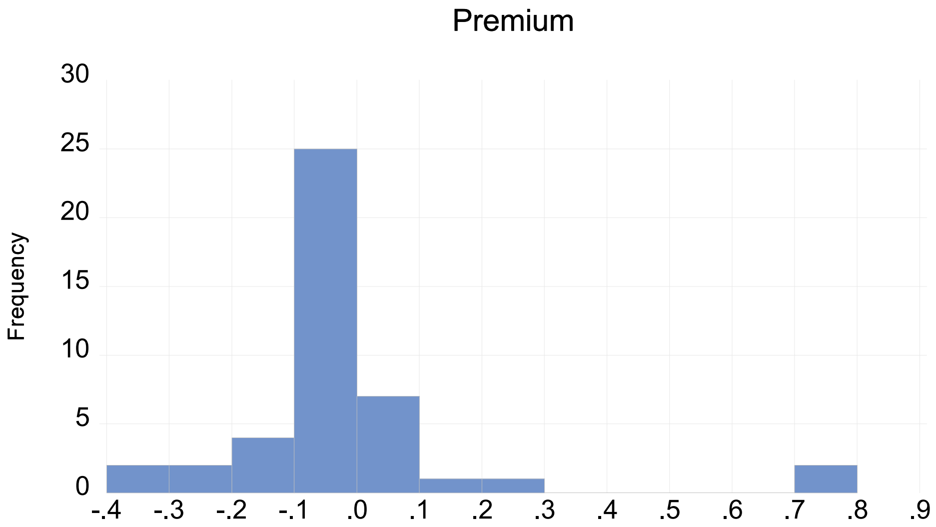

Figure 7. Histogram of green bond premia distribution

Subsequently, a sub-sample analysis is implemented to see the variations of the green bond premium across market segments, currencies and rating classes. In order to do so, as recommended by Zerbib (2019), the author performs Wilcoxon sign-rank tests for sub-samples to evaluate whether $\hat{\alpha}_i$ is significantly different from 0. The results of the tests are presented in Table 9 below. In general, the green premium of the full sample is different from 0 at a 5% significance level with a mean of -0.45 bps, which confirms the presence of a negative green bond premium on an overall perspective. When looking into market segments, Financials are reported to have a -2.6 bps premium on average at a significance level of 5%. Meanwhile, the Industrial and Utility sectors with mean premia of 5 bps and -3.6 bps, respectively, are not statistically different from 0.

When analyzing the green premia across different currencies and ratings, the figures are difficult to interpret. As shown in Table 9, CNY-denominated green bonds have a significant average green premium of -9.4 bps. Surprisingly, EUR and USD-denominated green bonds do not show any statistically significant mean values. On the other hand, A-rated and non-rated green bonds are found to have a negative and statistically significant average premium. Table 9 documents an average premium of -5.24 and -3.23 for A-rated and non-rated green bonds, respectively. Meanwhile, AA-rated, BBB-rated and B-rated green bonds do not have any statistically significant mean of premium. Consequently, the analysis could not provide evidence on the impact of credit rating and currency denomination on the green bond premium.

Table 9. Sub-sample analysis of the green bond premium

	Mean($\hat{\alpha}_i$)	Median($\hat{\alpha}_i$)	$\hat{\alpha}_i \neq 0$	No. GB
Full sample	-0.0045	-0.0134	**	44
Sector				
Financial Institutions	-0.0258	-0.0232	**	26
Industrial	0.0502	-0.0103		13
Utility	-0.0361	-0.0079		5
Currency				
AUD	-0.0140	-0.0140		2
CNY	-0.0945	-0.0048	**	7
EUR	0.0113	-0.0314		18
HKD	-0.0079	-0.0079		1
INR	0.0012	0.0012		1
MYR	-0.0027	-0.0027		1
NOK	0.2039	0.2039		1
SEK	-0.0216	-0.0286		3
THB	0.0097	0.0097		2
TWD	-0.0126	-0.0126		1
USD	0.0218	-0.0063		7

Rating				
AA	0.0223	-0.0129		11
A	-0.0524	-0.0426	*	9
BBB	-0.0338	-0.0464		7
B	0.7814	0.7814		1
NR	-0.0323	-0.0047	**	16

Note: The Wilcoxon sign-rank tests are conducted to evaluate whether the mean green bond premium of the sub-samples is significantly different from 0. The null hypothesis H_0: $\hat{\alpha}_i = 0$ is rejected when the probability is lower than the certain level of significance. *p < 0.1; **p < 0.05; ***p < 0.01.

