UNIVERSITY OF HELSINKI

FACULTY OF AGRICULTURE AND FORESTRY

VALUATION EFFECTS OF CORPORATE GREEN BOND OFFERINGS

MASTER’S THESIS
HENRI SAKKI
BUSINESS ECONOMICS OF FORESTRY
OCTOBER 2019

HELSINGIN YLIOPISTO — HELSINGFORS UNIVERSITET — UNIVERSITY OF HELSINKI

Tiedekunta/Osasto — Fakultet/Sektion — Faculty	Laitos — Institution — Department
Maatalous- metsätieteellinen tiedekunta	Metsätieteiden laitos

Tekijä — Författare — Author
Henri Aleksi Evert Sakki

Työn nimi — Arbetets titel — Title
Green Bond -joukkovelkakirja-annin vaikutukset yrityksen osakehintaan

Oppiaine —Läroämne — Subject
Metsäekonomia ja markkinointi / Liiketaloudellinen metsäekonomia (LME)

Työn laji — Arbetets art — Level	Aika — Datum — Month and year	Sivumäärä — Sidoantal — Number of pages
Pro gradu -tutkielma	Lokakuu 2019	68 + 28

Tiivistelmä — Referat — Abstract

Tutkimuksen tavoitteena on selvittää Green Bond-joukkovelkakirjan myynnin vaikutus pörssilistatun yrityksen osakehinnan kehitykseen. Green Bondit ovat verrattain uusi rahoitusväline ja sijoituskohde, jonka hinnoittelua ja vaikutuksia yrityksen arvoon ja menestykseen on tutkittu vasta vähän. Green Bond -joukkovelkakirjan erottaa tavanomaisesta joukkovelkakirjasta ehto, että kerätty rahoitus on käytettävä hankkeisiin, joilla on positiivisia ympäristövaikutuksia. Tutkimus selvitti myös tarkemmin, miten eri tekijät, kuten joukkovelkakirja luottoluokitus, liikkeellelaskuvuosi ja maturiteettiluokka sekä liikkeellelaskijan toimiala, pörssilaistausmuoto ja sijainti, vaikuttavat mahdollisen hintavaikutuksen suuruuteen ja suuntaan. Tutkimus toteutettiin Indufor Oy:n toimeksiannosta.

Tutkimuksen aineisto kerättiin Bloomberg-tietokannasta OP:n lisenssillä sekä avoimista internetlähteistä. Tutkimuksessa muodostettiin kaksi aineistoa. Ensimmäinen aineisto koostui yritysten vuosina 2014–2019 julkaisemien Green Bondien tiedoista ja sisälsi 219 havaintoa. Toinen aineisto sisälsi 183 tavanomaisen joukkovelkakirjan tiedot. Jälkimmäinen aineisto muodostettiin etsimällä pareja Green Bondeille siten, että aineistot olisivat mahdollisimman samankaltaisia joukkovelkakirjojen ja yritysten ominaisuuksien perusteella, käyttäen Mahalanobis-etäisyyttä samankaltaisuuden määrittelyyn.

Tutkimus toteutettiin kvantitatiivisena tapahtumatutkimuksena. Liikkeellelaskijoiden päivittäisien päätöskurssien perusteella muodostettiin neljällä faktorimallilla odotetut pörssikurssit joukkovelkakirjan julkaisupäivälle (päivä, jolloin yritys ensimmäisen kerran julkaisi aikeensa joukkovelkakirja-annista) ja viidelle päivälle ennen ja jälkeen tämän päivän. Odotettujen arvojen ja toteutuneiden arvojen erotukset tulkittiin aiheutuneen joukkovelkakirjan julkaisusta. Näitä ylituottoja testattiin tilastollisin menetelmin tilastollisen merkittävyyden selvittämiseksi.

Aikaisemmista tutkimuksista poiketen tutkimus näyttää, että Green Bond -joukkovelkakirjan julkaisu aiheuttaa negatiivisen muutoksen liikkeelle laskevan yrityksen osakehinnassa. Liikkeelle laskevan yrityksen pörssikurssi laskee keskimäärin yhteensä -0.267 % välillä [-1,1] joukkovelkakirjan julkaisun päivämäärän ympärillä. Vastaavaa reaktiota ei löydetty tavanomaisen joukkovelkakirjan liikkeellelaskun julkaisun yhteydestä, joten on tulkittavissa, että tämä negatiivinen reaktio johtuu Green Bond-joukkovelkakirjan ominaisuuksista. Liikkeellelaskijan maantieteellisellä sijainnilla löydettiin olevan myös vaikutus hintamuutoksen suuruuteen. Kehittyneillä markkinoilla hinta pääsääntöisesti laskee julkaisun yhteydessä, kun taas kehittyvillä markkinoilla reaktio julkaisuun on päinvastainen. Vuosina 2014–2016 pörssikurssien löydettiin reagoivan voimakkaammin negatiivisesti julkaisuun, kuin vuosina 2017–2019. Rahoitusyhtiöiden julkaisemien Green Bondien löydettiin aiheuttavan tilastollisesti merkittävän negatiivisen pörssireaktion, kun taas muiden toimialojen yritysten julkaisuihin ei löydetty tilastollisesti merkittävää reaktiota. Huonon luottoluokituksen saaneiden Green Bondien löydettiin johtavan merkittävään pörssikurssin laskuun. Hyvän luottoluokituksen saaneiden Green Bondien julkaisu aiheutti lievemmän negatiivisen reaktion, joka ei ollut tilastollisesti yhtä merkittävä.

Tulokset ovat yllättävät, sillä ympäristöystävällisen yritystoiminnan on löydetty johtavan hyvään taloudelliseen menestykseen aikaisemmissa tutkimuksissa ja Green Bondin myynti voidaan tulkita sitoumukseksi ympäristöystävälliseen toimintaan. Tutkimuksen perusteella on perusteltua suorittaa syvempää tutkimusta Green Bond -joukkovelkakirjoista.

Avainsanat — Nyckelord — Keywords
Green Bond -joukkovelkakirja, Climate Bond -joukkovelkakirja, Ylituotto, Kumulatiivinen ylituotto, Tapahtumatutkimus, Arvonmuutos

Säilytyspaikka — Förvaringsställe — Where deposited

Muita tietoja — Övriga uppgifter — Further information

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Master's thesis	October 2019	68 + 28

Tiivistelmä — Referat — Abstract

The aim of the thesis is to study how green bond offerings affects the stock price of a listed company. Green bonds are a relatively new form of securities. Their valuation effects, pricing and other effects on company success have been studied only little so far. A green bond differs from a conventional bond only in that the proceeds must be used for projects that contribute to environmental objectives. The thesis also analyses how different characteristics, such as bond credit rating, maturity type or year of issuance, or company industry, listing status and domicile affect the possible valuation effect of Green Bond issuance. This thesis has been commissioned by Indufor Oy.

The data for the study were collected from the Bloomberg database with OP's license and open online sources. Two samples were formed. The first consisted of the details of 219 corporate green bonds issued during 2014–2019. The second sample consisted of the details of 183 conventional bonds. The second sample was formed by identifying nearest neighbour matches for green bonds using the Mahalanobis distance to determine the closest match, based on bond and issuer characteristics.

The study was conducted as a quantitative event study. Closing prices of the issuing companies' shares were used to determine regular returns using four different factor models. The difference between these regular and actual realized returns on the announcement date of the bonds (when a bond was first announced to the public) and ten days surrounding this date were interpreted as abnormal returns attributable to the announcement of the bond. These abnormal returns were tested for statistical significance.

Contrary to previous research, the current study finds that announcing a green bond offering results in a statistically significant, negative stock price reaction. The average cumulative abnormal return during [-1,1] surrounding the announcement date is found to be -0.267%. A similar result is not found from the sample of conventional bonds. This leads to the assumption that the abnormal returns are attributable to the "greenness" of a green bond. The geographic location of issuers was found to impact the size of the stock price reaction. Green bonds issued by companies in developed countries were not found to result in significant stock price reaction. Green bonds issued by companies in developing countries on the other hand were found to result in a positive stock price reaction. During 2014–2016 stock prices were found to react more strongly to green bond announcements than during 2017–2019. During both periods, reactions were negative, however. Green bonds issued by financial companies resulted in statistically significant negative stock price reaction, while there were no statistically significant reactions to green bonds issued in other industries. Green bonds with poor credit ratings resulted in steeper negative price reactions than investment-grade green bonds, which was also statistically more significant.

The results are surprising, since environmentally sustainable business has been connected to improved financial success in previous studies, and green bond issuance can be understood to signal commitment to environmentally sustainable performance. Based on the current study it is reasonable to conduct further studies on green bonds.

Avainsanat — Nyckelord — Keywords
Green bond, Climate bond, Abnormal returns, Cumulative abnormal returns, Event study, Valuation effect

Säilytyspaikka — Förvaringsställe — Where deposited

Muita tietoja — Övriga uppgifter — Further information

ACKNOWLEDGEMENTS

Firstly, I would like to thank my supervisor, Professor Lauri Valsta for feedback and guidance during this process. I would also like to express my gratitude to my other supervisor, Dr. Silja Siitonen from Indufor Oy, who gave me this extremely interesting topic to study.

In addition, special thanks to Leena Kassinen and Valtteri Komulainen at OP, who took the time and effort to organise access to the Bloomberg database for me, without which this study would not have been possible. I am grateful to my former colleague, MMM Asko Siintola, who guided me to be in contact with the right people.

Furthermore, I would like to thank my old friend, Roope Halonen, who taught me many valuable lessons in the use of R and was always available to check my code. Finally, I thank all those, who had the time to discuss my research and gave me ideas and inspiration during this journey.

Helsinki, October 19, 2019

Henri Sakki

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1 INTRODUCTION

1.1 Background of The Study

Green bonds (GB) (also referred to as climate bonds, CB) are a relatively new form of securities. The first issue to be considered generally as a green bond was issued in 2007 by the European Investment Bank (EIB). GBs began attracting wider attention in 2013, when the USD 1 billion green bond issued by the International Finance Corporation (IFC), was sold in an hour. (Climate Bonds Initiative n.d.a.)

Green bonds are defined by the Climate Bond Initiative (2018) as:

> “Any type of bond instrument where the proceeds will be exclusively applied to finance or re-finance, in part or in full, new and/or existing eligible Green Projects and which are aligned with the four core components of the Green Bond Principles (GBP).”

Projects are considered *green*, if they contribute to environmental objectives, which are for example climate change mitigation, climate change adaptation, biodiversity conservation and pollution prevention and control (International Capital Market Association 2018).

The four core components of the GBP which are mentioned above are:

1. Use of Proceeds;
2. Process for Project Evaluation and Selection;
3. Management of Proceeds; and
4. Reporting.

These components stipulate how proceeds must be used (e.g. what types of projects are eligible), reporting requirements regarding e.g. project selection and the projects’ sustainability objectives, how proceeds should be managed and other reporting requirements, including annual reporting on the use of proceeds. (International Capital Markets Association 2018).

Green investments are crucial for achieving the goals set in the Paris Agreement, i.e. preventing the average global temperature from increasing by 2 degrees Celsius compared to the pre-industrial level and striving towards keeping the temperature rise to a maximum of 1.5 degrees Celsius (UNFCCC 2015). Estimates note that tens of trillions of USD are required for infrastructure investments, to transition into a low-carbon economy. Most infrastructure investments globally are financed by debt, including bonds. (OECD 2017, p.13)

Investors are increasingly interested in green investments and on a wider scope, in socially responsible investments (SRI) (Levi and Newton 2016). This is also mirrored for example by the proposition of the European Commission in 2018 to create a classification system for sustainable investing. The EU technical expert group on sustainable financing published their Taxonomy Technical Report in June 2019, along with their Report on EU Green Bond Standard (EU-GBS). The taxonomy guides policy makers, investors and industry in supporting and investing in sustainable economic activities, while the EU-GBS provides recommendations for the European Commission to create a non-legislative Green Bond Standard. (EU Technical Expert Group on Sustainable Financing 2019a, EU Technical Expert Group on Sustainable Financing 2019b)

Green bonds have also been shown to have benefits for issuers, such as diversification of their investor base, pricing advantages and reputational benefits (Bachelet et al. 2019). Thus, it is compelling to study whether investors' appraisal of a company is affected differently by the issuance of a green bond, compared to a conventional bond. A wide expanse of publications is available on the effects of conventional bond issuance, as well as the issuance of other financial products on stock price. This literature offers methods for investigating the question at hand, while also providing results to which the results of this study may be mirrored. This literature will be discussed in section 1.4.

This thesis has been commissioned by Indufor Oy. The company has a keen interest in the green bond market and on the effects that green bonds may have on a company's stock price, because it has recently attained the status of Approved Verifier under the Climate Bonds Standard.

1.2 Green Bonds

Green bonds have been gaining increasing popularity. Since their introduction in 2007, the total global issuance of labelled[1] GBs has risen to over USD 490 billion in 2018 (Climate Bonds Initiative database 2018). On average, issuance has grown by over 90 % year-on-year between 2007 and 2017. (Climate Bonds Initiative n.d.b.) However, in comparison to the total global bond market, the GB market is vanishingly small, with the former boasting USD 24 557 billion in outstanding debt alone in Q1/2018 (Bank for International Settlement 2018). Climate Bonds Initiative (2018) has estimated that in total, climate-aligned bonds[2] cover USD 1.45 trillion of the current bond market. For many years GBs did not attract wider attention or popularity among issuers. Growth of the market began increasing only in 2013, and a period of extremely rapid growth was seen in 2016 and 2017 (Figure 1).

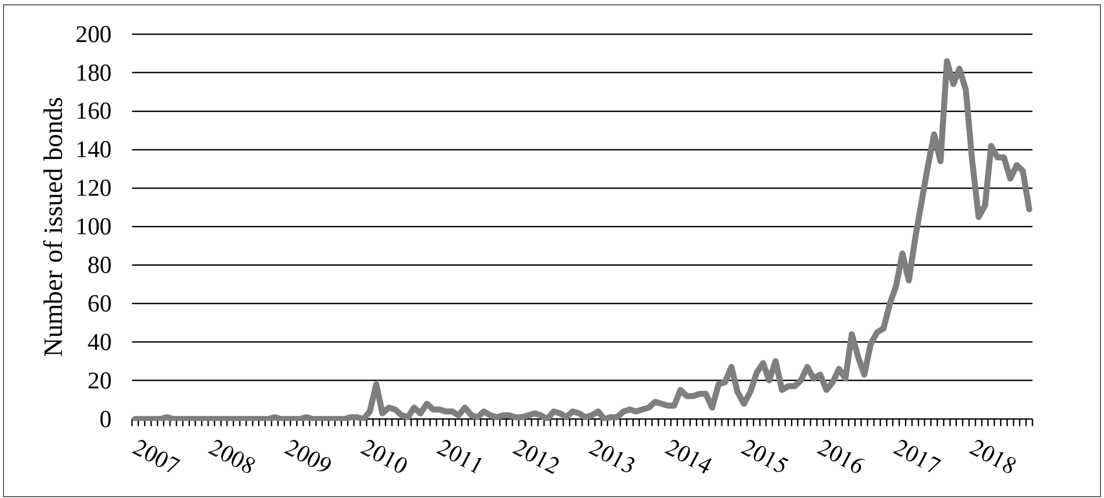

Figure 1. Number of GBs issued by month (as of 10/2018). Source: Climate Bonds Initiative database 2018.

The sharp rise in 2016 is partly attributable to Chinese green bonds entering the market (OECD 2017, p.24). The figures for 2018 sourced from the Climate Bonds Initiative

[1] Labelled green bonds are ones which have been labelled "green" by the issuer, but are not necessarily certified, whereas unlabelled green bonds have not been labelled nor certified as being green but are connected to projects which produce environmental benefits (UNDP 2017).
[2] Climate-aligned bonds are unlabelled green bonds, e.g. those issued by companies whose revenues derive in full or nearly so from actions that are aligned with the Climate Bonds Standard and could thus be certified under the Standard

database (2018) indicate a deceleration in the growth of the market, when measured in the number of issued GBs. However, this is due to not all 2018 issuance being yet included in the dataset. More recent figures for the issuance in 2018 indicate a slight growth from 2017, reaching approximately EUR 167 million (Climate Bonds Initiative n.d.c). Climate Bonds Initiative (n.d.d.) is estimating issuance in 2019 to reach USD 250 billion.

By the end of October 2018, a total of 3 793 GBs had been issued globally (Climate Bonds Initiative database 2018). Asset-backed securities are so far clearly the most common type of GB (Figure 2).

