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Master Thesis Financial Economics

'The contribution of sustainability to bond performance'

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Abstract

In order to quantify the green bond premium, green bonds and traditional bonds will be matched for the research period from 2014 - 2018. Three indicators will be used to assess the performance of these bonds: total return, excess return and the Sharpe ratio. Using panel data, t-tests and regression analysis several conclusions can be drawn: green bonds outperform traditional bonds when assessing excess return, and Sharpe ratio, the outperformance is 0.103 and 0.244, respectively. In contrast, green bonds underperform compared to traditional bonds when assessing total return (-0.267). As excess return and the Sharpe ratio take the risk-free rate, market conditions, and risk-adjusted returns into account, these results outweigh the total return results. Therefore, the conclusion of a significant contribution of sustainability to the performance of traditional bonds can be drawn. For the key stakeholders this means that investors without a specific responsible investing objective could also become interested in investing in green bonds and empirical evidence can now support decision makers' assessment of responsible investment policies. These findings can be seen as an essential step towards mobilizing capital in a sustainable direction.

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Table of Contents

1. Introduction

'Each of us must learn to work not just for his or her own self, family or nation, but for the benefit of all humankind. Universal responsibility is the real key to human survival'
Dalai Lama - 1999

As a consequence of President Trump's recent announcement of the United States' withdrawal from the Paris climate accord, concerns about failing to meet the agreements have grown. This accord was signed by 195 governments confirming the participation to keep the global temperature increase well below 2 degrees Celsius compared to pre-industrial level and pursue efforts to limit it to 1.5 degrees Celsius by 2020.

In order to meet these agreements, law and regulation force organizations and citizens to devote more effort to behave 'socially responsible' through 'corporate social responsibility' and 'individual social responsibility.'

For decades, academics have been trying to establish a clear definition for corporate social responsibility. As defined by Davis (1960), corporate social responsibility refers to when corporations engage in actions and decision-making processes beyond their profit-making interest. Eells et al. suggest that corporate social responsibility refers to the conflicts that arise when corporate enterprises cast their shadow on society, this negatively impacts the relation between corporations and society and results in the necessity to refine ethical principles in society (Eells et al., 1961). The word 'social' in corporate social responsibility has also been elaborately debated and the direction as to whom the corporation is responsible is lacking. As a matter of fact, every 'stakeholder' of a firm, which means every individual who has a claim, interest, or stake in the firm's practices and decisions has this responsibility (Carroll, 1991).

The quoted concept of the Dalai Lama could be interpreted as individual social responsibility and refers to the individual human being being responsible for his or her actions affecting communities outside his or her immediate circle. Haigh & Hazelton (2004) argue that both socially responsible investment funds and shareholder resolutions lack the ability to induce long-term desired environmental and social outcomes when trying to address social problems by targeting individual firms. They argue that both mechanisms are unable to create significant corporate or systematic change. Therefore, larger entities must take action in order to mobilize capital in a sustainable direction, as addressing issues at a broader level would provide a legitimate basis for the claim that firms' practices can be improved by socially responsible investments.

The global financial market can be seen as being powerful enough to induce such a change. As a response to the financial markets' responsibility, the European Investment Bank introduced their cooperation by issuing a €600 million 'green bond' in 2007. This issue was the start of a new asset class aimed at financing investments focusing on climate change mitigation or adaption to reduce vulnerability to environmental changes (Morel, 2012). Green bond issuance gained popularity by the introduction of the Green Bond Principles (GBP)[1] in 2014. This is a set of criteria constructed by the Climate Bond Initiative (CBI)[2] to assess whether a bond can be labelled as green. This development contributed to transparency and market integrity.

In summary, environmental sustainability will be researched, assessing the contribution of greenness to the performance of bonds. This will be done by means of a comparison between green bonds and traditional bonds. As only a small amount of research is focused on the quantitative performance of green bonds, this research aims to find an answer to the following research question:

To what extent does sustainability contribute to the performance of bonds?

In order to structure the research, several hypotheses are formed and discussed.

Hypothesis 1:
Greenness does contribute to bond performance as it creates a higher total return compared to traditional bonds

Hypothesis 2:
Greenness does contribute to bond performance as it creates a higher excess return compared to traditional bonds

[1] GBP: Green Bond Principles, from now on Green Bond Principles will be abbreviated
[2] CBI: Climate Bonds Initiative, from now on Climate Bonds Initiative will be abbreviated

Greenness will be assessed with the use of the Bank of America Merrill Lynch Green Bond Index[3]. This index keeps track of the performance of debt issued by quasi-governments and corporations. The proceeds of the issue are to be used entirely for projects that promote environmental sustainability purposes. An increase in green bond issuance in the past years and the expected substantial issuance in the near future have caused and cause the interest in the green bond market to increase, thereby contributing to the development of this index. Both total return and excess return depict performance of a bond (Brinson, 1995). While seeking income from investing, exclusively focusing on a bond's yield is not enough, as this does not account for the activity of the dividends or distributions. Therefore, also the total return must be considered (Bloomberg, 2018). Total return is the actual rate of return over a given evaluation period and consists of two parts of return: firstly, income from interest paid by fixed income investments, dividends or distributions and secondly, capital appreciation, associated with principal fluctuation. Total return is expressed as a percentage of the amount invested, it is used to analyze an organization's historical performance, and it is an important metric in evaluating and determining future returns of a security.