5.2 Determinants of the green bond premium

The thesis proceeds by investigating essential factors influencing the green bond premium discovered in the previous section. To do so, the cross-sectional regressions of the estimated green bond premium are run on various bond-specific characteristics. As mentioned earlier, to avoid the possibility of artificially high R^2, the analysis eliminates groups (categorized by sector, credit rating, currency, year of issuance) in which less than two observations are available. As a result, the sample size is reduced to 38 observations.

The cross-sectional regressions in this study are performed under the assumption that errors have a zero mean value and are homoscedastic. The Breusch-Pagan checks support the above assumption. Furthermore, the Normality tests report that the residual values are not normally distributed. Finally, to check the multicollinearity problem, the Variance Inflation Factors are obtained, which states that the explanatory variables are slightly correlated. The results of the tests could be found in Appendix 6.

Table 10 presents six model specifications in line with equation (2) stated in the previous chapter. (a) regresses the green bond premium on four fundamental bond features: *Rating, Sector, Issued Amount, Maturity*. (b) the *Maturity* variable is replaced by the *External*

Review dummy variable. (c) includes the *Currency* dummy and drops the *External Review* variable. (d) further comprises the *External Review* dummy. (e) drops the *Rating* dummy. (f) excludes the *Currency* dummy and considers the effect of the *Rating* × *External Review* variable. Across all the specifications, it is reported that R^2 varies from 8.89% to 23.98%. The low R^2 is expected since the recent emergence of the corporate green bond market restricts the number of observations, and hence the explanatory power of the models.

Across all variants of the regression, neither maturity nor sector has a statistically significant influence on the green bond premium. Similarly, when being considered in model (c) and (d), the currency seems not to have any statistically significant correlation with the green bond premium. On the contrary, the green bond's issue amount is negatively associated with the green bond premium. This pattern is consistent and significant across model (a), (b) and (f). Specifically, in model (a) and (b), the coefficient of the *log(Issued Amount)* variable is -0.06 at a 10% significance degree. Meanwhile, this figure in model (f) is -0.05 at a 5% significance level.

Besides, the rating factor appears to have a statistically negative impact on the green bond premium when being embedded into model (a), (b), (c) and (d). Specifically, across four models, the coefficients for the *Rating* dummy span from 0.05 to 0.06 and are significant at least at a 10% level. Lastly, the external review cannot derive any statistically significant influence on the green bond premium in model (b), (d) and (e).

As stated earlier, external reviews provide additional information about the credibility of green bonds. Meanwhile, the credit rating of a bond represents its creditworthiness. Therefore, in model (f), the interaction variable *Rating* × *External Review* is included to assess the joint effect of external review and rating on the green bond premium. The regression outcome shows that *Rating* × *External Review* positively impacts the green bond premium with a coefficient of 0.05 at a 1% significance level.

Table 10. Determinants of the green bond premium

	Dependent variable: $\hat{\alpha}_i$					
	(a)	(b)	(c)	(d)	(e)	(f)
Constant	0.9530*	0.8581	0.5489	0.6101	0.2489	0.8704*
	(0.5300)	(0.5172)	(0.5748)	(0.5876)	(0.5834)	(0.4703)
Rating	0.0474*	0.0485*	0.0556**	0.0526*		
	(0.0275)	(0.0259)	(0.0258)	(0.0264)		
Sector	-0.0126	0.0094	0.0121	0.0154	-0.0006	0.0098
	(0.0456)	(0.0418)	(0.0418)	(0.0424)	(0.0435)	(0.0441)
Currency			0.0289	0.0214	0.0132	
			(0.0207)	(0.0239)	(0.0245)	
log(Issued Amount)	-0.0578*	-0.0551*	-0.0424	-0.0459	-0.0194	-0.0524**
	(0.0288)	(0.0275)	(0.0287)	(0.0294)	(0.0274)	(0.0248)
Maturity	0.0140					0.0012
	(0.0195)					(0.0188)
External Review		0.0794		0.0474	0.0730	
		(0.0640)		(0.0734)	(0.0754)	
Rating × External Review						0.0537***
						(0.0192)
Observations	38	38	38	38	38	38
R^2	0.1376	0.1688	0.1786	0.1892	0.0889	0.2398
Adjusted R^2	0.0331	0.0681	0.0791	0.0625	-0.0216	0.1476
F-Statistic	1.3164	1.6754	1.7944	1.4937	0.8048	2.6018