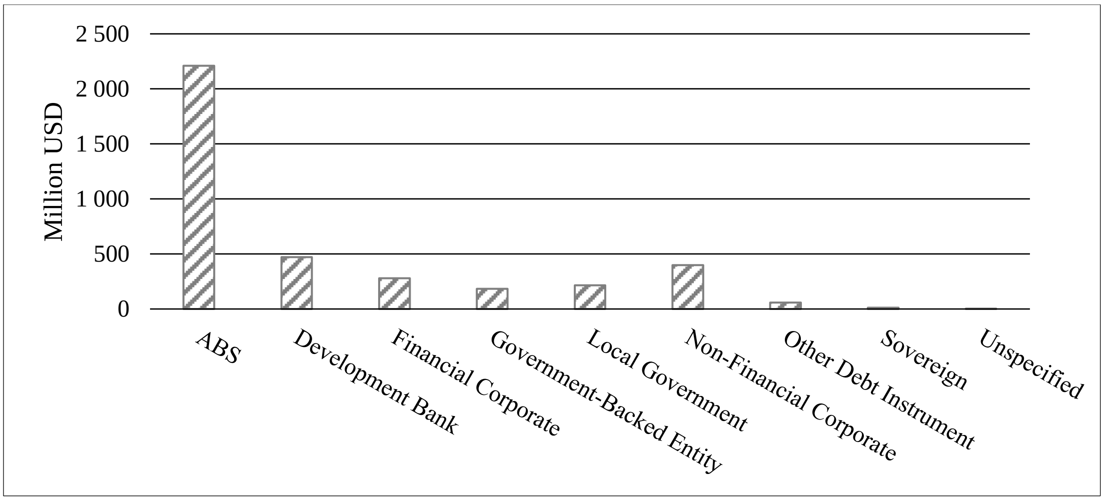

Figure 2. Total number of GBs issued by type (as of 10/2018). Source: Climate Bonds Initiative database 2018.

This is in part explained by the extremely high frequency at which Fannie May has issued ABS GBs in the past few years. When measured in total volume of issuance (in USD), Development bank GBs have been the most common type of GB so far, followed by non-financial and financial corporate GBs (Figure 3).

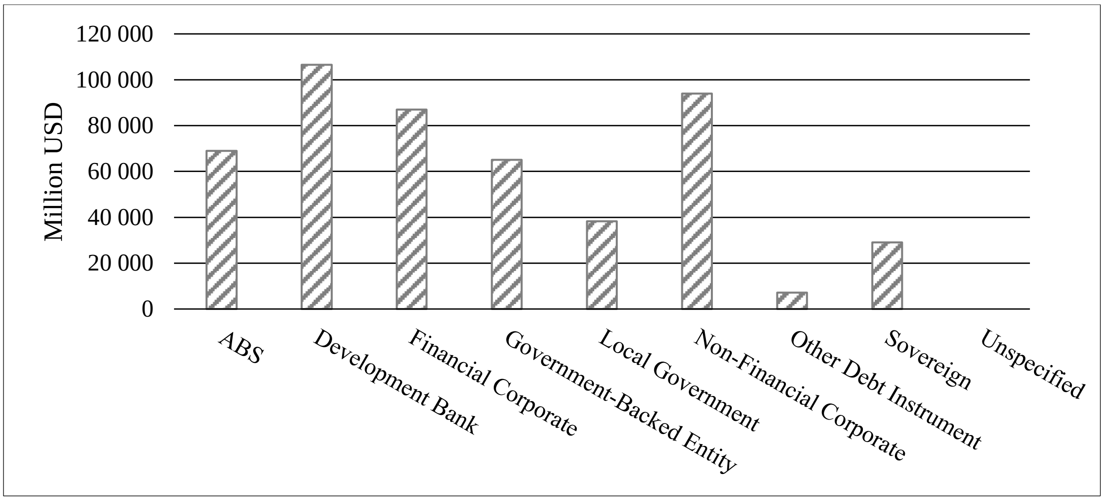

Figure 3. Total nominal volume of issued GBs by type (as of 10/2018). Source: Climate Bonds Initiative database 2018.

Corporate GB issuance has been largest in China, followed by the US and France. The largest corporate GBs on average have however been issued in the Netherlands, followed by Spain and Germany (Figure 4).

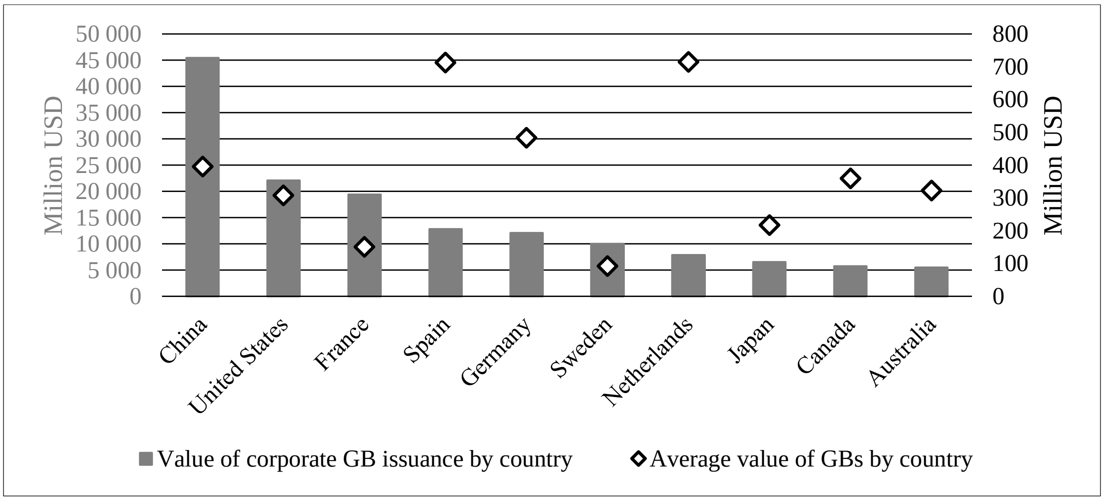

Figure 4. Total value and average size of corporate GB issuance by country in ten largest countries (as of 10/2018) (bars on the left axis, diamonds on the right). Source: Climate Bonds Initiative database 2018.

Corporate GB issuance has been most frequent in France, followed by China and Sweden (Figure 5).

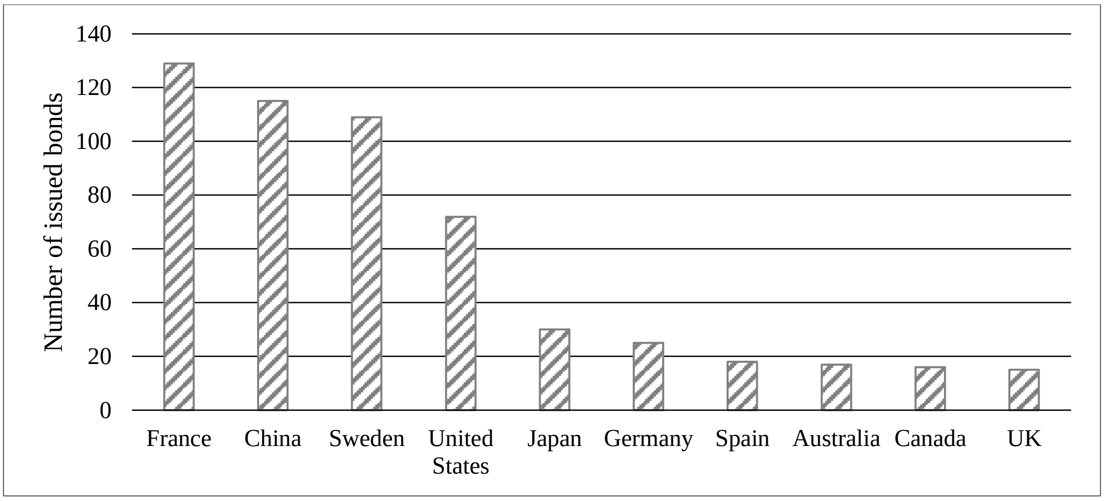

Figure 5. Total count of issued corporate GBs by country of origin from ten largest countries (as of 10/2018). Source: Climate Bonds Initiative database 2018.

The most common currencies in which corporate GBs have been issued are the Euro (EUR), United Stated Dollar (USD) and Swedish Krona (SEK) consecutively, (Figure 6), which is to be expected as Eurozone countries, Sweden and the US are most common origins of GB issuance (Climate Bonds Initiative database 2018).

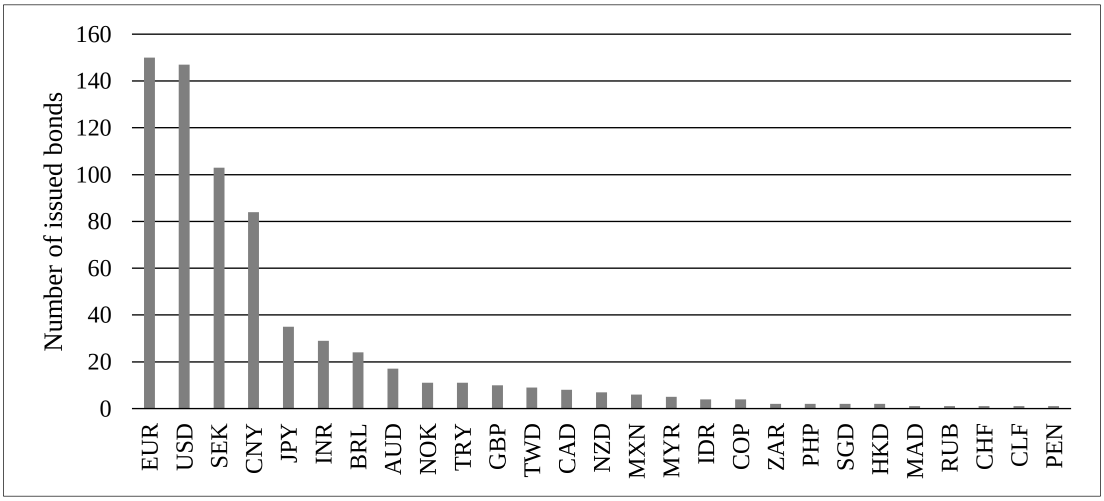

Figure 6. Number of corporate GBs by currency of offerings (as of 10/2018). Source: Climate Bonds Initiative database 2018.

The Climate Bonds Initiative database (2018) categorises the use of proceeds of GBs into eight categories (*energy*, *buildings*, *transport*, *water*, *waste*, *nature-based assets*, *industry* and *ICT*), and more than one category can be assigned to any given bond. The most common use of proceeds among the corporate bonds in the database by

November 2018 is *energy*, followed by *transport* and *buildings*, while none of the corporate bonds so far have been categorised under *nature-based assets* (Figure 7).

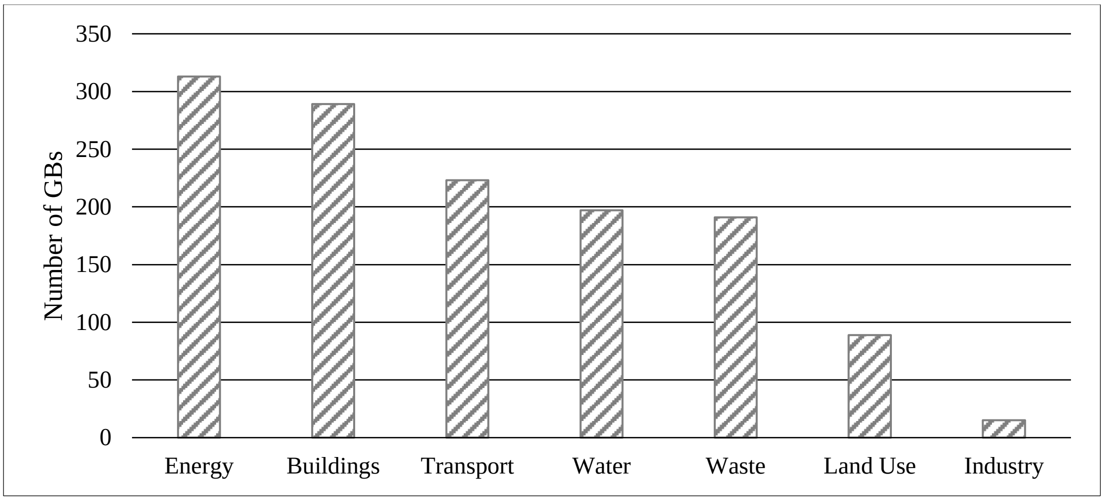

Figure 7. Use of proceeds of corporate GBs (as of 10/2018). Source: Climate Bonds Initiative database 2018.

1.3 Aim of the study

This study focuses on researching the effect that issuing a green bond has on the share price of a publicly listed company. By analysing this effect, this study aims to uncover how equity investors value green bond issuance. This is an interesting question, as green bond issuance can be seen to have a different informational value compared to the issuance of a conventional vanilla bond, and thus investors may value them differently. Green bonds may be seen to provide investors with information of environmental commitments or performance of the issuing company.

The central research question of this study is:

- *Does the announcement of a green bond offering result in a significant stock price reaction? Does this reaction differ from that of a conventional non-green bond?*

Supporting research question are:

- *Is there a change over time in the size of the possible reaction?*
- *Does the possible stock price reaction to green bond issuance differ between financial sector companies and other industries?*

- *Is there a difference in the possible stock price reaction depending on the region where the issuer is domiciled?*
- *Does the credit rating of a green bond affect the size of the possible stock price reaction?*
- *Does the possible stock price reaction differ depending on the maturity type of the bonds?*

Two previous studies (Flammer 2018 and Tang and Zhang 2018) have already studied the effects of GB issuance on company valuation, following a similar methodology to that which is adopted in this study. This study deviates from these publications in that it also analyses, whether there is variability in the valuation effects of GB issuance over time, and across different markets.

Guenster et al. (2011) studied the effect of corporate eco-efficiency and the integration of corporate social responsibility (CSR) into a company's operations, and how surpassing compliance requirements can affect the company's performance and valuation. Green bonds can be viewed as a proxy for implementing eco-efficiency. Guenster et al. (2011) listed three possible perspectives that indicate why investors could assume GB issuing companies to perform better in the long term compared to conventional bond issuing companies, and thus why GB issuance would be expected to affect company valuation differently to conventional bond issuance:

1. a management perspective: CSR can act as a proxy for management skills. This in turn can help a company mitigate and adapt to climate risks, resulting in lower overall risk and thus in lower cost of capital;
2. a reputational perspective: the company image is improved when environmental commitments are made, thus enabling stronger performance; and
3. the innovation perspective: CSR may reflect innovativeness and can thus lead to economic advantages.

Flammer (2018) also noted, that evidence exists to suggest that a company's environmental responsibility correlates positively with stock market performance.

Alternatively, differing valuation effects may result from average issuer characteristics (e.g. better credit ratings on average, etc.) – for example, Karpf and Mandel (2018) concluded, that differences in the yields of GBs and conventional bonds on the US municipal bonds market can be mostly explained by the differences between the structure and fundamentals of GBs and conventional bonds (e.g. GB issuers had, on average, higher credit-worthiness).

The effects of bond ratings will also be studied. Bond ratings have a significant role in mitigating information asymmetries, which can affect stock prices during bond offerings (Burnie and Ogden 1996). This study will compare the effects of bond ratings on the valuation of stocks of green bond issuing companies and conventional bond issuing companies.

1.4 Previous Studies

1.4.1 Studies on valuation effects of green bond issuance on stock performance

A study by Flammer (2018) had a very similar aim as this thesis. Flammer (2018) investigated the effects of green bond offerings on stock price both on the short- and long-term, as well as on environmental performance of the issuing company, increases in green innovation and the changes in ownership structure. Thus, the study is slightly different in its scope.

In addition to Flammer (2018), Tang and Zhang (2018) have investigated whether green bond issuance benefits stockholders. That study investigated four possible hypothesis, which were identified as: (1) Green benefits; (2a) Investor attention; (2b) Fundamental; and (2c) Financing cost. The first hypothesis predicted that stock prices of green bond issuers will rise after the announcement of the green bond offering. This is the same hypothesis that this current thesis will be investigating. The latter three hypothesis investigated possible explanations for the predicted market reaction. The hypothesis 2a, b, and c predicted that the price increase of the issuing company's stock is either due to:

- increased media coverage because to the offering, which increases interest towards the company,
- to the offering revealing information to investors about valuable investment opportunities, and emphasising the company's environmental friendliness, which is believed to help the company survive in the long run, or

- to green bonds being a method of gaining financing at a lower cost than through conventional bonds. (Tang and Zhang 2018)

These studies are the only two found that investigate the valuation effects of green bonds on common stocks. Other applicable literature had discussed for example the yield spread of green bonds (see Karpf and Mandel 2018), as well as the valuation effects of other events on stocks, such as for example the issuance of conventional and convertible bonds, and seasoned equity offerings, which will be reviewed next.

1.4.2 Studies on the valuation effects of corporate bond offerings

A working paper by Fungacova et al. (2015) studied the stock market reactions to bond issuance and loan announcements. The paper summarised that extensive previous research (e.g. Mikkelson and Partch 1986; Eckbo 1986; Spiess and Affleck-Graves 1999) has found the market reactions to announcements on loans are positive, while reactions to announcements on bond issuance are insignificant or negative. The results of Fungacova et al. (2015) however showed that both tested debt instruments (loans and bonds) resulted in positive and significant cumulative abnormal returns (CAR), contrary to results they reviewed from previous literature. The CARs for bonds were found to be still lesser than those of loans.

Mikkelson and Partch (1986) studied the effects of different security offerings on stock price. Their analysis showed, that announcements of common stock and convertible bond offerings decrease share price, as these are understood to signal overvaluation of the company's stock to investors; Managers may either knowingly attempt to benefit from overvaluation of the stock price, or perceptions of the correct stock price differ between investors and managers. The study also investigated the effect of bond offerings on stock price and found that these conventional bond offering announcements cause a statistically significant, yet small, negative effect on stock price. (Mikkelson and Partch 1986)

Burnie and Ogden (1996) included the hypothesis of information asymmetry in their study as well and evaluated its effects on stock price in the case of bond offerings. Burnie and Ogden (1996) specifically studied the valuation effects on initial bond offerings, whereas Mikkelson and Partch (1986) did not discern between seasoned and initial offerings. Burnie and Ogden (1996) also hypothesised, that if information asymmetries are eliminated by an efficient market mechanism, the effects of a bond offering on stock price should be negligible. One such mechanism presented is obtaining a bond rating, which allows a third party to verify to investors the quality of a bond.

Shyam-Sunder (1991) concluded that bond ratings do not have a significant effect on the size of the market reaction to a bond offering announcement, and that overall, conventional bond offering announcements do not cause a significant stock market reaction.

Eckbo (1986) corroborated the findings of Mikkelson and Partch (1986). The study concluded that conventional bond offerings have a "non-positive" effect on stock price of the issuing company. The study found, that convertible bond offerings have a negative effect on stock price. In addition, the study also analysed the significance of bond offering characteristics and the company's performance on the stock price. The amount of debt, the increase in the company's debt-related tax shield, the rating of the bond, the abnormal change in the issuing company's earnings in the period immediately following the offering or the offering method were not found to have any statistically significant relationship with the valuation effect of bond offerings. (Eckbo 1986)

Spiess and Affleck-Graves (1999) studied the long-run performance of stock prices after bond offerings and found a statistically significant underperformance in the years following an offering. The study likened the long-run underperformance to that which has been documented in companies that have issued seasoned equity (Spiess and Affleck-Graves 1999).

Interestingly, Flammer (2018) found evidence, that GB issuance results in significant positive abnormal stock returns – this is in line with the findings of Fungacova et al. (2015). Tang and Zhang (2018) also reached a similar result to that of Flammer's (2018), by concluding that the stock price of green bond issuers does increase after the announcement of the green bond offering. However, this is contrary to most other studies researching the valuation effect of conventional bond issuance.

Myers (1984) considered two theories of corporate financing decisions and discussed the strengths and weaknesses on these theories, their application and non-applicability. Myers (1984) reached a conclusion, that the *pecking order hypothesis* can explain the valuation effects of bond offerings on common stocks, while recognizing information asymmetries. The presented theory suggests, that stock price should not fall when conventional bond offerings are made, and that stock price will fall in the event of a seasoned equity offering. However, a stringency on this theory is, that the debt is default-free. Thus, the abovementioned studies neither manage to disprove or prove this theory definitively.

1.4.3 Studies on green bond pricing and premia

Karpf and Mandel (2018) studied the pricing of green bonds on the US municipal bond market. While their study did not consider the effects of a green bond issuance on share price, it investigated if investors value green bonds differently compared to conventional bonds (Karpf and Mandel 2018). The research offers valuable insight into the values of investors; if green bonds warrant a premium (negative or positive), it is thus reasonable to expect that this premium is reflected in share price as well. However, issuers in this study were public, not commercial, entities. As such, the results of the study are not comparable to the results of the current research, but both contribute to the study of green bonds and how investors value them.

Green bonds have been found to allow a lower cost of capital to issuers, than conventional bonds do (Karpf and Mandel 2018). However, it has also been found that the differences in return rates between green bonds and conventional bonds can be explained by issuer characteristics, rather than the fact that green bonds are *green* (Karpf and Mandel 2018). This is the same finding that Tang and Zhang (2018) documented in their study.

After studying the yield spreads of green bonds and conventional bonds issued by commercial entities Tang and Zhang (2018) concluded, that when compared to similar firms that have issued conventional bonds, green bonds have pricing benefits for their issuers. However, when comparing conventional and green bonds issued by the same firm, pricing benefits are non-existent. These results are somewhat unreliable, as the sample size is quite small (41 observations), and as such the test may not have sufficient power to warrant any strong conclusions on the matter. (Tang and Zhang 2018)

1.4.4 Studies on the effects of Corporate Social Responsibility and environmental performance on returns and stock performance

Numerous publication (e.g. Murphy 2002, Guenster et al. 2011, Nakai et al. 2013, Murguia and Lence 2014) have undertaken the task to uncover how markets react to Corporate Social Responsibility (CSR) and how it affects a company's profitability and stock price.

Guenster et al. (2011) studied the impacts of a company's eco-efficiency on the profitability and valuation of a company. Similarly to Flammer (2018), Guenster et al. (2011) utilised ROA as the profitability metric and Tobin's Q as the measure for company valuation. "Eco-efficiency" was defined as a firm's environmental governance actions that surpass those required by basic legislation and regulations, and as a company's ability to "create more value with fewer environmental resources resulting in less environmental impact". The findings indicated, that eco-efficiency does have a positive impact on a company's profitability and valuation. (Guenster et at. 2011)

Murphy (2002) analysed results of previous research and summarised that there is a clear correlation between environmental performance and the profitability of companies. Companies that have been found to exceed the demands of environmental regulations, have achieved superior stock price development compared to the S&P 500. Companies that have fared worse in environmental performance have been found to also realise poorer stock returns. (Murphy 2002)

Murguia and Lence (2015) found that investors react to a company's changing ranking on *Newsweek's* "Global 100 Green Ranking". The results indicate that moving one position closer to the top of the ranking increases a company's valuation on average by USD 11 million (Murguia and Lence 2015). Nakai et al. (2013) found that inclusion of a company on Morningstar's Socially Responsible Investment Index results in significant, positive cumulative abnormal stock returns, while exclusion from the index does not result in a corresponding negative reaction. The study also found, that in the earlier years of the study period of 2003–2010, inclusion in the Index resulted in a negative stock price reaction, while during latter years the reaction was positive (Nakai et al. 2013).

Klassen and Mclaughlin (1996) found that strong environmental performance results in significant positive abnormal returns, while negative abnormal returns were reported for companies with weak environmental performance. The study used the receipt of environmental performance awards as an indicator for good environmental performance. Cross-sectional analysis also revealed, that the positive effect was stronger for first-time winners of an award and weaker for companies operating in so-called "dirty industries[3]". The study attributed this weaker reaction in "dirty industries" to possible market scepticism, e.g. investors do not believe that the company can be a strong performer environmentally, due to the reputation of the industry in general (Klassen and Mclaughlin 1996.) Correspondingly, Elliott et al. (2014) found that CSR activities in general result in positive valuation effects.

This ties in with the findings of green bond issuance improving stock performance; Green bond offerings convey information to the market about a company's environmental considerations. As investors value environmental considerations in business, this is reflected in the stock price.

[3] Industries which are associated with high emissions or causing environmental degradation (Klassen and Mclaughlin 1996).

2 APPROACH AND THEORETICAL FRAMEWORK

2.1 Approach of the study

An event study is a well-established method for studying the impacts of bond offerings on stock price (Bowman 1983, Eckbo 1986, Mikkelson and Partch 1986, Flammer 2018, Tang and Zhang 2018). The event study methodology in finance is based on the assumption that stock markets are efficient in reflecting new information into prices (Bodie et al. 2005, p. 381). As the name indicates, an event study attempts to observe the impacts of a certain event on the dependent variable, in this case the security's price, for example the effect an announcement of a dividend payment has on the company's stock price (Bowman 1983). There are four types of event studies: i.) information content, ii.) market efficiency, iii.) model evaluation, and iv.) metric explanation (Bowman 1983). Under this classification the current research is an information content study, as this type focuses on analysing security price performance prior to and during the event. This differs to a market efficiency study in that such a studies also include analysis of price performance following an event. (Bowman 1983)

There are variations for the appropriate structure and variables for an event study. Using a market model approach for estimating abnormal returns has been found to be a well-specified approach, when the sample securities are not unrepresentatively exposed to extra-market factors, and when the event dates are not clustered (Strong 1992). Extra-market factors are not expected to cause issues. This is due to the fact that the events being analysed are company-specific and have occurred over time, instead of being a set overarching of events affecting all companies simultaneously. This results in heterogenous exogenous and non-parallel influences, which reduces potential systematic error (Bowman 1983).

Following the methodologies of previous studies (Eckbo 1986, Mikkelson and Partch 1986, Flammer 2018) and the review by Strong (1992), this thesis will utilise the market model approach to calculate the abnormal returns of green bond issuing companies. The market model is a statistical method which presents the linear relationship between a company's returns and the market return (Jensen 1975). The theory behind this models lies within the Arbitrage Pricing Theory described in section 2.2.4.

In addition to the market model, the Fama-French three-factor model (FF3) will be used to conduct a second analysis of the abnormal returns. This model has also been used in previous studies by e.g. Tang and Zhang (2018). The purpose of this parallel analysis is to verify the robustness of results obtained from the analysis with the market model.

2.2 Theoretical Framework

Corporate finance and investment theory provide the theoretical framework for this study. As mentioned in the previous chapter, this thesis will rely on an event study methodology to uncover any unexpected performance in the stocks of GB issuing companies. An event study is based on some key finance theories and econometric models as follows.

2.2.1 Stock valuation

Understanding stock valuation is essential in researching stock prices. The most common method for valuing common stocks is the discounted-cash-flow (DCF) model. The discount model understands a stock’s price to be the net present value (NPV) of all future dividend payments the stock’s holder is entitled to, discounted with the shareholder’s expected or required return. The discount model can be presented as:

$$P_0 = \sum_{t=1}^{\infty} \frac{D_t}{(1+r)^t}$$

Where:
P_0 = Stock price today
D_t = Dividends in year t
r = discount rate, e.g. the expected return (%) of the stock
t = time in years
(Brealey et al. 2011, p. 78–80)

There are obvious problems with the model, as it requires knowledge of *all* future dividend payments. This is naturally impossible, as a company is not legally bound to even pay dividends. Thus, the dividends are usually estimated or forecasted. (Brealey et al. 2011, p. 80–81)

If stock pricing is expected to follow the DCF model, changes in stock price should occur only through either changes in dividend expectations or through changes in the return requirements of investors.

2.2.2 Modern Portfolio Theory

Modern portfolio theory (MPT) was established by Harry Markowitz (1952, Bodie et al. p. 281, 2005). MPT theorizes how investors can construct so-called *efficient portfolios*, to gain highest possible returns with the lowest possible risk. According to the theory, this is achieved by constructing a portfolio which is set on the *efficient frontier*, a graphical depiction of all possible portfolio options, with the outermost curve indicating the efficient frontier. (Figure 8) (Bodie et al. 2005, p. 224–241)

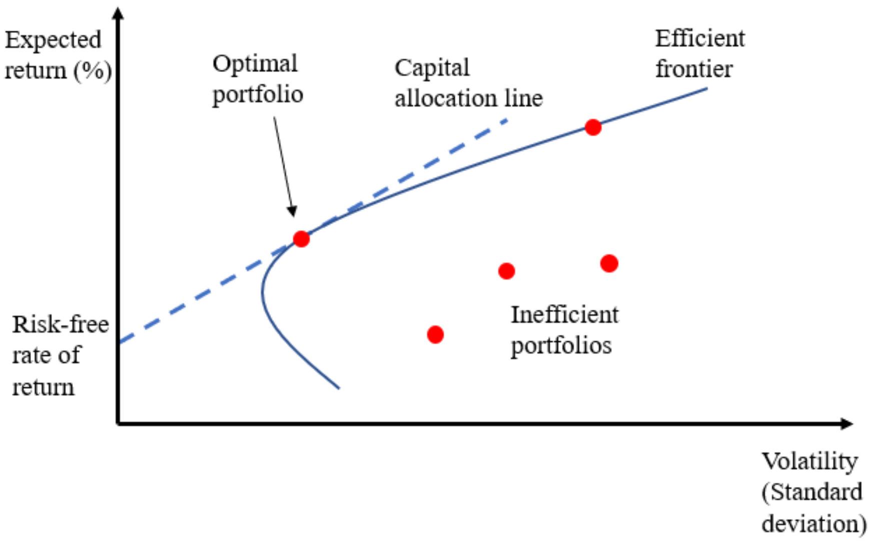

Figure 8. The Efficient Frontier. Adapted from: Bodie et al. (2005, p. 241 – 244).

A portfolio on the efficient frontier offers the best return for each level of risk; this is seen as the only sensible option for investors, as being positioned below the frontier would mean exposing oneself to higher risk with a sub-par return and thus not efficiently taking advantage of the market. (Bodie et al. 2005, p. 224–241)

2.2.3 The Capital Asset Pricing Model (CAPM)

The CAPM is a central model in modern financial economics and supplements the MPT. It was developed by William Sharpe, John Lintner and Jan Mossin between 1964–1966. The model makes several assumptions about security markets, which do not hold true in real life. Regardless of this the model is widely used, as it is sufficiently accurate for decision making. The *beta coefficient* (beta) of a security indicates how a security's returns move in relation to the *market return* (the return of a market portfolio, i.e. the aggregated return of all securities and assets in an economy), i.e. it indicates the volatility of a security in relation to the whole market, or so-called *systematic risk* (Table 1). (Bodie et al. p. 281–284, 2005)

Table 1. Interpreting beta. Source: Bodie et al. p. 283, 2005

Value of beta	Interpretation
$\beta < -1$	The stock's returns are negatively correlated with the market return and move more pronouncedly, i.e. if the market return increases 10%, the stock's return will decrease by e.g. 20%
$-1 < \beta < 0$	The stock's returns are negatively correlated with the market return, but move less pronouncedly, i.e. if the market return increases 20%, the stock's return will decrease by e.g. 10%
$\beta = 0$	The stock's returns are not correlated with the market return.
$0 < \beta < 1$	The stock's returns are positively correlated with the market return, but move less pronouncedly, i.e. if the market return increases 20%, the stock's return will increase by e.g. 10%
$\beta = 1$	The stock's returns mimic the movements of the market return, i.e. if the market return increases 10%, so does the stock's return.
$\beta > 1$	The stock's returns are positively correlated with the market return, and move more pronouncedly, i.e. if the market return increases 10%, the stock's return will increase by e.g. 20%

Another coefficient estimated with the CAPM model is the alpha coefficient. It indicates a security's past tendency to "beat" the market return; if the alpha is positive, the security in question has returned a higher return than the market over the period for which the alpha has been calculated. (Bodie et al. p. 281–284, 2005)

The most familiar expression of the CAPM is the expected return-beta relationship, which can be expressed mathematically as:

$$E(r_i) = r_f + \beta_i(r_m - r_f)$$

Where

$E(r_i)$ = The expected return of security i

r_m = The realized market return

r_f = The risk-free return (usually the interest of a 10-year government bond)

β_i = The beta of security i

(Bodie, et al. p. 282-292, 2005)

Note that the CAPM does not include an alpha coefficient in this form, as it assumes it to be equal to zero, as it should be if markets price securities fairly. (Bodie, et al. p. 327–328, 2005).

However, as noted in section 3.2.2, the CAPM will not be used for modelling abnormal return in this study. Instead, the market model will be used. However, the Fama-French three-factor model is a variation of the CAPM and will be used for robustness checks.

2.2.4 Arbitrage Pricing Theory (APT)

Arbitrage refers to opportunities in the market to earn risk-free profits due to sub-optimal pricing (Bodie, et al. p. 343–344, 2005). Such an opportunity would arise for example when the same security is traded simultaneously on two exchanges, but at different prices. A key concept is the *Law of One Price*, which states, that if two assets are equal in all relevant ways, they should have the same price (Bodie, et al. p. 349, 2005). The APT resembles CAPM in that they both predict a link between expected returns and risk (the Security Market Line, SML), but in fact differ quite much. APT was developed by Stephen Ross in 1976, and relies on three key assumptions:

1. A factor model can describe security return;
2. Enough securities exist for unsystematic risk to be diversified away; and
3. Arbitrage opportunities do not persist in well-functioning markets.

The theory states, that if an arbitrage opportunity is discovered on a market, this opportunity will be eliminated by investors pursuing this opportunity with high amounts of investments, until the pressure created by this new demand forces prices to shift back to an equilibrium. (Bodie et al. p. 348–349, 2005)

2.2.5 Market Efficiency and Information Asymmetry

If a market is efficient, all available information is reflected in stock prices as soon as the information is made available. This concept is referred to as the Efficient Market Hypothesis (EMH) (Bodie, et al. p. 369–371, 2005). Efficient markets are a central concept in the APT, as inefficient markets do not price new information into securities, and arbitrage opportunities are thus commonly created (Knüpfer and Puttonen, p. 169-171, 2018). Market efficiency can be divided into three levels (Table 2).

Table 2. Levels of Market Efficiency. Source: Knüpfer and Puttonen, p. 172.

Level of efficiency	Requirements
Weak-form	Stock prices reflect all historical pricing information.
Semi strong-form	Stock prices reflect all information about historical returns and all publicly available information
Strong-form	Stock prices reflect all historical pricing information, all other publicly available information, as well as all *insider information*[4].

The concept of market efficiency is important when studying the performance of stocks, because if markets are inefficient, stock prices cannot be expected to reflect all relevant information immediately. An event study relies on markets pricing new information into stocks instantly.

As outlined in section 1.4.2, finance studies have researched and identified the effects of information asymmetries on equity valuation. This is a key consideration in this

[4] Information that is available within the company but has not been made available for the public. Such information may be for example plans to conduct a hostile take-over of a competing company.

thesis as well, as the issuance of green bonds is hypothesised to signal different information to investors, versus conventional bonds offerings.