Note: Standard errors are reported in parentheses.

*p < 0.1; **p < 0.05; ***p < 0.01.

5.3 Results interpretations and discussion

The conducted empirical analysis documents a small green bond premium of -0.45 bps, meaning that on average, investors are willing to sacrifice 0.45 bps of yield to invest in green bonds over comparable non-green bonds. Consequently, the study supports hypothesis H_1, confirming that corporate green bonds are traded with a lower yield than their identical conventional counterparts. Although the estimated green bond premium is small, it highlights the investors' interests in green bonds. This outcome is in line with previous studies on green bond premium in the secondary market (Barclays, 2015; Zerbib, 2019; Partridge & Medda, 2020). To a broader extent, this result underscores the view that the taste for certain types of assets could drive investment decisions (Fama & French, 2007). The findings can also be related to the Economic Theories of Social Norms which proposes that investors might accept an extra cost to mitigate the risks associated with the violation of social norms (Elster, 1989).

Nevertheless, it is noteworthy that not all green bonds are priced higher than their conventional twins. In fact, a total of 25% of the discovered green premia is positive, meaning that these green bonds exhibit higher yields than their non-green peers. The outcome implies that at some points, green bonds are considered cheaper than their identical ordinary counterparts. Therefore, although the study identifies a small negative green premium, the finding does not contradict CBI (2018) which finds that investors have opposing perspectives when evaluating green bonds. Since the green bond market is still immature and regulations are being developed, the pricing of green bonds is an ongoing challenge for the market participants.

The liquidity difference captured by the bid-ask spread (ΔBA) is demonstrated to have an adverse relationship with the yield differential between green bonds and their conventional peers. To be specific, a 1% increase in ΔBA leads to a 0.82% decline in the yield spread between two varieties of bonds. This result supplements the findings from Bao et al., (2011), Howeling et al. (2005), which argue that liquidity difference has an influence on the bond yield spread.

The second part of the analysis aims to test hypothesis H_2 by providing evidence on the drivers of the estimated green bond premium. An important outcome from the study is that the issue amount of green bond and the green premium are negatively correlated. Particularly, a 1% increase in the issue amount of the green bond results in a range between 0.05 to 0.06 bps decrease in green bond premium. This co-movement is consistent with empirical findings from Karpf and Mandel (2017), Bachelet et al. (2019), figuring out the negative linkage between green bond premium and the principal amount of the green bond issuance.

Consistently with the existing research on the green bond premium, the sector does not seem to have a substantial impact on the variation of the green bond premium. However, a sub-sample test confirms that the Financial industry exhibits a green premium of -2.6 bps on average, considerably higher than that of the entire sample (-0.45 bps). As speculated by Zerbib (2019), financial green bonds have a significant negative premium on average because the Financials are the most active issuers on the corporate green bond market. Also, the Financial sector can attract considerable financial resources for the implementation of green or climate-related projects (Bachelet et al., 2019).

Similar to prior studies, the inclusion of the currency dummy into the regression does not display any significant effect on the variation of the green bond premium. However, when breaking down the green bond premia by sub-samples of currencies, it is noticeable that the CNY-denominated green bonds have an average premium of -9.45 bps. This figure is far higher than the mean of the entire sample, implying the interest of the investors in the Chinese green bond market, where has witnessed substantial growth in recent years with the construction of many large green infrastructures.