3 DATA AND METHODS

3.1 Data

The data utilised in this thesis are time series data and cross-sectional data. Time series data are the daily returns of the selected stocks and daily market index values. These data are obtained from the Bloomberg database (2019) and Yahoo Finance (2019). Cross-sectional data used to conduct further analysis on the time series data are obtained from the Bloomberg database (2019). These data include:

- Descriptive information about the bonds under inspection
    - Coupon rate;
    - Announcement date of the offering;
    - Date of the offering and maturity;
    - Collateral and maturity type;
    - Size (in EUR, USD or SEK)
    - Credit rating; and
- Descriptive information about the bond issuers
    - Industry denoted by the Bloomberg Industry Classification System (BICS);
    - Country where the company is domiciled;
    - Credit rating

The study will focus on bonds which have been priced in Euro (EUR), US Dollar (USD) and Swedish Krona (SEK) currencies, as these are the three most common currencies in which GBs have been issued (Climate Bonds Initiative database 2018). Only bonds announced on or since 1.1.2014 were selected into the dataset, as the ICMA's Green Bond Principles (GBP) were published in January 2014 (International Capital Market Association 2017). This was set as the cut-off point, because the GBP was the first attempt to begin standardizing the green bond market and the concept of green bonds. Thus, it is assumed that bonds released following the publication are better suited for analysis, as they are likely to be more homogenous group than those bonds released prior to the publication of the GBP. The dataset includes GBs announced until 17.6.2019.

The total number of corporate green bonds in the dataset is 363. Of this total, 123 bonds were issued by financial sector companies and 240 by companies operating in a range of other industries. The data includes 211 unique issuers of GBs. Table 3 further describes the dataset. Standard deviation is provided in parentheses where applicable.

Table 3. Descriptive statistics of the green bond dataset[5].

	All	Private	Public[6]	Final dataset for analysis
Number of green bonds	363	117	246	219
Number of unique issuers	211	64	147	131
Total issuance (billion EUR)	213.4	63.5	149.9	137.9
Average size (million EUR)	587.8	542.7	609.2	629.9
SD	(714.9)	(750.6)	(699.3)	(735.8)
Average coupon (%)	2.53	2.23	2.68	2.57
SD	(2.1)	(1.8)	(2.2)	(2.14)
Coupon range (%)	0–15.5	0–7.5	0–15.5	0–15.5
Average maturity (years)[7]	10.8	8.73	11.73	12.26
SD	(52.8)	(6.1)	(64.3)	(68.1)
Maturity range (years)[8]	1–1000 6 perpetual	2–30.5 1 perpetual	1–1000 5 perpetual	1–1000 5 perpetual
S&P Credit rating (median)	A- (244 rated)	A- (57 rated)	A- (187 rated)	A- (166 rated)
Maturity type (number)[9]				
At maturity	225	72	153	136

[5] Standard deviation is provided in parentheses where appropriate
[6] Public includes also those issuers, which are not themselves listed, but either their direct parent company or ultimate parent company is listed.
[7] Excluding perpetual bonds
[8] Excluding perpetual bonds
[9] Maturity types are explained in Annex 1

Callable	124	38	86	77
Perpetual	6	1	5	5
Sinkable	7	6	1	0
Callable/sinkable	1	0	1	1
Collateral type (no.)[10]				
Sr unsecured	222	68	154	138
Company grtd	74	16	58	50
Sr secured	29	18	11	8
1st mortgage	12	0	12	12
Pfandbriefe	8	8	0	0
Covered	7	3	4	4
Jr subordinated	5	1	4	4
Genl ref mort	2	0	2	2
Secured	1	1	0	0
Govt guaranteed	1	0	1	1
Unsecured	1	1	0	0
Bank guaranteed	1	1	0	0

The final dataset of GBs used in the analysis is slightly smaller than the number of GBs issued by publicly listed companies due to issues with stock price data. Stock price data was not available for some companies for the necessary period prior to the announcement of the GB. For some companies, stock price data existed on days when it should not have existed, such as price data for July 4th for a stock listed in the US. In such cases, it was deemed that the observation should be excluded from the dataset, as to avoid any issues with the analysis. In total, 12 bonds were excluded from the dataset due to uncertainties. This also resulted in eight control group observations to be discarded. The final dataset used in the regression models consisted of 219 companies and their stock price data.

The average size of the bonds in the final dataset is approximately EUR 20 million larger than in the set of all green bonds issued by public companies. The average

[10] Collateral types are explained in Annex 1

coupon is smaller by 0.11% and maturity is longer by slightly over 0.5 years. Other characteristics of the final dataset follow the full set of green bonds issued by public companies quite closely.

In addition to GBs, a large dataset of corporate non-green bonds was obtained. All bonds announced between 1.1.2014–26.6.2019 in EUR, SEK and USD were selected for companies operating in all BICS industries except “Banks”, “Diversified banks”, “Financial services”, “Consumer finance” and “Property & Causality Insurance”. This group of five industries shall be referred to as “financial institutions” (FI). Data on all FI non-green bonds were not downloaded due to the vast number of non-green bonds issued during the period of interest and the downloading limits of Bloomberg. These bonds were instead filtered further within the database prior to downloading, to limit the amount of data. Non-green FI bonds were filtered so that only bonds which matched FI GBs based on country, industry, the initial credit rating of the bond, and collateral and maturity type would be downloaded. With this method, a dataset containing a total of 4 221 bonds, was obtained from Bloomberg (2019). All in all, the full dataset of non-green bonds included 16 149 bonds.

After the matching process was completed, the final control group of non-green bond issuers included a total of 183 bond offerings and 149 unique bonds (Table 4). Some bond offerings were included more than once in the dataset, if they matched closest with more than one GB offering. The matching process is further detailed in section 3.2.3.

Table 4. Descriptive statistics of the full corporate non-green bond dataset and control group of non-green bonds and corresponding green bond group.

	All	Control group, non-green bonds	Green bonds
Number of corporate non-green bonds	16 230	183	183
Number of unique bonds	16 230	149	183
Number of unique issuers	3 288	116	106
Total issuance (billion EUR)	12 400	116.2	122.9
Average size (million EUR)	764	634.9	667.9
SD	(3 754)	(778.3)	(788)
Average coupon (%)	3.78	2.66	2.51
SD	(2.15)	(1.77)	(2.13)
Coupon range (%)	-0.17–52.13	0–9.45	0–15.5
Average maturity (years)[11]	7.88	12.8	12.9
SD	(13.77)	(74.5)	(74.2)
Maturity range (years)[12]	0.23–1 000.5	1–1 000.5	1–1 000
S&P Credit rating (median)	BBB+	A	A
Maturity type (number)[13]			
Call/put	24		
At maturity	5 431	113	113
Convertible	2 506		
Callable	7 901	66	66
Putable	22		
Sinkable	83		
Call/sink	28		

[11] Excluding perpetual bonds
[12] Excluding perpetual bonds
[13] Maturity types are explained in Annex 1

Sink/ext	26		
Call/ext	10		
Conv/call	1		
Conv/put/call	1		
Extendible	2		
Perp/call	193	4	4
Perpetual	1		
Perp/call/put	1		
Collateral type (number)			
Company guaranteed	4 828	37	37
Sr secured	816	7	7
Sr unsecured	9 789	119	119
Jr subordinated	116	3	3
Secured	135	0	
1st mortgage	18	12	12
Genl ref mort	17	2	2
Govt guaranteed	3	0	
Unsecured	31	0	
Covered	139	3	3
Asset backed	15	0	
Other	323	0	

The characteristics of the control non-green bond dataset follow the characteristics of the full non-green bond dataset. Bonds which are paid at maturity are the most common, followed by callable bonds and perpetual/ callable bonds, as convertible bonds are ineligible for the control group. Senior unsecured bonds are most common in both group, followed by company guaranteed bonds. Other collateral types are small minorities in both groups. The median credit rating is slightly better in the control group than in the full dataset. Thus, the median credit rating of green bonds is also slightly better than that of conventional bonds, so it would seem that companies that are more liquid, financially sound or trustworthy are more likely to issue green bonds. The average size of the control group bonds is approximately EUR 103 million smaller than for the full dataset. The average coupon is also over 1% smaller in the control group than in the full dataset, while average maturity is nearly 5 years higher.

The control group of non-green bonds matches the matched green bond group exactly in terms of maturity, ratings and collateral types, since these are requirements that must be exactly matched by the control group observations. In terms of total issuance and average size of the bonds, the green bond group includes larger bonds and total issuance is larger. The standard deviation of the size of the bonds in the control and matched group is very nearly the same. The average maturity in both groups is nearly identical, as well as the standard deviations of the maturities. The average coupon size is approximately 0.15% smaller in the green bond set than in the control set, and the standard deviation is notably higher.

3.2 Event study methodology

The purpose of an event study in finance is to quantify possible impacts of an event on company stock price. The method leans on the assumption that markets are efficient and that they consequently reflect new information into prices immediately. (MacKinlay 1997)

This study follows the five steps for conducting an event study by Bowman (1983):

1. Identify the event of interest
2. Model the security price reaction
3. Estimate the excess return
4. Organize and group the excess returns
5. Analyse the results

3.2.1 Identifying the event of interest

The event of interest is the announcement of a green bond offering by a publicly listed company. The offering date itself is not of interest, but the date when the information of the offering reached the public, e.g. the announcement date, is. On the actual day of the offering itself, the information of the offering has already been priced into the company's stock, and thus no abnormal returns are to be expected at this date. An important step would be to also control for possible confounding events, i.e. event which occur concurrently with the event of interest, to minimize the risk of including the effects of wrong events. (Bowman 1983.) However, due to restricted access to the Bloomberg (2019) database, data of other events was not obtained.

3.2.2 Regression Models and Calculating Abnormal Returns

Event studies in finance involve estimating the abnormal returns (AR) of a company's stock during an event window, which is typically three, five, or ten days surrounding the event date. Abnormal returns are any irregular movements in the company's stock which can be attributed to the event of interest. (Benninga 2014, p. 331–332.) All analyses in this study are conducted using R software (R Core Team 2019) through RStudio (RStudio Team 2016). Packages that are used are *tidyverse* (Wickham 2017), *lubridate* (Grolemund and Wickham 2011), *broom* (Robinson and Hayes 2019), *openxlsx* (Walker 2019) and *readxl* (Wickham and Bryan 2019).

First, the returns of all stocks being studied must be calculated for a base period, the estimation period, using a time series regression model, which will provide the regular returns of each stock. This baseline is computed using a simple market model. Formally the market model is presented as:

$$R_{it} = \alpha + \beta_i R_{Mt} + \varepsilon_{it}$$

Where:
R_{it} = the returns of stock i for period t
R_{Mt} = the market return for period t, which will be represented by a market index return
ε_{it} = Random error term
(Bowman 1983, Benninga 2014, p.333.)

The alpha and beta coefficients are constants specific for each security, estimated using a basic OLS regression. The error terms of the model are assumed to have the following properties:

$$E(\varepsilon_{it}) = 0$$

$$var(\varepsilon_{it}) = \sigma^2_{\varepsilon_{it}}$$

The expected value of the error terms is zero, which in turn leads to any non-zero values being interpreted as abnormal returns. (Bowman 1983.) The calculation of abnormal returns is detailed below.

The beta is the slope of the company's return curve, while alpha is the y-axis intercept. The beta represents systematic risk, e.g. how sensitive a company's returns are to changes in market return, while the alfa represents by how much the company on average either out or underperforms the market (e.g. an alpha of 0.1 means that the company on average has produced 10% higher returns than the market). (Bodie, et al. p. 319–330, 382–383, 2005; Jensen, 1975)

The model estimates the expected return of a stock by modelling a linear relationship between a company's returns and the market return (Jensen, 1975). The market index is country specific. For example, the S&P 500 is used for companies in the US, the CAC 40 in France and the FTSE 100 in Great Britain. Each country's leading stock market index is used. A full list of the utilised market indices is included in Annex 2. In addition to calculating the market model with the country-specific market indexes, the model will be estimated using a global market index (MSCI World Index) for all companies, to verify the robustness of the results. The model estimated using country-specific market indexes is denoted as "regional market model", while the model estimated using the global market index is denoted as "global market model". The R script used for the regional market model estimation is provided in Annex 4.

The above model for each stock is calculated for a period of [-164; -15] trading days prior to the event date [0]. Typically, the estimation period is 252 trading days, e.g. a year in length (Benninga 2012, p. 333), but due to limited data availability, the shorter period was selected as it allowed for minimal exclusion of observations. However, the length of the selected estimation period is sufficient to produce robust results (Benninga 2014, p. 333). As the estimation period lengthens, it is able to capture more of the "normal" development of the returns, and the effect of short-term fluctuations decreases. Previous studies have utilised longer estimation periods, such as [-220; -21] in Flammer (2018) and [-300; -50] in Tang and Zhang (2018).

Using the modelled returns detailed above, abnormal daily returns will be calculated for the event period as follows:

$$AR_{it} = R_{it} - \hat{R}_{it}$$

These daily abnormal returns are summed and divided by the number of companies to obtain cumulative average abnormal returns (CAR):

$$CAR_t = \frac{\sum_{t=1}^{T} \sum_{i=1}^{n} AR_{it}}{n}$$

Where:

CAR_t = the average cumulative abnormal returns of stocks i…n over period t

R_{it} = the realized return of stock i over period t

$\hat{R}_{it}$= the expected return of stock i over period t

T = the number of time periods being aggregated (the event window)

n = the number of companies in the sample

(Benninga 2014, p. 333, Bowman 1983)

CARs are selected as the measure for abnormal performance of stocks, as individual, day-specific abnormal returns may not account for any possible leakage of information (i.e. the public has uncovered the information prior to the reported announcement day) (Bodie et al. 2005, p. 382, Strong 1992). Typical event windows are three, five, or ten days surrounding the event date, and the estimation period is typically 252 trading days (Benninga 2014, p. 333). The event window selected in this study is [-5; +5]. CARs are calculated for each stock for [-5; +5], [-5; -2], [+2; +5], [-1; 0], [0;1], [-1;1] and [0]. CARs are estimated for event windows which are wider than [0] to account for uncertainties about the exact event date; a company may have made an announcement regarding a GB offering already on day [-1], but the media may have reported on the matter to a wider public on day [0], which may have been then recorded as the event date (Bowman 1983).

Wider time periods extending backwards in time are chosen for analysis to assess whether information leakage has occurred during a broader time period. Periods extending after the announcement day itself are analysed, to assess whether markets efficiently price the information released on the announcement day – if significant shifts occur days after the announcement, it is reasonable to expect that the market is not functioning efficiently (Bodie et al. 2005, p. 383). However, these shifts may also be caused by subsequent announcements and other events. The CARs indicate how each company has performed during the event window compared to its historical performance. Figure 9 depicts the timeline of the estimation period, event window and event date.

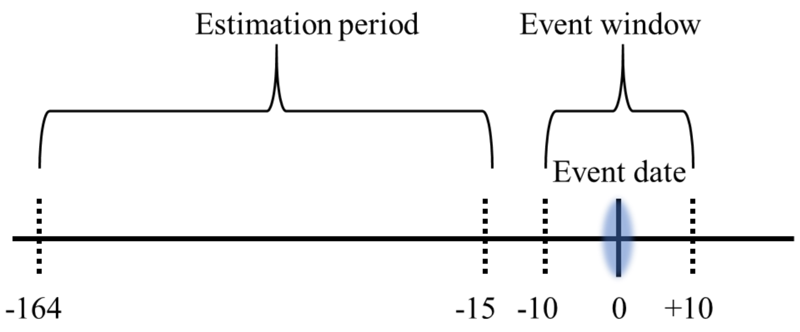

Figure 9 Timeline of the estimation period, event window and event date

In addition to using the market model to estimate abnormal returns the Fama-French three-factor model (FF3) will also be used to verify results obtained by the market model (Fama and French 1992, 1993, Strong 1992, Spiess and Affleck-Graves 1999, Flammer 2018, Tang and Zhang 2018). The model is presented mathematically as:

$$r_{it} = \alpha_i + \beta_{iM}R_{Mt} + \beta_{iSMB}SMB_t + \beta_{iHML}HML_t + \varepsilon_{it}$$

Where:

r_{it} = Return of security i for time t

α_i = The alpha of security i; how much on average has the security beat the market (index)

β_i = The beta of security i, or the factor loading of each variable

R_{Mt} = The market (index) return for time t

SMB_t = The return of a portfolio of small stocks in excess of the return of a portfolio of large stocks

HML_t = The return of a portfolio of stocks with high book-to-market ratio in excess of the return on a portfolio of stocks with low book-to-market ratio

ε_{it} = Random error term

(Fama and French 1992, 1993, Bodie, et al. 2005, p. 360)

Fama and French (1992, 1993) show that stocks are subject to at least three common risk factors; the size factor, market factor and book-to-market factor. Thus, the power of the FF3 model to explain stock returns should be superior to that of a simple one-factor model, such as the CAPM or market model, which only account for the market factor. Kenneth French provides global factor loadings, as well as regional factor loadings for developed markets on his website (French 2019). Region-specific factor loading for Europe, North America and Japan were utilised. For companies outside of these regions, global factor loadings were used. In addition, a model using only global factor loadings was estimated, for verifying the robustness of the market model and regional FF3 approaches (Flammer 2018). This global model also uses the global stock market index (MSCI World index) for all companies. Abnormal returns are calculated as in the analysis with the market model. The model estimated using country-specific market indices is denoted as "regional FF3 model", while the model estimated using the global market index is denoted as "global FF3 model".