In contradiction of Karpf and Mandel (2017), Zerbib (2019), Li et al. (2019), who point out that green bonds with higher credit ratings have lower premia, this study reports that a 1-level increase in bond rating leads to an approximately 5 bps increase in green bond premium. Besides, the sub-sample tests document the negative and statistically significant mean of premium for the A-rated and non-rated categories of bonds. To be precise, the average premia of A-rated and non-rated green bonds are -5.24 bps and -3.23 bps, respectively.

When investigating the cross effect of rating and external review on the green bond premium, it is noted that non-rated bonds with external review have a higher premium of 5.37 bps compared to non-rated bonds without external review. This figure goes up by 5.37 bps when there is a 1-scale increase in the rating of certified green bonds. It signals that higher rated green bonds exhibit lower premia. This study could not interpret a logical relationship between credit rating and the green bond premium from those outcomes. However, the author suspects that the observed effects arise from the fact that 7 out of 12 examined non-rated green bonds are denominated in CNY, the category whose average premium is previously shown to be significant and negative.

Additionally, this study observes no statistically significant difference in green premium between green bonds with and without verification from a third party. This finding is inconsistent with existing research underlining the importance of third-party verification of green bonds (Bachelet et al.,2019; Li et al., 2019). A possible reason behind this contradiction is the discrepancy in the green bond database selection. Bachelet et al. observe the CBI-aligned green bond listed on the Climate Bond Initiative database while Li et al. (2019) focus on the Chinese green bond market. Meanwhile, all green bonds listed on the Bloomberg Terminal are aligned with the Green Bond Principles (GBP) which already require the integrity, transparency and accuracy in reporting and communication among green bond issuers and investors. Therefore, it is suspected that the importance of external verification for green bonds could be diminished.

6 Conclusions

Rising concerns about the sustainable development of the business sector have paved the way for the growth of innovative means of financing. In that tendency, the substantial evolution of green bonds has gained much attention from the financial market participants. The empirical analysis of the field of Green Bond could be related to SRI and CSR studies. Earlier research states that good CSR practices would help firms improve their financial performance to some extent and reduce environmental or climate-related risks. The green bond issuance is also a channel for the communication between corporates and their investors about environmental affairs. Considering the potential advantages of green bonds, both bond and equity investors are found to appreciate this novel financial instrument. However, existing empirical evidence is insufficient to make a sound conclusion about the impact of green bonds on firms' financial position.

This thesis extends previous research by focusing on the corporate sector. At the time of writing this study, to the best knowledge of the author, there is no published empirical research examining the valuation of green bonds solely in the corporate green bond market. The primary goal of this thesis is to investigate the pricing of green bonds through a comparison with their identical conventional peers. As stated in the previous chapters, the Matching method is employed to select the most appropriate pairs of green and non-green bonds for the empirical analysis. This approach minimizes the effects of liquidity bias and the maturity difference between two types of bonds. By adopting the Matching method and analyzing the dataset of corporate green bonds derived from the Bloomberg Terminal, the results of the thesis would be of added value to the ongoing academic debate on the presence of the green bond premium.

This study contributes to a better understanding of green bonds by documenting a small negative premium of 0.45 basis points, representing the existence of a green bond premium in the secondary corporate bond market. Additional tests for sub-samples reveal that Financial green bonds, CNY-denominated, A-rated and non-rated green bonds exhibit a significant and negative average of premium. These results confirm that not all bond investors value green bonds at a premium compared to non-green bonds. Since this type of securities has just recently introduced, the market could misprice or have a conservative view about the prospects of green bonds. Further exploration of the estimated green bond premia reveals the negative association between the issued amount of green bonds and the green premium. Besides, the role of external assurance of the "greenness" towards the pricing for green bonds could not be witnessed from the empirical outcomes. Future studies would be needed to identify the key drivers of the green bond premium.

The thesis has numerous implications for corporate issuers and bond investors. Firstly, the presence of a small negative green premium signals the investors' pro-environmental preferences as well as the oversubscription of green bonds. Although there is no clear evidence that green bonds are a cheaper source of financing compared to conventional bonds, corporates could still benefit from attracting bond investors who are interested in environmental-related financial assets. Therefore, green bond issuance enables corporates to expand their investor base as proposed by Shishlov et al. (2016) and Zerbib (2019). From the investor's perspective, it appears that the extra cost incurred when choosing to invest in green securities over the normal ones, or the switching cost, is relatively small. Combining with the fact that credible green bonds usually come along with enhanced transparency and additional information provided by the issuers, the green bond could be an attractive investment option.