After abnormal and cumulative abnormal returns are obtained for all companies, a selection of different portfolios will be constructed to study whether industry, listing country or listing status of the issuer, the maturity type or initial credit rating of the bond or the issuance year affect the size or significance of the abnormal returns. This will be done by grouping the companies based on these characteristics, and the CARs calculated for the resulting portfolios as described above.

The statistical significance of the estimated cumulative average abnormal returns is evaluated with the Student t-test. Formally, the Student t-test is presented as follows.

$$\frac{\hat{\beta}_{jt} - \tau_i}{S_\beta} \sim t_{n-k}$$

Where β is the abnormal return of company j on day t and S_β is the standard error of the abnormal returns of company j, t_{n-k} is the degrees of freedom, and τ_i is the test value from the hypothesis of the test. The hypotheses are

$$H_0: \beta_j = \tau_i$$

$$H_1: \beta_j \neq \tau_i$$

where the value of τ_i is zero, because it is of interest whether the abnormal return differs from zero. (Benninga 2014, p. 337–339, Sumelius 2018, p. 42–43)

3.2.3 Matching procedure for compiling control group

A control dataset of conventional bond issuers is compiled by matching GB issuing companies with conventional bond issuing companies with similar characteristics. The matching procedure is conducted based on four characteristics:

- Industry, denoted by BICS classification
- Country where the issuer is domiciled
- Credit rating
- Listing status of the issuer (whether the issuer is listed, or the direct or ultimate parent is listed and not the issuer itself)

In addition to matching company characteristics, the following bond characteristics are also matched:

- Size
- Currency
- Coupon
- Maturity type
- Collateral type

Matching is based on Mahalanobis distance (MD), which can be used to test whether an observation belongs to a certain group of observations (Stöckl and Hanke 2014).

From a pool of non-green bond issuing companies which have issued conventional bonds, companies that match each GB issuing company based on industry, country, and credit rating are selected. The initial pool of non-green bond issuing companies consists of issuances all non-green bonds available in the Bloomberg database, issued between 1.1.2014-11.6.2019 in all industries besides "banks", "diversified banks",, "financial services", "property and casualty insurance", "real estate" and "consumer finance", as defined by the BICS classification. For these industries, the data search from Bloomberg was first narrowed to limit the amount of data to be downloaded. This was done by limiting the search for each year separately, based on maturity types, collateral types, industries, countries, currencies, coupons and amounts in which GBs had been issued. From the resulting pool, companies were filtered based on the maturity type and collateral type of the bonds they have issued, as well as on the year of issuance. Then, companies were further filtered based on their country, industry and listing status (whether the issuer itself, it's direct parent or ultimate parent is a listed company). The final step in the matching process is pairing GB issuers with the remaining non-green bond issuers using the MD, by selecting the control company with the lowest MD to each treated company, i.e. the nearest neighbour, based on the coupon, size and maturity (in years) of the bonds.

Mahalanobis distance is formally presented as:

$$MD = [(X_i - X_j)'\Sigma^{-1}(X_i - X_j)]^{1/2}$$

Where:

Xi = the (3 x 1) vector containing the 3 matching variables of a treated observation

Xj = the (3 x 1) vector containing the 3 matching variables of a control observation

Σ = the covariance (3 x 3) matrix of the matching criteria of the full population of GB issuing companies

(Stöckl and Hanke 2014, Fresard and Valta 2015, Flammer 2018)

The matched group of companies and bonds will undergo the same analysis, to which the GB issues will be compared to. The matched group serves to indicate how the GB issuing companies would have performed without issuing green bonds, and instead had issued non-green bonds. Annex 5 displays the R script used for the matching procedure.

4 RESULTS

The following section displays the results obtained with the regional market model estimation and briefly discusses the results obtained with the other three models. Result tables from the global market model, the regional FF3 model and the global FF3 model are provided in Annex 3.

Cumulative abnormal returns of GB issuing companies was found to be -0.267% during the period [-1,1] with the regional market model estimation (Table 5). The result is significant at the 5% level.

Table 5. Stock market reaction to green bond issuance analysed with the regional market model.

Event window	**CAR**[14]
	Regional market model
[0]	-0.054 %
[0, 1]	-0.162 %
[-1,0]	-0.160 %
[-1, 1]	-0.265 %**
[2, 5]	0.133 %
[-5, -2]	0.214 %
[-5, 5]	0.086 %

The results over other event windows were not statistically significant at any level. However, the reaction to the GB announcement is negative in all windows [0], [-1,0] and [0,1], while reactions are positive during [-5, -2] and [2,5], even though not statistically significant. Similar results were found with the three other models used to estimate abnormal returns as well (Table A3.1). Estimation with the global market model results in a CAR of -0.27% during [-1;1] which is significant at the 10% level. The

[14] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.

regional FF3 model estimation results in a CAR of -0.283% over the same event window (5% level of significance). Other CARs are not statistically significant with these two models either. The results differ with the global FF3 model estimation, which finds statistically significant CARs for [-5;-2] (0.459%, significant at 5% level) and [-5;5] (0.567%, significant at 10% level). However, also the global FF3 model estimation indicates negative CARs within [-1;1].

4.1 Variation over time

The stock price shift caused by GB issuance was studied between 2014–2016 and between 2017–2019.

For announcements made during 2014–2016, on the announcement day itself, there was no statistically significant shift in stock price based on all the models. However, during [-1;1], the regional market model estimation finds a -0.82% reaction, which is significant on the 1% level (Table 6).

Table 6. Stock market reaction to green bond issuance between 2014–2016 and 2017–2019 analysed with the regional market model.

Event window	**Regional market model CAR**[15]	
	2014–2016	2017–2019
[0]	-0.064 %	-0.050 %
[0, 1]	-0.475 %**	-0.037 %
[-1,0]	-0.408 %*	-0.061 %
[-1, 1]	-0.820 %***	-0.042 %
[2, 5]	-0.108 %	0.231 %
[-5, -2]	0.656 %*	0.037 %
[-5, 5]	-0.263 %	0.230 %

[15] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.

A similar result was replicated with each model, the reaction varying between -0.728% – -0.852%. With the global market model, the result was significant at the 5% level, while the other results were significant at the 1% level. CARs are mainly positive during [-5;-2] and [2;5] (Annex 3, Table A3.2).

The stock market reaction to GB announcements during 2017–2019 is statistically insignificant for all event windows across all models, except for the event window [-5;5] with the global FF3 model (Annex 3, Table A3.3). This event window was found to have a positive CAR of 0.546% with the result being statistically significant at the 10% level. CARs within the window [-1;1] are mainly negative, and outside of this period mainly positive.

These results would indicate that green bond issuance has had no effects on stock valuation during the period 2017–2019, while a statistically significant, negative stock market reaction is observable during the period 2014–2016.

4.2 Differences between industries

The observations were divided into two groups; financial and non-financial. The financial companies are those grouped as “financial institutions” (FI) above, while non-financial includes all others. Between 2014–2019, the regional market model indicates that companies in the financial group experienced statistically significant (10% level) CARs of -0.167% during the event date [0], and CARs of -0.303% during [-1;0] (significant at the 5% level) (Table 7).

Table 7. Stock market reaction to green bond announcements by financial sector companies between 2014-2019 analysed with the regional market model.

Event window	**Regional market model CAR**[16]	
	Financial	Non-financial
[0]	-0.167 %*	0.057 %
[0, 1]	-0.146 %	-0.178 %
[-1, 0]	-0.303 %**	-0.020 %
[-1, 1]	-0.274 %	-0.255 %
[2, 5]	0.410 %*	-0.135 %
[-5, -2]	0.887 %***	-0.458 %
[-5, 5]	1.150 %***	-0.927 %**

Results are all negative within [-1;1] with all models, but most are not statistically significant (Annex 3, Table A3.4 and Table A3.5). A statistically significant (1% level), strong positive stock price reaction is observed during [-5;5] with all models. It seems that stock prices rise prior to and after an announcement of a green bond offering announcement. The initial reaction to an announcement is negative, but the stock price rebounds quickly afterwards. For non-financial sector companies, there are no statistically significant CARs within [-1,1], but there are significant negative CARs during [-5,5].

CARs for non-financial companies are negative across all models and event windows, apart from the CAR on the event date [0] for all models. None of the results are however statistically significant, except for the CAR for [-5;5] with the regional FF3 model estimation and the regional market model, as shown above. The result for the regional FF3 model is -0.821% and is significant at the 5% level.

[16] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.

4.3 Differences between regions

For European companies, no statistically significant stock price reaction is observed during any event window within [-5,5], while a reaction of -0.646% of observed for North American companies (significant at the 10% level) (Table 8).

Table 8. Stock market reaction to green bond announcements in Europe, North America, Japan, and other countries.

Event window	**Regional market model CAR[17]**			
	Europe	North America	Japan	Other[18]
[0]	-0.082 %	-0.048 %	-0.418 %	0.049 %
[0, 1]	-0.182 %	-0.261 %	-0.756 %	0.063 %
[-1, 0]	-0.061 %	-0.435 %	-0.953 %*	0.039 %
[-1, 1]	-0.151 %	-0.648 %*	-1.290 %*	0.053 %
[2, 5]	0.080 %	-0.095 %	-1.117 %*	0.635 %
[-5, -2]	0.025 %	0.368 %	0.250 %	0.415 %
[-5, 5]	0.006 %	-0.376 %	-2.079 %**	0.991 %*

The results of the region-specific analysis are mainly not significant. What is noteworthy however is, that the results for European, North American and Japanese companies are all negative during [-1,1], while the results for companies outside of these regions are positive during each selected event window. This result is replicated with the other three models as well, with small exceptions (Annex 3, Tables A3.6– A3.8).

4.4 Effect of bond credit rating

There are notable differences between the CARs of investment-grade bonds, junk bonds and bonds without ratings. The announcement of an investment-grade bond results in a CAR of -0.274% during [-1,1], while the announcement of a junk bond

[17] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
[18] Includes the following countries: Brazil, South Korea, Australia, Hong Kong, Chile, Taiwan, India, China, and Singapore.

offering results in a CAR of -1.527% during the same event window. Both results are statistically significant (Table 9).

Table 9. Difference between stock market reactions to announcements of green bond offerings with differing credit ratings.

Event window	**Regional market model CAR**[19]		
	Investment-grade[20]	Junk[21]	No rating
[0]	-0.126 %	-0.129 %	0.168 %
[0, 1]	-0.128 %	-1.403 %***	0.143 %
[-1, 0]	-0.278 %**	-0.252 %	0.190 %
[-1, 1]	-0.274 %*	-1.527 %***	0.166 %
[2, 5]	0.192 %	0.279 %	-0.081 %
[-5, -2]	0.325 %*	-1.746 %*	0.499 %
[-5, 5]	0.302 %	-3.539 %**	0.617 %

The other three models corroborate the findings obtained with the market model estimation, indicating that the market react strongly to a junk bond offering, compared to an investment-grade bond offering. It is also noteworthy, that bond offerings that are not accompanied by a credit rating, result in mainly positive CARs across all models and all event windows. However, most of these results are not statistically significant (Annex 3, Tables A3.9– A3.11).

4.5 Effects of listing status

Testing for the effects of listing status on CARs did not result in any notable results. Most CARs across all models and all event windows are statistically insignificant. The effects are mostly negative in event windows within [-1;1] (Table 10, Annex 3 Tables A3.12– A3.14).

[19] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
[20] Investment grade bonds are those rated BBB- and above by S&P (Investopedia 2019a).
[21] Junk bonds are those rated below BBB- by S&P (Investopedia 2019a).

Table 10. Stock market reaction to GB issuance by companies that are themselves listed, their parent company is listed, or their ultimate parent company is listed, based on the regional market model.

Event window	**Regional market model CAR**[22]		
	Directly listed	Parent is listed	Ultimate parent is listed
[0]	-0.023 %	0.104 %	-0.263 %
[0, 1]	-0.199 %	0.107 %	-0.320 %
[-1, 0]	-0.033 %	-0.229 %	-0.408 %
[-1, 1]	-0.197 %	-0.226 %	-0.465 %
[2, 5]	0.470 %*	0.130 %	-0.233 %
[-5, -2]	0.225 %	0.895 %	-0.045 %
[-5, 5]	0.536 %	0.747 %	-0.743 %

4.6 Effects of maturity type

As is the case with listing type, the type of maturity associated with a green bond does not seem to have any statistically significant influence on the formation of CARs. CARs are mainly negative during event windows within [-1;1] and positive outside this period, but most results across all models are statistically insignificant (Table 11, Annex 3 Tables A3.15– A3.17).

[22] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.

Table 11. Stock market reaction to GB issuance by maturity type, based on the regional market model.

Event window	**Regional market model CAR**[23]		
	At maturity	Perpetual/ callable	Callable
[0]	-0.155 %	0.024 %	0.121 %
[0, 1]	-0.250 %*	0.036 %	-0.022 %
[-1, 0]	-0.085 %	-0.558 %*	-0.253 %
[-1, 1]	-0.172 %	-0.546 %	-0.395 %*
[2, 5]	0.186 %	-0.380 %	0.004 %
[-5, -2]	0.275 %	0.320 %	0.073 %
[-5, 5]	0.304 %	-0.605 %	-0.319 %

4.7 Green bonds vs non-green bonds

The results of the event study analysis conducted on the non-green bond offering announcements are conflicting (Table 12).

[23] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.

Table 12. Stock market reaction to matched non-green bond offerings based on the regional market model, global market model, regional FF3 model and global FF3 model.

Event window	**CAR[24]**			
	Regional market model	Global market model	Regional FF3 model	Global FF3 model
[0]	-0.067 %	0.028 %	-0.172 %**	-0.031 %
[0, 1]	-0.134 %	-0.033 %	-0.264 %**	-0.091 %
[-1, 0]	0.112 %	0.231 %*	-0.029 %	0.135 %
[-1, 1]	0.045 %	0.169 %	-0.121 %	0.075 %
[2, 5]	0.176 %	0.228 %	0.179 %	0.325 %
[-5, -2]	-0.053 %	0.082 %	-0.078 %	0.037 %*
[-5, 5]	0.167 %	0.479 %	-0.021 %	0.437 %

The regional market model does not find any significant stock price reaction to conventional bond issuance, whereas the global market model finds a positive reaction, significant at the 10% level during [-1,0] and the regional FF3 model finds a negative reaction, significant at the 5% level during [0,1]. Insignificant results within [-1,1] indicate both negative and positive reactions, with three of the four models indicating a negative stock price reaction on the announcement date [0].

As the portfolio of control observations does not include a matched company for each GB in the full GB portfolio, the event study analysis was also conducted for a reduced group of GBs, for comparable results between the GB issuing and non-green bond issuing companies. The results obtained from this are similar to the results obtained from the analysis on the full group of GB issuing companies (Table 13).

[24] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.

Table 13. Stock market reaction to the matched group of GB offerings based on the regional market model, global market model, regional FF3 model and global FF3 model.

Event window	**CAR**[25]			
	Regional market model	Global market model	Regional FF3 model	Global FF3 model
[0]	-0.105 %	-0.102 %	-0.103 %	-0.104 %
[0, 1]	-0.126 %	-0.136 %	-0.114 %	-0.086 %
[-1, 0]	-0.257 %**	-0.258 %**	-0.290%***	-0.151 %
[-1, 1]	-0.274 %*	-0.286 %*	-0.303%**	-0.133 %
[2, 5]	0.049 %	0.118 %	0.035 %	0.137 %
[-5, -2]	0.507 %***	0.533 %***	0.539 %***	0.581 %***
[-5, 5]	0.296 %	0.376 %	0.296 %	0.585 %

The analysis on the reduced set of green bond offerings finds a statistically significant, negative stock price reaction during [-1,0] and [-1,1] with all models besides the global FF3 model. A peculiarity in the results are the highly significant positive CARs during [-5,-2] found with all models. This can possibly indicate some form of anticipation from the market to an announcement prior to the announcement itself. All results within [-1,1] are negative. The CARs surrounding the non-green bond offering announcements differs somewhat to those surrounding the green bond offering announcements. The non-green bond announcements do not clearly result in a negative or positive stock price reaction, and the results are mostly insignificant, whereas the reaction to the green bond announcements seems to be uniformly negative across all models, and results are statistically significant in more cases.

[25] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
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4.8 Consistency of different models

The additional three models, the global market model, regional FF3 model and global FF3 model mainly corroborate the results of the regional market model. The results of these three models are found in Annex 3 as mentioned previously.

A statistically significant, negative stock price reaction is observed with the global market model and regional FF3 model for all companies within the event window [-1;1] for the entire dataset. The global FF3 model also indicates a negative stock price reaction, but the results are insignificant. These findings corroborate the results of the baseline estimation with the regional market model.

The model comparisons also corroborate other findings. Statistically significant, negative stock price reactions are observable for the green bond announcements between 2014–2016 within the event window [-1,1], but no statistically significant results are found for announcements between 2017–2019, in line with the regional market model results.

The global market model and regional FF3 model indicate a negative stock price reaction to green bond announcements by financial sector companies within the event window [-1,0], but no significant reaction is found for non-financial companies. A somewhat puzzling result is, that all models indicate highly significant, notable positive cumulative abnormal returns prior to the announcement date, during [-5,-2]. Further analysis of the issue would be required to ascertain why such results are obtained. A possible reason is, that the market is anticipating an announcement and price these expectations into the stock.