This thesis, however, is subject to several limitations. A major limitation of this study originates from the data availability. Focusing solely on the corporate green bond market segment confines the number of green bonds eligible for this thesis. The small sample size and the omission of undiscovered factors could lead to the inaccurate and insignificant regression results. Besides, the sample is not heterogeneous enough, potentially causing the biased generalization. Furthermore, considering that the corporate green bond market has recently emerged, the findings of the green bond premium are provisional. Therefore, it is necessary to conduct the same analysis at a later point of time when the market matures and the quality of the data is enhanced.

Another limit of this thesis could be attributed to the use of ask yield, or ask yield to maturity, as a measure for valuation since the author attempts to understand how investors price green bonds. The underlying assumption that bonds are held until maturity is not realistic since bond investors do not always hold bonds until maturity. Thus, it would be interesting to identify a more effective metric to capture the pricing discrepancy between green bonds and their identical non-green peers. Finally, the use of the Bloomberg green bond database substantially limits the number of observations because green-labeled bonds that are not aligned with the GBP are eliminated. Building on this research, comparing the performance of green bonds complied with different voluntary guidelines could be of interest.

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Appendices

Appendix 1. Acronyms of the currencies

ID	*Currency*
AUD	Australian Dollar
CNY	Chinese Yuan
EUR	Euro
HKD	Hong Kong Dollar
INR	Indian Rupee
MYR	Malaysian Ringgit
NOK	Norwegian Krone
SEK	Swedish Krona
THB	Thai Baht
TWD	Taiwan Dollar
USD	US Dollar

Appendix 2. Robustness test results of model (1) with fixed-effects panel regression

	$\Delta Yield_{i,t} = \alpha_i + \beta_1 \Delta BA_{i,t} + \varepsilon_{i,t}$			
	Test	*Statistic*	*P-value*	*Conclusion*
Serial correlation	Durbin-Watson	0.509		Serial correlation
Normality	Jarque-Bera	1822994	0.000	Non-normality
Heteroskedasticity	Breusch-Pagan	0.986	0.321	Homoskedasticity
Unit root test	Levin, Lin & Chu	-26.537	0.000	Stationarity
Unit root test	Im, Pesaran & Shin	-36.296	0.000	Stationarity
Unit root test	ADF-Fisher	1418.48	0.000	Stationarity
Unit root test	PP-Fisher	2638.60	0.000	Stationarity
Fixed vs. Random effects	Hausman	1.138	0.286	Random effects

Appendix 3. Robustness test results of model (1) with random-effects panel regression

	$\Delta Yield_{i,t} = \alpha_i + \beta_1 \Delta BA_{i,t} + \varepsilon_{i,t}$			
	Test	*Statistic*	*P-value*	*Conclusion*
Serial correlation	Durbin-Watson	0.417		Serial correlation
Normality	Jarque-Bera	2470139	0.000	Non-normality
Heteroskedasticity	Breusch-Pagan	0.986	0.321	Homoskedasticity
Unit root test	Levin, Lin & Chu	-26.534	0.000	Stationarity
Unit root test	Im, Pesaran & Shin	-36.295	0.000	Stationarity
Unit root test	ADF-Fisher	1418.40	0.000	Stationarity
Unit root test	PP-Fisher	2638.64	0.000	Stationarity

Appendix 4. Robustness test results of model (3)

	$\Delta Yield_{i,t} = \alpha_i + \beta_1 \Delta BA_{i,t} + \beta_2 Year_t + \varepsilon_{i,t}$			
	Test	*Statistic*	*P-value*	*Conclusion*
Serial correlation	Durbin-Watson	0.509		Serial correlation
Normality	Jarque-Bera	1829074	0.000	Non-normality
Heteroskedasticity	Breusch-Pagan	36.387	0.000	Heteroskedasticity
Unit root test	Levin, Lin & Chu	-25.843	0.000	Stationarity
Unit root test	Im, Pesaran & Shin	-35.290	0.000	Stationarity
Unit root test	ADF-Fisher	1373.98	0.000	Stationarity
Unit root test	PP-Fisher	2499.22	0.000	Stationarity