The regional market model indicated a negative, yet insignificant stock price reaction to green bond issuance announcements in Europe, a negative and significant reaction in North America and Japan, but a positive yet insignificant stock price reaction in other countries. The global market model corroborates this mainly, with the exception that negative yet insignificant CARs are found for the other countries -group in the event windows [-1,0] and [-1,1]. The regional and global FF3 models replicate the direction of the stock price reactions across the different regions, but the significance of results varies. Nonetheless, the results of the regional market model are mainly confirmed by the other three models.

Grouping the CARs by credit rating resulted in negative and significant stock price reaction to both investment grade and high-yield green bond announcements within [-1,1]. This result was replicated by all the other models. All models also indicate that the stock price reaction to non-rated bonds is positive, yet insignificant.

Grouping the CARs by listing status of the issuers did not result in any statistically significant results with any of the models, with one exception (see Table A3.13, Annex 3). All results indicate a negative stock price reaction to announcements of green bond issuance, even though results are not significant. Grouping the CARs by maturity type reveals that announcements of green bonds which are callable or perpetual result in a steeper negative stock price reaction than announcements of green bonds which will be repaid at maturity. This is replicated across all models, but at varying levels of significance.

In addition to verifying results by using different models for estimating abnormal returns, the results of the regional market model results were verified by accounting for possible outlier in the data. This was conducted by removing the largest and smallest 10% of the company-specific cumulative abnormal returns from the sample and calculating the average cumulative abnormal returns from the resulting sample.

The results of this analysis continue to confirm the initial findings of the study; announcements of green bond offerings result in a negative stock price reaction (Table 14).

Table 14. Stock market reaction to green bond issuance analysed with the regional market model, conducted with a dataset excluding the largest and smallest 10% of company-specific CARs.

Event window	**CAR**[26]
	Regional market model
[0]	-0.085 %*
[0, 1]	-0.192 %***
[-1,0]	-0.225 %***
[-1, 1]	-0.286 %***
[2, 5]	0.010 %
[-5, -2]	0.168 %
[-5, 5]	-0.187 %

By removing the largest and smallest observations from the sample, the statistical significance of the results is notably increased, while the scale of the average cumulative abnormal returns has remained similar compared to the analysis conducted on the entire group of observations.

[26] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.

5 DISCUSSION

5.1 Previous studies and usability of the results

The results of this study conflict with the findings in Flammer (2018) and Tang and Zhang (2018), the two only publications found to have studied the valuation effects of green bonds prior to this study. Tang and Zhang (2018) finds a positive reaction to green bond announcements. The study reports a CAR of 1.39% during the event window [-10;10] (Table 15).

Table 15. Comparison of results on valuation effects of green bond offering announcements. (Under Tang and Zhang (2018), results outside of brackets are those from first-time green bond offering announcements, those in in brackets are of subsequent issues).

Study	Model	Event window	CAR	Significance level
Current study	Market model	[-1,1]	-0.265 %	5%
Tang and Zhang (2018)	CAPM	[-10,10]	1.39% (0.12%)	5% (Not significant)
	FF3	[-10,10]	1.14% (0.10%)	5% (Not significant)
	FF5[27]	[-10,10]	1.29% (0.50%)	5% (Not significant)
Flammer (2018)	Market model	[-1,0]	0.673%	5%
	FF3	[-1,0]	0.735%	5%

Tang and Zhang (2018) use a slightly different method for calculating CARs than the current study and Flammer (2018), as it utilises the CAPM to establish “normal

[27] Fama-French 5-factor model

returns" for estimating CARs, not the market model. Another notable difference is the event window, which spans 21 days, compared to the one, two and three used in this study and the two used in Flammer (2018). Tang and Zhang (2018) present results for the event window [-5,10] as well. Flammer includes event windows spanning [-20,20] around the event date, but does not lean on the broader period for establishing the core results. Without narrower event windows from Tang and Zhang, it is difficult to ascertain when the reported valuation effect actually occurs; before, during or after the event. As such, room for doubt exists in whether the results are believable, and this broader event window may in part explain the vast difference in results compared to the current study. As an example, in analysing the impact of bond credit rating on the stock price reactions of green bond issuance, this study found statistically significant abnormal returns prior to the event date (in the period [-5,-2] in Table 7 and the corresponding period in Table 9), which skews the results of the widest analysed event window [-5,5]. By only recognizing the results from this period would result in a completely contrary conclusion than what is the actual result of this study; that green bond issuance results in a positive stock price reaction. Thus, it should be recognized that statistically significant abnormal returns may be found outside of the expected days, which may skew the results. Positive cumulative abnormal returns found in this study during [-5,-2] may be caused by the market's anticipation of an announcement by the companies.

Flammer (2018) and Tang and Zhang (2018) both conduct robustness checks on their initial findings by estimating abnormal returns with the FF3 model, as was done in the current study. Flammer (2018) also checks for robustness with a global index market model, as was done in the current study. These robustness check resulted in statistically significant, positive abnormal returns, in line with their initial results. The contradiction between the results found in Flammer (2018) and Tang and Zhang (2018) may be due to:

- Temporal restrictions of the current study and overall sample selection
- Different selection of market indices
- Length of the estimation period

The current study as restricted the sample somewhat more than Tang and Zhang (2018) and Flammer (2018). These studies have not restricted the used sample temporally, whereas in this current study, only green bond announcements which have occurred since 1.1.2014 have been included. In addition, this current study has included only those observations, where a green bond has been issued in either USD, EUR, or SEK, unlike the other studies. The only requirement for selection of observations in Flammer (2018) is that the issuer must be a publicly listed company. Tang and Zhang (2018) restricts the observations to exclude those companies that have made separate announcements close to the announcement of the GB, to minimize the risk of interpreting the impact of completely different events, as that caused by the green bond announcement.

Market index selection may also cause issues with the current study. The most well-known market index was selected for each country and used in estimating abnormal returns for all companies domiciled in that country. Companies may have been listed on another exchange within the same country. This may cause misspecification in the models as different stock exchanges within the same country may perform differently (Campbell and Wasley 1993).

The dataset utilised in the current study may have been biased in the regional distribution of green bond issuance, as it only included bonds issued in EUR, SEK and USD. Many companies outside of the regions using these currencies have issued bonds in one of these currencies, but some companies within these regions may have also issued green bonds in other currencies. Chinese green bonds for example are most likely underrepresented in the sample, which was used, as the Chine Renminbi (CNY) is the fourth most common currency of green bond issuance (Figure 6). However, this does not invalidate the findings of this study. Further research would be required with a dataset including all green bond offerings by public companies, to ascertain whether there is in fact a difference in the valuation effects of green bond issuance depending on where the bond issuer is domiciled. Similarly, it could be studied in further detail whether the issuing currency and in which market the bond is issued has an impact on the stock price reactions.

The current findings would indicate, that green bond issuance has a negative effect on stock price in developed markets (Europe, North America, and Japan) whereas in other markets (mainly less developed markets such as China, Brazil, Chile, Taiwan, India), green bond issuance raises the stock price of the issuer. A possible interpretation for this result is, that in developed markets, investors already expect companies to act in an environmentally conscious manner, while in developing markets this same expectation does not apply. The issuance of a green bond in developed markets is then seen to only result in added costs and requirements for the company, without additional environmental benefits. The issuance of a green bond in developing markets, however, is seen to bring additional environmental benefits which are not expected by investors as “business-as-usual”, and thus the company is awarded for this development by an increase in stock price. An added benefit of green bonds for investors is, that green bonds impose further reporting requirements, which can offer investors valuable information on the issuer. Companies in developed markets may be subject to stringent reporting requirements already, and the additional information disclosure is not seen to be significant by investors. In developing markets, company information may be more difficult to access and obtain, and thus the additional reporting resulting from GB issuance is seen to lower risks of equity investors which is then reflected in stock price.

Cheung et al. (2010) investigates the valuation effects of CSR performance of companies in emerging Asian markets between 2001–2004. The results indicate, that companies achieve improved stock price performance with good CSR performance, which is measured by CSR scores by Credit Lyonnais Securities. However, only one out of six criteria within the CSR score evaluates environmental performance, so the results are not truly indicative of how environmental performance effects corporate valuation. It is, in any case, an interesting finding and offers perspective for the results of the current study, but does not confirm the hypothesis presented above, that environmental performance would be rewarded poorly in developed markets and better in emerging markets.

Further evidence of investor reactions to environmental performance from emerging markets, more specifically India, indicate that stock markets penalize poor environmental performance and awards good performance (Gupta and Goldar 2005). Green ratings caused both statistically significant negative and positive CARs in stocks depending on the rating issued. Those companies that received low ratings typically experienced negative abnormal returns, while companies which performed well in the ratings experienced positive abnormal returns (Gupta and Goldar 2005). This is in line with the current finding, that green bond issuance results in a positive stock market reaction, even though the CARs were found to be statistically insignificant.

King and Lenox (2001) question the relationship between environmental performance and stock price performance. By analysing whether any other underlying attributes of companies may be responsible for the perceived effect of environmental performance on company value, King and Lennox (2001) conclude that there is insufficient evidence to prove causality between higher financial performance and firm value and smaller pollution levels of a company, and that other company characteristics may explain superior financial performance of companies that perform well environmentally. This supports the current findings, in which green bond issuance was not found to increase stock price. It does not however, support the result of stock prices decreasing. Konar and Cohen (2001) on the other hand find that reducing emissions of toxic chemicals by a S&P 500 company results on average in a USD 34 million increase in the company's market value.

Lee et al. (2017) investigates how environmental audits effects company valuation in Japan and finds that on average companies that have conducted such audits have a 9% higher market value than those that have not conducted such audits. Audits and disclosure of environmental information is voluntary in Japan. The study uses environmental audits as an indication of a company's commitment to environmental protection and of a proactive attitude towards environmental performance. Third-party assurance is found to play a central role in the valuation effects (Lee et al. 2017.) This would indicate that green bonds which are certified via third-party verification could probably result in positive stock price reactions. This should be investigated in further detail in future research of green bonds. However, this does not confirm, nor disprove, the hypothesis about good environmental performance being expected in developed markets, and Japan specifically.

Studies focused on the pricing of green bonds have found that there is a negative premium associated with green bonds, e.g. investing in green bonds yields lower returns compared to conventional bonds (Karpf and Mandel 2018, Tang and Zhang 2018). This is a positive aspect for issuers, as it reduces financing costs, if the costs associated with issuing a green bond are covered by the negative premium. However, stock investors may feel that additional expenditures related to issuing a green bond are not appropriate use of a company's capital, they may "punish" the company by decreasing the share price through lower bids. It would be expected that the lower cost of capital associated with green bonds would result in a positive reaction from the stock market, though.

The fact that possible confounding event were not identified and controlled for somewhat undermines the obtained results of this study (Bowman 1983). It is possible, that enough company-specific, parallel event occurred alongside the green bond announcements, to cause major disruptions in the measurements of CARs associated with the green bond announcement. Further studies are advised to control for such confounding events, to reliably either corroborate or contradict the current findings.

The previous two studies (Flammer 2018, Tang and Zhang 2018) did not research whether there has been variation in the valuation effects of green bond announcements over time. This is an interesting topic to study, as the novelty of GB offerings may have initially resulted in more pronounced valuation effects, or price movements into a contrary direction. This is somewhat the result found in Tang and Zhang (2018), which reports a statistically significant, higher positive stock price reaction to announcements of first-time green bond offerings, while reactions to announcements of seasoned GB offerings were all insignificant and much closer to zero. The current study finds a completely opposite result. Assuming that the sample for announcements between 2014–2016 includes a higher percentage of first-time issuers, it would be expected to show higher, positive abnormal returns if the results of Tang and Zhang (2018) are used as the target result. However, the current results indicate that the "older" observations result in notably larger negative stock price reactions, than the announcements that have occurred during 2017–2019. Further research is advised to analyse whether the current findings remain true, once the temporal restriction is removed and a dataset containing all corporate green bonds issued by publicly listed companies are included is used. An interesting analysis would be focused on the CARs that are found from issues prior to 1.1.2014; are these positive or negative, and are they significant? Additionally, it could be studied whether CARs associated with first-time issuance announcements versus announcements of seasoned issuance differ over time. This would reveal any possible changes in attitudes towards green bonds over time.

A vast number of publications have studied the valuation effects of different security offerings as outlined already in section 1.4. Studies focused on the effects of conventional bond offerings on common stock have varied slightly (Table 16).

Table 16. Valuation effects of stock and bond issuance in previous research.

Study	Debt type	Model	Event window	CAR	Significance level
Mikkelson and Partch (1986)	Conventional bond	Market model	[-1,0]	-0.39%	Not significant
	Convertible bond	Market model	[-1,0]	-1.57%	5%
	Common stock	Market model	[-1,0]	-3.44	5%
Shyam-Sunder (1991)	Conventional bond	Market model	[-1,0]	-0.11	Not significant
Burnie and Ogden (1996)[28]	Conventional bond	Market model	[-1,0]	-0.023%	Not significant
	Convertible bond	Market model	[-1,0]	-0.95%	5%
Eckbo (1986)[29]	Conventional bond (excl. mortgage bonds)	Market model	[-1,0]	-0.06%	Not significant
	Mortgage bonds	Market model	[-1,0]	-0.20%	10%
	Convertible bond	Market model	[-1,0]	-1.25%	1%
Eckbo (1986)[30]	Conventional bond (excl. mortgage bonds)	Market model	[-1,0]	-0.15%	Not significant
	Mortgage bonds	Market model	[-1,0]	-0.01%	Not significant
	Convertible bond	Market model	[-1,0]	-1.13%	1%

[28] Initial public bond offerings
[29] Initial public bond offering
[30] Second public bond offerings

In addition to the results summarised in Table 16, Smith (1985) summarises further findings of valuation effect of bond offerings. The summary illustrates that there is a clear difference between stock price reactions to security offerings by industrial companies and utilities, e.g. common stock offerings by industrials leads to a -3.14% stock price reaction, while the figure for utilities is -0,75%, and correspondingly for preferred stock -0.19% and 0.08%, for convertible preferred stock -1.44% and -1.38%, and for conventional bonds -0.26% and -0.13%.

Even though there has been variation in the statistical significance, size and direction of the stock price effects from bond offerings, the majority of previous research that was reviewed indicate that conventional bond offerings do not result in a positive stock price reaction. Convertible bond offerings have been found to result in statistically significant negative stock price reaction. The current study does not include any observations of convertible green bond issues, so corroborating the previous results regarding convertible bond issues is not possible.

The current study finds both a statistically significant positive stock price reaction, as well as statistically significant negative stock price reactions to the issuance of conventional bonds, depending on the model which is used. Results are mixed on whether conventional bond offerings result in a negative stock price reaction, or a positive one, and most results are insignificant. This is mainly in line with findings in previous publications. This finding also distinguishes, that the stock price reaction to green bond offering announcements is in fact due to the "greenness" of a bond, rather than to the bond itself, if it is assumed that confounding events have not occurred.

Shyam-Sunder (1991) studied the effects of bond ratings on the valuation effects of bond issuance and found that there is no statistically significant relationship between bond rating class and the scale of stock price reactions (Table 17). This is contrary to the findings of the current study, which found high-yield bond offerings to result in a notably stronger negative stock price reaction than that of investment grade offerings.

Table 17. Abnormal returns for conventional bond offerings during 1980 to 1984 by bond rating (Shyam-Sunder 1991).

Credit rating (Moody's)	Abnormal returns	Significance level
AAA	0.11%	Not significant
AA	-0.31%	Not significant
A	-0.17%	Not significant
BAA	0.24%	Not significant
BA	-0.57%	Not significant
B	-0.03%	Not significant
Unrated	0.51%	Not significant

However, the results of the current study seem to indicate a similar reaction to bond offerings as was found in Shyam-Sunder (1991). The current study finds a statistically significant, negative reaction to both investment grade and high-yield bond issuance, which is similar to the results in Shyam-Sunder (1991), even though results in Shyam-Sunder (1991) are insignificant. Similarities continue with unrated issues. The current study finds insignificant positive stock price reactions to unrated issues, which is the same finding as in Shyam-Sunder (1991).

5.2 Methods

The market model has been used in numerous event studies to calculate abnormal returns. Brown and Warner (1985) find that OLS estimates of the market model are well specified for using standard parametric tests, supporting the use of this method in this study. However, Barakat and Terry (2013) note, that all of the many methods devised for calculating expected, abnormal, cumulative abnormal and buy-and-hold returns are subject to significant limitations. The main critique in Barakat and Terry (2013, ref. Greene 1997) of the market model is that it does not include all relevant factors, which leads it to produce inefficient and inconsistent estimates of expected returns. This concern was addressed by conducting the analysis also with the FF3, which includes additional factors to the market model.

Ideally the matching procedure would have account for several characteristics of the issuers, namely company size, profitability, leverage and value. These characteristics have been used in previous financial literature for constructing control groups (e.g. Almeida et al. 2012, Fresard and Valta 2016, Flammer 2018). This would have resulted in a control group which would be as similar as possible to the treated group (e.g. the GB issuing companies). However, as these data were unavailable, it was decided to attempt the matching with the available variables. The S&P credit rating which was used instead of profitability, size, value and leverage indicators was thought to include indication of such indicators, and that companies with similar ratings would also be similar in these aspects. However, it is a suboptimal proxy for these variables at any rate.

Specification of the regression models could have been further improved by including industry-return indexes in addition to the market index (Benninga 2014, p. 350–355). The robustness of obtained results could have also been verified using industry-adjusted CARs, to ensure that no industry trends are driving the detected abnormal returns (Flammer 2018).

5.3 Data

The dataset utilised included all corporate green bonds issued in USD, EUR and SEK currencies between 1.1.2014-11.6.2019 that were available on the Bloomberg database on 18.7.2019, excluding asset backed securities (ABS). This provided a sufficient number of observations to conduct an econometric analysis of the data. However, excluding older observations from the dataset restricted the number of possible different analyses. One such analysis that could not be conducted was that of comparing the reactions to first-time announcements of green bond offerings to seasoned offerings. Such an analysis has been conducted by Tang and Zhang (2018) and it would have been interesting to compare results. As the dataset excluded green bond offering announcements which occurred prior to 1.1.2014, it was impractical to ascertain which announcements in the dataset were in fact of initial offerings of green bonds.

Another potential shortcoming of the data used was the return data of indices used in estimating the returns of the companies. The index return data was sourced from open online sources such as Yahoo Finance. As the index data was not in each case of total returns (e.g. not a total return index), it may skew the results of the regressions models and may have caused over or underestimation of the level of normal returns of some or all of the companies. This was addressed in part by substituting country-specific indices with a single global index (MSCI World index), which in most part corroborated the findings obtained with the country-specific indices.

Overall the data utilised is considered to be of good quality, as it was sourced mostly from the Bloomberg (2019) database, which is considered a reliable source of market data. The data covers a large portion of issued corporate green bonds even with the above mentioned restrictions set on the dataset. However, due to the restrictions on the currency of the offerings, it is believed that the results may not apply well outside of North America and Europe. Within these markets the data is representative of the entire population and the results are believed to be applicable. All in all, the currency restriction allows the inclusion of most green bonds, as EUR, USD and SEK are the most common currencies of GB offerings (see Figure 6).

6 CONCLUSIONS

The research finds that green bond issuance results in statistically significant, negative cumulative average abnormal returns in the issuer companies' stock. Analysis of the full sample of green bonds finds statistically significant CARs of -0.265% during the event window [-1;1]. Analysis of different portfolios constructed from the full sample indicates that green bonds result in negative valuation effects, regardless of bond rating, maturity type, industry or listing status of the bond. A notable finding was that the stock price reaction to green bond announcements by companies domiciled in developed markets resulted in statistically significant negative cumulative abnormal returns, while announcements by companies domiciled in other, mainly emerging markets, resulted in positive CARs, which were not statistically significant. This is an interesting finding, as it indicates that the attitude towards green bonds may differ across markets and should be further investigated in future research. No explanation was found for this finding, and the hypothesis formulated for explaining the finding does not hold when compared to research on the valuation effects of environmental performance, conducted across different emerging and developed markets (King and Lennox 2001, Konar and Cohen 2001, Gupta and Goldar 2005, Cheung et al. 2010, Lee et al. 2017).

The stark contrast between the current findings and the results of previous research into the valuation effects of green bond issuance (Flammer 2018, Tang and Zhang 2018) warrants additional research to be carried out on the topic. A new approach taken in the current study was to analyse, whether the stock price reaction caused by green bond announcements has changed over time. This has not been done by previous research. The results indicate, that green bonds announced between 2014–2016 have resulted in much more pronounced negative CARs than those announced between 2017–2019. As the current dataset does not contain observations prior to 1.1.2014, future research should investigate what the reaction to green bond announcements has been prior to this date. This study concludes that green bond announcements have a negative effect on the value of the issuing company's stock during the event window [-1;1].

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Annex 1 Collateral and maturity types explained

Table A1.1. Explanations for collateral types. Sources: Investopedia 2018a; 2019c.

Type	Definition
Guaranteed bonds	Guaranteed bonds offer a guarantee that interest and principal payments will be made by a third party in case the bond issuer defaults. This guarantee lowers the risk involved for the investor and thus guaranteed bonds typically have a lower interest rate than bonds which are not guaranteed
Company guaranteed	The bond is guaranteed by another corporation.
Government (Govt) guaranteed	The bond is guaranteed by a government.
Bank guaranteed	The bond is guaranteed by a bank.
Senior (Sr) secured	Bonds labelled “senior” have priority over other debt payments in case of default. “Secured” indicates that the debt is backed with collateral.
Senior (Sr) unsecured	As above, “senior” refers to the bond having priority over other debt payments in case of default. “Unsecured” means that there is no collateral backing them.
Junior (Jr) subordinated	“Junior” bonds are those which are subordinate to senior bonds in priority, e.g. in case of default, next in line for payments from what remains, after senior debts have been paid.
Secured	The bond is guaranteed by a specific collateral, which in case of default will be passed onto the bondholders.
Unsecured	The bond is not guaranteed with a specific collateral, and is secured only by the issuer’s “good name” and credit standing.
Covered	These are equivalent to secured bonds in a way, that they are backed by assets, but are issued by financial institutions. In

	case the financial institution defaults, the underlying assets cover the principal and interest payments.
1st mortgage	A bond which is covered by payments from first mortgages, which are the original mortgages taken on any given property. A first mortgage has priority to any other claims on the property in case of default. Similar to a covered bond.
General mortgage (Genl ref mort)	A bond which is covered by mortgages, which may be subordinate to more senior claims and are thus usually riskier than e.g. 1st mortgage bonds.
Pfandbriefe	A type of a covered bond, which are issued by German mortgage banks. These are backed by mortgages usually.

Table A1.2. Explanations for maturity types. Sources: Investopedia 2018b, c, 2019d.

Title	**Definition**
At maturity	The principal is paid at the stated date of maturity.
Callable	The issuer may redeem the bond prior to the stated maturity date.
Perpetual	The bond has no maturity date and the principal is never repaid.
Sinkable	The bond is covered by a “sinking fund”. The issuer sets aside money into a separate fund when issuing the bond, for paying back the principal and interest payments. This reduces the risk involved for investors and typically reduces the interest rate and improves the credit rating. The bond principal is also repaid partially each year instead of fully at maturity, e.g. 1/10 of the principal of a 10-year bond will be repaid annually.
Callable/sinkable	

Annex 2 Full list of used stock market indices

Table A2.1. Stock market indices used in market model estimation.

Country	Index name
Abu Dhabi	Abu Dhabi Securities Market General Index
Austria	Austria Traded Index
Australia	S&P ASX 200
Belgium	BEL 20
Brazil	Bovespa Index
Canada	S&P TSX Composite Index
Chile	S&P CLX IPSA
China	SSE Composite Index
Germany	DAX Performance Index
Denmark	OMXC20
Spain	IBEX 35
Finland	OMXH 25
France	CAC 40
Great Britain	FTSE 100
Hong Kong	Hang Seng Index
India	S&P BSE Sensex
Italy	FTSE MIB
Japan	Nikkei 225
South Korea	Kospi Composite Index
The Netherlands	AEX Index
Norway	Oslo Bors All-share Index
Peru	S&P BVL Peru General Index
Philippines	PSE Composite Index

Portugal	PSI 20
Sweden	OMXS 30
Singapore	STI Index
Taiwan	TAIEX
US	S&P 500
Global	MSCI World Index

Annex 3: CARs calculated with the global market model, regional FF3 model and global FF3 model.

Reaction to all GB offering announcements

Table A3.1. Stock market reaction to green bond issuance analysed with the global market model, regional FF3 model and global FF3 model.

Event window	**CAR[32]**		
	Global market model	Regional FF3 model	Global FF3 model
[0]	-0.054 %	-0.033 %	-0.047 %
[0, 1]	-0.159 %	-0.145 %	-0.103 %
[-1, 0]	-0.171 %	-0.170 %	-0.116 %
[-1, 1]	-0.270 %*	-0.283 %**	-0.172 %
[2, 5]	0.216 %	0.132 %	0.280 %
[-5, -2]	0.310 %	0.255 %	0.459 %**
[-5, 5]	0.260 %	0.118 %	0.567 %*

[32] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.

Variation over time

Table A3.2. Stock market reaction to green bond issuance between 2014-2016 analysed with the global market model, regional FF3 model and global FF3 model.

Event window	**CAR[33]**		
	Global market model	Regional FF3 model	Global FF3 model
[0]	-0.137 %	-0.012 %	0.038 %
[0, 1]	-0.506 %**	-0.417 %*	-0.416 %
[-1, 0]	-0.483 %**	-0.383 %*	-0.275 %
[-1, 1]	-0.852 %***	-0.788 %***	-0.728 %**
[2, 5]	0.020 %	-0.122 %	0.230 %
[-5, -2]	0.796 %	0.680 %*	1.118 %**
[-5, 5]	-0.007 %	-0.230 %	0.619 %

Table A3.3. Stock market reaction to green bond issuance between 2017-2019 analysed with the global market model, regional FF3 model and global FF3 model.

Event window	**CAR[34]**		
	Global market model	Regional FF3 model	Global FF3 model
[0]	-0.020 %	-0.042 %	-0.081 %
[0, 1]	-0.019 %	-0.035 %	0.021 %
[-1, 0]	-0.047 %	-0.086 %	-0.053 %
[-1, 1]	-0.037 %	-0.081 %	0.049 %
[2, 5]	0.296 %	0.236 %	0.300 %
[-5, -2]	0.114 %	0.084 %	0.197 %
[-5, 5]	0.370 %	0.261 %	0.546 %*

[33] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.

[34] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.

Differences between industries

Table A3.4. Stock market reaction to green bond announcements by financial sector companies between 2014-2019 analysed with the regional market model, global market model, regional FF3 model and global FF3 model.

Event window	CAR[35]		
	Global market model	Regional FF3 model	Global FF3 model
[0]	-0.172 %*	-0.138 %	-0.110 %
[0, 1]	-0.182 %	-0.125 %	-0.048 %
[-1, 0]	-0.295 %*	-0.287 %**	-0.118 %
[-1, 1]	-0.293 %	-0.276 %*	-0.056 %
[2, 5]	0.549 %**	0.318 %	0.655 %**
[-5, -2]	0.895 %***	0.915 %***	0.976 %***
[-5, 5]	1.232 %***	1.103 %***	1.575 %***

Table A3.5. Stock market reaction to green bond announcements by non-financial sector companies between 2014-2019 analysed with the regional market model, global market model, regional FF3 model and global FF3 model.

Event window	CAR[36]		
	Global market model	Regional FF3 model	Global FF3 model
[0]	0.063 %	0.069 %	0.016 %
[0, 1]	-0.136 %	-0.164 %	-0.158 %
[-1, 0]	-0.050 %	-0.056 %	-0.114 %
[-1, 1]	-0.248 %	-0.290 %	-0.288 %
[2, 5]	-0.104 %	-0.047 %	-0.095 %
[-5, -2]	-0.275 %	-0.405 %	-0.059 %

[35] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.

[36] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.

[-5, 5]	-0.667 %	-0.821 %**	-0.442 %

Differences between regions

Table A3.6. Stock market reaction to green bond announcements in Europe, North America, Japan, and other countries analysed with the global market model.

Event window	**Global market model CAR[37]**			
	Europe	North America	Japan	Other[38]
[0]	-0.078 %	-0.058 %	-0.321 %	0.037 %
[0, 1]	-0.136 %	-0.272 %	-0.915 %*	0.024 %
[-1, 0]	-0.016 %	-0.493 %*	-1.021 %**	-0.021 %
[-1, 1]	-0.061 %	-0.707 %*	-1.615 %**	-0.035 %
[2, 5]	0.165 %	-0.110 %	-0.958 %*	0.801 %*
[-5, -2]	0.128 %	0.345 %	0.355 %	0.609 %
[-5, 5]	0.263 %	-0.472 %	-2.445 %*	1.350 %*

Table A3.7. Stock market reaction to green bond announcements in Europe, North America, Japan, and other countries analysed with the regional FF3 model.

Event window	**Regional FF3 model CAR[39]**			
	Europe	North America	Japan	Other[40]
[0]	-0.084 %	-0.001 %	0.084 %	0.013 %
[0, 1]	-0.242 %*	-0.156 %	-0.148 %	0.049 %
[-1, 0]	-0.096 %	-0.443 %*	-0.588 %	0.018 %
[-1, 1]	-0.255 %	-0.599 %*	-0.821 %*	0.054 %
[2, 5]	-0.004 %	-0.059 %	-0.690 %	0.691 %
[-5, -2]	0.081 %	0.422 %	0.235 %	0.423 %
[-5, 5]	-0.082 %	-0.235 %	-1.423 %	1.056 %*

[37] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
[38] Includes the following countries:
[39] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
[40] Includes the following countries:

Table A3.8. Stock market reaction to green bond announcements in Europe, North America, Japan, and other countries analysed with the global FF3 model.

Event window	**Global FF3 model CAR[41]**			
	Europe	North America	Japan	Other[42]
[0]	-0.096 %	-0.035 %	-0.298 %	0.083 %
[0, 1]	-0.158 %	-0.218 %	-0.437 %	0.178 %
[-1, 0]	-0.098 %	-0.402 %	-0.496 %	0.204 %
[-1, 1]	-0.161 %	-0.585 %*	-0.635 %	0.300 %
[2, 5]	0.180 %	-0.168 %	0.556 %	0.842 %*
[-5, -2]	0.296 %	0.350 %	0.730 %	0.813 %
[-5, 5]	0.315 %	-0.403 %	0.651 %	1.955 %***

[41] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
[42] Includes the following countries:

Effects of bond credit rating

Table A3.9. Stock market reaction to GB issuance by credit rating based on the global market model.

Event window	**Global market model CAR[43]**		
	Investment grade	Junk	No rating
[0]	-0.149 %*	-0.141 %	0.234 %
[0, 1]	-0.132 %	-1.304 %**	0.138 %
[-1, 0]	-0.335 %**	-0.200 %	0.283 %
[-1, 1]	-0.310 %*	-1.364 %**	0.187 %
[2, 5]	0.268 %	0.349 %	0.030 %
[-5, -2]	0.392 %**	-1.755 %*	0.706 %
[-5, 5]	0.383 %	-3.105 %**	0.962 %

Table A3.10. Stock market reaction to GB issuance by credit rating based on the regional FF3 model.

Event window	**Regional FF3 model CAR[44]**		
	Investment grade	Junk	No rating
[0]	-0.129 %	-0.007 %	0.219 %
[0, 1]	-0.127 %	-1.323 %***	0.185 %
[-1, 0]	-0.289 %**	-0.363 %	0.215 %
[-1, 1]	-0.290 %*	-1.679 %***	0.181 %
[2, 5]	0.097 %	0.563 %	0.090 %
[-5, -2]	0.362 %*	-1.682 %*	0.543 %
[-5, 5]	0.238 %	-3.315 %**	0.848 %

[43] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.
[44] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.

Table A3.11. Stock market reaction to GB issuance by credit rating based on the global FF3 model.

Event window	**Global FF3 model CAR**[45]		
	Investment grade	Junk	No rating
[0]	-0.191 %**	0.104 %	0.305 %
[0, 1]	-0.163 %	-1.055 %*	0.367 %
[-1, 0]	-0.373 %***	-0.045 %	0.580 %*
[-1, 1]	-0.345 %*	-1.203 %*	0.643 %**
[2, 5]	0.345 %*	0.886 %	-0.095 %
[-5, -2]	0.460 %**	-0.831 %	0.869 %
[-5, 5]	0.459 %	-1.147 %	1.417 %**

[45] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.

Effect of listing status

Table A3.12. Stock market reaction to GB issuance by companies that are themselves listed, their parent company is listed or their ultimate parent company is listed, based on the global market model.

Event window	**Global market model CAR**[46]		
	Directly listed	Parent is listed	Ultimate parent is listed
[0]	-0.032 %	0.073 %	-0.218 %
[0, 1]	-0.204 %	-0.025 %	-0.203 %
[-1, 0]	-0.075 %	-0.243 %	-0.263 %
[-1, 1]	-0.239 %	-0.341 %	-0.248 %
[2, 5]	0.419 %*	-0.013 %	-0.330 %
[-5, -2]	0.125 %	0.835 %*	-0.162 %
[-5, 5]	0.378 %	0.334 %	-0.733 %

Table A3.13. Stock market reaction to GB issuance by companies that are themselves listed, their parent company is listed or their ultimate parent company is listed, based on the regional FF3 model.

Event window	**Regional FF3 model CAR**[47]		
	Directly listed	Parent is listed	Ultimate parent is listed
[0]	-0.044 %	0.110 %	-0.144 %
[0, 1]	-0.224 %	-0.039 %	-0.077 %
[-1, 0]	-0.092 %	-0.290 %	-0.224 %
[-1, 1]	-0.275 %	-0.439 *%	-0.157 %
[2, 5]	0.349 %	0.018 %	-0.215 %
[-5, -2]	0.160 %	0.796 %*	-0.036 %

[46] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.

[47] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.

[-5, 5]	0.329 %	0.223 %	-0.406 %

Table A3.14. Stock market reaction to GB issuance by companies that are themselves listed, their parent company is listed or their ultimate parent company is listed, based on the global FF3 model.