Appendix 5. Cross-sectional specific green bond premium

Issuer	*ISIN*	*Premium*
Covanta Holding Corp	US22282EAG70	0.7814
DZ Bank AG Deutsche Zentral-Genossenschaftsbank Frankfurt Am Main	DE000DDA0NB1	0.7206
Vasakronan AB	NO0010815202	0.2039
Commerzbank AG	DE000CZ40NG4	0.1284
ABN AMRO Bank NV	XS1808739459	0.0854
National Australia Bank Ltd	XS1872032369	0.0457
BTS Group Holdings PCL	TH0221039504	0.0334
KBC Group NV	BE0002602804	0.0225
Southern Power Co	US843646AT75	0.0080
Bank of Qingdao Co Ltd	CND10000G4D6	0.0014
Bajaj Finance Ltd	INE296A07LL7	0.0012
Westpac Banking Corp	XS1722859532	-0.0017
Cypark Ref Sdn Bhd	MYBVJ1901961	-0.0027
Jiangsu Guoxin Investment Group Ltd	CND10001ZNB5	-0.0031
Bank of Gansu Co Ltd	CND10000HFT3	-0.0040
Vasakronan AB	SE0007666136	-0.0046
China Jushi Co Ltd	CND10002DYF8	-0.0048
HKCG Finance Ltd	HK0000375300	-0.0079
Commonwealth Bank of Australia	AU3CB0243657	-0.0111
Apple Inc	US037833CX61	-0.0121
Far Eastern New Century Corp	TW000B501576	-0.0126
OP Corporate Bank plc	XS1956022716	-0.0129
BTS Group Holdings PCL	TH0221032509	-0.0139
Westpac Banking Corp	AU3CB0237683	-0.0169
Swedbank AB	XS1711933033	-0.0224
ING Bank NV	XS1324217733	-0.0240

Castellum AB	SE0009161615	-0.0286
Vasakronan AB	SE0010830893	-0.0317
Svenska Handelsbanken AB	XS1848875172	-0.0389
BNP Paribas SA	XS1808338542	-0.0426
Skandinaviska Enskilda Banken AB	XS1567475303	-0.0433
Bank of Nanjing Co Ltd	CND10000H8W6	-0.0435
EDP Finance BV	XS1893621026	-0.0454
Intesa Sanpaolo SpA	XS1636000561	-0.0464
Intesa Sanpaolo SpA	XS2089368596	-0.0611
Apple Inc	US037833BU32	-0.0633
Hyundai Capital Services Inc	USY3815NAV39	-0.1098
Hyundai Capital Services Inc	US44920UAG31	-0.1101
Credit Agricole SA/London	FR0013385515	-0.1254
Engie SA	FR0013245859	-0.1327
BNP Paribas SA	FR0013405537	-0.2033
Bank of Communications Co Ltd	CND10000F3H0	-0.2949
Hebei Financial Leasing Co Ltd	CND10000J0M2	-0.3127
National Australia Bank Ltd/New York	US63254ABA51	-0.3413

Appendix 6. Robustness test results of model (2)

		Dependent variable: $\hat{\alpha}_i$					
		(a)	(b)	(c)	(d)	(e)	(f)
Homoskedasticity							
Breusch-Pagan	P-value	0.4108	0.4803	0.5004	0.6613	0.9037	0.6058
Normality							
Jarque-Bera	P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Multicollinearity	VIF						
Rating		1.7218	1.5856	1.5892	1.6349		
Sector		1.3018	1.1323	1.1452	1.1617	1.1200	1.3775
Currency				1.2401	1.6198	1.5710	
log(Issued Amount)		1.5925	1.5101	1.6576	1.7183	1.3656	1.3462
Maturity		1.4498					1.5266
External Review			1.1004		1.4374	1.3935	
Rating × External Review							1.5079

Note: Rating × External Review are slightly correlated, with a coefficient of 0.2

Correlation matrix of *Rating* and *External Review* variables

	Rating	External Review
Rating	1.0000	0.2025
External Review	0.2025	1.0000