Event window	**Global FF3 model CAR[48]**		
	Directly listed	Parent is listed	Ultimate parent is listed
[0]	-0.124 %	0.175 %	-0.092 %
[0, 1]	-0.249 %	0.278 %	-0.149 %
[-1, 0]	-0.054 %	-0.153 %	-0.211 %
[-1, 1]	-0.180 %	-0.050 %	-0.268 %
[2, 5]	0.544 %**	0.163 %	-0.168 %
[-5, -2]	0.348 %	1.068 %*	0.128 %
[-5, 5]	0.712 %*	1.181 %	-0.308 %

[48] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.

Effects of maturity type

Table A3.15. Stock market reaction to GB issuance by maturity type, based on the global market model.

Event window	**Global market model CAR**[49]		
	At maturity	Callable	Perpetual/ callable
[0]	-0.154 %	0.110 %	0.179 %
[0, 1]	-0.281 %*	0.021 %	0.350 %
[-1, 0]	-0.090 %	-0.290 %	-0.327 %
[-1, 1]	-0.207 %	-0.379 %	-0.157 %
[2, 5]	0.296 %	0.051 %	-0.406 %
[-5, -2]	0.426 %	0.066 %	0.516 %
[-5, 5]	0.534 %	-0.262 %	-0.047 %

Table A3.16. Stock market reaction to GB issuance by maturity type, based on the regional FF3 model.

Event window	**Regional FF3 model CAR**[50]		
	At maturity	Callable	Perpetual/ callable
[0]	-0.118 %	0.119 %	-0.026 %
[0, 1]	-0.214 %	-0.028 %	-0.068 %
[-1, 0]	-0.057 %	-0.329 %*	-0.586 %*
[-1, 1]	-0.153 %	-0.476 %**	-0.628 %
[2, 5]	0.129 %	0.108 %	-0.449 %
[-5, -2]	0.341 %	0.052 %	0.497 %
[-5, 5]	0.349 %	-0.316 %	-0.580 %

[49] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.

[50] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.

Table A3.17. Stock market reaction to GB issuance by maturity type, based on the global FF3 model.

Event window	**Global FF3 model CAR**[51]		
	At maturity	Callable	Perpetual/ callable
[0]	-0.104 %	0.060 %	-0.027 %
[0, 1]	-0.161 %	-0.006 %	0.121 %
[-1, 0]	0.019 %	-0.302 %	-0.479 %
[-1, 1]	-0.039 %	-0.369 %	-0.331 %
[2, 5]	0.346 %	0.144 %	-0.734 %
[-5, -2]	0.677 %**	0.071 %	0.024 %
[-5, 5]	0.985 %**	-0.154 %	-1.040 %

[51] *, ** and *** indicates significance of the result at the 10%, 5% and 1% level respectively, as analysed with the t-test.
.

Annex 4: R script for estimating cumulative abnormal returns with the market model, including analyses of variation in stock price reactions between different years, industries, credit ratings, listing statuses and maturity types

```
#upload packages
library(tidyverse)
library(readxl)
library(lubridate)
library(broom)
library(openxlsx)

#upload data
df <- read_excel('MASTER r data.xlsx')

#rename columns
colnames(df) <- str_replace_all(colnames(df), ' ', '_') %>%
str_to_lower()

#remove arbitrary "country" column and rename "listed_country" as
"country"
df <- df %>% select(-country)

names(df)[names(df)=="listed_country"] <- "country"

# save market model equation for obtaining "normal returns"
market_model <- function(df) {
  lm(return ~ index_return, data = df)
}

# Remove "N/A" values and reformat dataframe
market_df <- df %>% drop_na() %>% group_by(ticker) %>% nest()

### estimate market model coefficients
# market model
market_df <- market_df %>% mutate(model = data %>% map(mar-
ket_model))
market_df <- market_df %>% mutate(tidy = model %>% map(tidy))

# export coefficients, st.dev, t-Stat an p-value to new dataframe
```

```
market_model_estimates <- unnest(market_df, tidy)


# upload full return timeseries for companies for calculating abnor-
mal returns
all_returns_market_model <- read_excel('MASTER r data.xlsx', 'all
returns')


# remove "N/A" values
all_returns_market_model <- all_returns_market_model %>% drop_na()


# rename columns
colnames(all_returns_market_model) <- colnames(all_returns_mar-
ket_model) %>%  str_replace(' ', '_') %>% str_to_lower()


# reformat data
all_returns_market_model$announcement_date <- as_date(all_re-
turns_market_model$announcement_date)
all_returns_market_model$date <- as_date(all_returns_mar-
ket_model$date)


# group data by company and reformat data
all_returns_market_model <- all_returns_market_model %>%
group_by(ticker) %>%
  mutate(count = row_number() - 1)


announce_dates <- all_returns_market_model %>% filter(date == an-
nouncement_date) %>%
  select(ticker, count) %>% rename(announce_date = count)


# transport data to appropriate dataframe and form date index where
annoucement date = 0


all_returns_market_model <- all_returns_market_model %>%
left_join(announce_dates)


all_returns_market_model <- all_returns_market_model %>%
  mutate(to_announce = count - announce_date) %>%
  select(-count, -announce_date)


# transport data to appropriate dataframe
all_returns_market_model <- all_returns_market_model %>%
left_join(market_model_estimates %>%
  select(ticker, term, estimate) %>%
```

```
  spread(term, estimate) %>%
  rename(intercept = `(Intercept)`,
         beta = index_return)) %>%
  select(-name)

all_returns_market_model <- all_returns_market_model%>% drop_na()

# upload full index returns data for calculating expected returns with market
index <- read_excel('MASTER r data.xlsx', sheet = 'indices long')

index <- index %>% select(date, country, return) %>%
  rename(index_return = return)

# calculate abnormal returns, AR = r - E(r)
all_returns_market_model <- all_returns_market_model %>% left_join(df %>% select(ticker, country) %>% unique())
all_returns_market_model <- all_returns_market_model %>% left_join(index %>% mutate(date = as_date(date)))
all_returns_market_model <- all_returns_market_model %>% mutate(exp_ret = intercept + beta * index_return)
all_returns_market_model <- all_returns_market_model %>% mutate(ab_ret = return - exp_ret)

# calculate CARs for each company for specific event window periods
CAR0 <- all_returns_market_model%>% group_by(ticker) %>%
  filter(to_announce==0) %>% summarise(CAR0=sum(ab_ret, na.rm = FALSE))

CAR10 <- all_returns_market_model%>% group_by(ticker) %>%
  filter(to_announce>=-1) %>% filter(0>= to_announce) %>%
  summarise(CAR10=sum(ab_ret, na.rm = FALSE))

CAR01 <- all_returns_market_model%>% group_by(ticker) %>%
  filter(to_announce>=0) %>% filter(1>= to_announce) %>%
  summarise(CAR01=sum(ab_ret, na.rm = FALSE))

CAR11 <- all_returns_market_model%>% group_by(ticker) %>%
  filter(to_announce>=-1) %>% filter(1>= to_announce) %>%
  summarise(CAR11=sum(ab_ret, na.rm = FALSE))

CAR55 <- all_returns_market_model%>% group_by(ticker) %>%
```

```
  filter(to_announce>=-5) %>% filter(5>=to_announce) %>%
  summarise(CAR55= sum(ab_ret, na.rm= FALSE))

CAR52 <- all_returns_market_model%>% group_by(ticker) %>%
  filter(to_announce>=-5) %>% filter(-2>=to_announce) %>%
  summarise(CAR52=sum(ab_ret, na.rm = FALSE))

CAR25 <- all_returns_market_model%>% group_by(ticker) %>%
  filter(to_announce>=2) %>% filter(5>= to_announce) %>%
  summarise(CAR25=sum(ab_ret, na.rm = FALSE))

all_cars <- CAR0 %>% left_join(CAR0) %>% left_join(CAR10) %>%
  left_join(CAR01) %>% left_join(CAR11) %>% left_join(CAR55) %>%
left_join(CAR52) %>% left_join(CAR25)

all_cars_long <- all_cars %>% gather("CAR", 'cumsum', -ticker)

final_cars <- all_cars_long %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
# ==========================================================
# Estimate CARs by years [2014-2016] and [2017-2019]
# establish announcement year
years <- all_returns_market_model %>% filter(to_announce == 0) %>%
select(ticker, date) %>%
  mutate(year = year(date)) %>% select(-date)

# Add other necessary variables to dataframe
all_cars_long <- all_cars_long %>%
  inner_join(df %>% select(ticker, industry, region, standardpoor,
listing, maturity) %>%unique()) %>%
  left_join(years)

industries <- df %>% select(ticker, industry_group) %>% unique()
all_cars_long <- all_cars_long %>% left_join(industries)

# Calculate CARs for 2014-2016 and 2017-2019
CAR1416 <- all_cars_long %>% group_by(ticker) %>%
  filter(2016>=year) %>% filter(year>=2014)
```

```
CAR_2014_2016 <- CAR1416 %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))

CAR1719 <- all_cars_long %>% group_by(ticker) %>%
  filter(year>=2017) %>% filter(2019>=year)

CAR_2017_2019 <- CAR1719 %>%
group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
# =========================================================
#Estimate CARs by region Europe, North America, Japan & Other
cars_oth <- all_cars_long %>%
  filter(region %in% c('OTH')) %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
cars_oth$region <- rep('OTH',nrow(cars_oth))

cars_eur <- all_cars_long %>%
  filter(region %in% c('EUR')) %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
cars_eur$region <- rep('EUR',nrow(cars_eur))

cars_us <- all_cars_long %>%
  filter(region %in% c('US')) %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
cars_us$region <- rep('US',nrow(cars_us))
```

```
cars_jp <- all_cars_long %>%
  filter(region %in% c('JP')) %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
cars_jp$region <- rep('JP',nrow(cars_jp))

cars_regional <- rbind(cars_eur, cars_jp, cars_oth, cars_us)
# ========================================================
# Calculate CARs for financial and non-financial companies (finan-
cial = "financial" under BICS, non-financial=all other)

cars_financial <- all_cars_long %>%
  filter(industry_group %in% c('1')) %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
cars_financial$industry_group <- rep('financial',nrow(cars_finan-
cial))

cars_non_financial <- all_cars_long %>%
  filter(industry_group %in% c('2')) %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
cars_non_financial$industry_group <- rep('non-finan-
cial',nrow(cars_non_financial))

cars_by_industry <- rbind(cars_financial, cars_non_financial)
# ========================================================
#Calculate differences in stock price reaction to bonds rated [AAA;
BBB-], below BBB- and non-rated
cars_aaa <- all_cars_long %>% group_by(ticker) %>%
  filter(standardpoor>=1) %>% filter(11>=standardpoor)
car_high_rating <- cars_aaa %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
```

```
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
car_high_rating$rating <- rep('investment grade',nrow(car_high_rat-
ing))

cars_b <- all_cars_long %>% group_by(ticker) %>%
  filter(standardpoor>=12)
car_low_rating <- cars_b %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
car_low_rating$rating <- rep('junk',nrow(car_low_rating))

cars_na <- all_cars_long %>% group_by(ticker) %>%
  filter(standardpoor==0)
car_no_rating <- cars_na %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
car_no_rating$rating <- rep('NA',nrow(car_no_rating))

cars_by_rating <- rbind(car_high_rating, car_low_rating, car_no_rat-
ing)
cars_by_rating
# ==========================================================
# CARs by listing status; directly listed, parent is listed or ulti-
mate parent is listed
cars_listed <- all_cars_long %>% group_by(ticker) %>%
  filter(listing==1)
car_directly_listed <- cars_listed %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
car_directly_listed$listing <- rep('directly listed',nrow(car_di-
rectly_listed))

cars_parent <- all_cars_long %>% group_by(ticker) %>%
  filter(listing==2)
```

```
car_parent_listed <- cars_parent %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
car_parent_listed$listing <- rep('parent listed',nrow(car_par-
ent_listed))

cars_ultimate <- all_cars_long %>% group_by(ticker) %>%
  filter(listing==3)
car_ultimate_listed <- cars_ultimate %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
car_ultimate_listed$listing <- rep('ultimate parent
listed',nrow(car_ultimate_listed))

cars_by_listing <- rbind(car_directly_listed, car_parent_listed,
car_ultimate_listed)
# ==========================================================
# CARs by maturity type

car_call <- all_cars_long %>% group_by(ticker) %>%
  filter(maturity==1)
car_callable <- car_call %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
car_callable$maturity <- rep('callable',nrow(car_callable))

car_perpcall <- all_cars_long %>% group_by(ticker) %>%
  filter(maturity==2)
car_per_callable <- car_perpcall %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
car_per_callable$maturity <- rep('perpetual calla-
ble',nrow(car_per_callable))
```

```
car_maturity <- all_cars_long %>% group_by(ticker) %>%
  filter(maturity==3)
car_at_maturity <- car_maturity %>%
  group_by(CAR) %>% summarise(
    estimate = tidy(t.test(x=cumsum)) %>% pull(estimate),
    t_value = tidy(t.test(x=cumsum)) %>% pull(statistic),
    p_value = tidy(t.test(x=cumsum)) %>% pull(p.value))
car_at_maturity$maturity <- rep('at maturity',nrow(car_at_maturity))

car_maturity <- rbind(car_callable, car_per_callable, car_at_ma-
turity)
# ========================================================
# export data to excel
write.xlsx(market_df, "market_df.xlsx", asTable = FALSE)
write.xlsx(market_model_estimates, "market_model_estimates.xlsx",
asTable = FALSE)
write.xlsx(all_returns_market_model, "all_returns_expected_re-
turns.xlsx", asTable = FALSE)
write.xlsx(final_cars, "all_cars_market.xlsx", asTable = FALSE)
write.xlsx(CAR_2014_2016, "cars_2014_2016_market.xlsx", asTable =
FALSE)
write.xlsx(CAR_2017_2019, "cars_2017_2019_market.xlsx", asTable =
FALSE)
write.xlsx(cars_regional, "cars_regional_market.xlsx", asTable =
FALSE)
write.xlsx(cars_by_industry, "cars_by_industry_market.xlsx", asTable
= FALSE)
write.xlsx(cars_by_rating, "cars_by_rating_market.xlsx", asTable =
FALSE)
write.xlsx(cars_by_listing, "cars_by_listing_market.xlsx", asTable =
FALSE)
write.xlsx(car_maturity, "cars_by_maturity_market.xlsx", asTable =
FALSE)
```

Annex 5: Matching procedure R script

```
# Import packages
library(tidyverse)
library(readxl)
library(lubridate)

df <- read_excel('Matching data_final.xlsx')

# Cleaner column names
colnames(df) <- colnames(df) %>% str_replace_all(' ', '_') %>%
str_to_lower()

# Filter
filter_df <- df %>%
  select(
      bloomberg_id,
      industry_index,
      country,
      currency,
      maturity_index,
      collateral_index,
      type,
      announce_date,
      `green_y/n`
    )

# filter_df$announce_date <- as.Date(filter_df$announce_date,
'%d.%m.%Y')

filter_df <- filter_df %>%
  select(-announce_date) %>%
  mutate(id = paste(industry_index, country, currency, maturity_in-
dex, collateral_index, type))

unique_ids <- filter_df %>% filter(`green_y/n` == 'y') %>% pull(id)
%>% unique()
filter_df <- filter_df %>% filter(id %in% unique_ids)

matching_df <- df %>% right_join(filter_df %>% select(bloomberg_id,
id))
matching_df$cpn <- as.numeric(matching_df$cpn)
```

```
matching_df$`maturity_(years)` <- matching_df$`maturity_(years)` %>%
replace_na(99999)

green_cov <- matching_df %>%
  filter(`green_y/n` == 'y') %>%
  select(cpn, `amount_issued_(eur/usd/sek)`, `maturity_(years)`) %>%
  drop_na() %>%
  cov(use = 'complete.obs')

browns <- matching_df %>%
  filter(`green_y/n` != 'y') %>%
  select(bloomberg_id, id, cpn, `amount_issued_(eur/usd/sek)`, `ma-
turity_(years)`)

greens <- matching_df %>%
  filter(`green_y/n` == 'y') %>%
  select(bloomberg_id, id, cpn, `amount_issued_(eur/usd/sek)`, `ma-
turity_(years)`)

ids <- greens %>% pull(bloomberg_id)

main_df <- tibble()

for (i in ids) {
  g <- greens %>% filter(bloomberg_id == i)
  b <- browns %>% filter(id == g$id)

  if (nrow(b) != 0){
    m_distance <- mahalanobis(
      b %>% select(cpn, `amount_issued_(eur/usd/sek)`, `ma-
turity_(years)`),
      colMeans(g %>% select(cpn, `amount_issued_(eur/usd/sek)`, `ma-
turity_(years)`)),
      MASS::ginv(green_cov),
      TRUE
    ) %>% tibble()
    b <- b %>% select(bloomberg_id, id) %>% add_column(m_distance)
%>%
      group_by(id) %>% nest()
    g <- g %>% select(bloomberg_id, id) %>% left_join(b)
```

```
    if (nrow(main_df) == 0) {
      main_df <- g
    } else {
      main_df <- main_df %>% union_all(g)
    }
  }
}

main_df <- main_df %>%
  mutate(
    closest = map(data, ~filter(.x, m_distance == min(m_distance,
na.rm = TRUE)) %>%
                    pull(bloomberg_id)))

main_df <- main_df %>% unnest(closest)

# write to excel
write.xlsx(main_df, "matches_final.xlsx", asTable = FALSE)
```