Excess return is the return of an investment exceeding the risk-free rate and can also be used to assess returns that exceed a particular benchmark or the risk-free rate. Bloomberg defines excess return as a security's return minus the return from a risk-free security during the same period. When the excess returns are positive, this indicates that the investment outperformed the benchmark or risk-free rate, vice versa, negative excess returns indicate underperformance of the investment compared to the benchmark or risk-free rate. The excess returns show the added value of the portfolio or investment manager. In this case, the BofA ML Green Bond Index uses the German government bond to calculate excess return (Bloomberg, 2018).

A portfolio or security might outperform a particular benchmark, which can be found using excess return. However, if this outperformance also includes taking more risk, the excess return metric would not account for this. Therefore, the Sharpe ratio will also be researched; this metric represents the risk-adjusted return of a portfolio or security. It

[3] Bank of America Merrill Lynch will be abbreviated to BofA ML

measures how much average return is obtained in excess of the risk-free rate for each theoretical unit of total risk (Ambrosio, 2007). The Sharpe ratio is defined as the most commonly used metric for the calculation of the risk-adjusted return of a security. By means of the Sharpe ratio the individual bond's performance can be isolated by subtracting the risk-free rate from the mean return. If a portfolio has no risk, this portfolio has a Sharpe ratio of zero. Generally, the higher the value of the Sharpe ratio, the higher the risk-adjusted return and the more attractive the security.

Hypothesis 3:
Greenness does contribute to bond performance as it generates a higher Sharpe ratio compared to traditional bonds

Measures of risk adjustment and performance evaluation allow investors to compare the expected financial returns associated with differing levels of risk and enable investors to make a choice between different investments (Dowd, 2000). The Sharpe ratio can also be referred to as reward-to-variability ratio (Israelsen, 2004).

The green bonds, subtracted from the BofA ML Green Bond Index, will be matched to comparable traditional bonds, based on their issuer, currency, and maturity. The focus will be on a particular part of the developed market of the green index. Specifically, the index will be filtered researching only the United States Dollar, Euro and British Pound universe of bonds in the index. In order to conduct a matching procedure, several assumptions will be necessary. Also, the variables composite rating, effective duration, and face value will be taken into account. The assumptions for the matching procedure will be discussed in Section 4, in which the methodology will be discussed.

Contribution to existing literature
In order to meet the Paris accord agreements, CBI (2017) reports and Christiana Figueres[4] state that the green bond market should reach $1 trillion of issuance by 2020. Latest reports show an aggregate of $895 billion issues in 'climate-aligned bonds' in 2017,

[4] Christiana Figueres was appointed Executive Secretary of the UN Framework Convention on Climate Change (UNFCCC) in 2010 and dedicates herself to rebuilding fairness, transparency and collaboration in the global climate change negotiation process.

of which only a part is labelled as 'green bond'. At the current rate of growth in issuance, the stated target of $1 trillion will be reached (CBI, 2017). The findings of this thesis will influence global investor interests in sustainable bonds, as well as firms' issuance decisions, and the global financial market as a whole. Eventually, more clarity regarding law and regulation for the member countries of the Paris climate accord will be gained. Consequently, this will increase decision makers' ability to assess responsible investment policies in order to meet the Paris climate accord. The continuing growth of the green bond market has the potential to entice both sustainability driven and traditional fixed income investors, this emphasizes the importance to quantify the sustainability premium (Kochetygova, 2014), as the financial return of a bond investment is seen as the ultimate criterion for investing in a particular asset. While researching whether investing in green bonds is attractive even for investors without a specific socially responsible investing focus, Lewis and Mackenzie argue that there exists no direct trade-off between investors' morals and the financial return from their investments, but they argue that investors are willing to sacrifice part of the financial return in order to align the return with their morals (Lewis & Mackenzie, 2000). Also, Renneboog argues that for socially responsible investors suboptimal financial returns seem acceptable as this enables them to pursue their ethical objectives (Renneboog et al., 2008). Moreover, investors are increasingly expecting fair treatment, timely information, transparency, and reliable forecasting in addition to competitive returns on their investments (Paine, 2003).

Despite a lot of information on socially responsible investing and the trend of an increasing focus on social responsibility, neither of these researches quantify the sustainability premium. This forms an important gap in the existing literature, and therefore it will be useful to research this sustainability premium.

This research seems to find evidence for a positive contribution of sustainability to traditional bond performance, measured with three different performance metrics. The results seem to be robust for various definitions of the concepts used and different performance indicators. This thesis' objective to quantify the green bond premium is achieved. Concerning excess return and the Sharpe ratio, the contribution of sustainability is 0.103 and 0.244, respectively. Concerning total return the contribution of sustainability is negative; -0.267.

In the absence of the quantification of the green bond premium, it will be difficult for investors and regulators to enforce sustainability objectives on civil society (Ross, 2018). With the findings of this thesis, individual investors can be sure to obtain a positive significant excess return and Sharpe ratio to their investment in green bonds. These findings imply that investors without a specific responsible investing objective could also become interested in investing in green bonds. With these conclusions, it is expected that the green bond demand will increase. With the knowledge of the advantages associated with issuing green bonds for issuing institutions, these institutions might become more prone to issue green bonds than to issue traditional bonds. Consequently, the global green bond market is expected to grow. Moreover, decision makers' assessment of responsible investment policies can now be supported by empirical evidence. This evidence can be seen as an essential leap towards mobilizing capital in a sustainable direction.

While researching three hypotheses; the total return, excess return and Sharpe ratio differentials between investing in green bonds and investing in traditional bonds, this thesis aims to research the contribution to the performance of a bond if the bond is considered to be green. In this thesis, the definition of green is the definition that the BofA ML Green Bond Index employs, which means the green bonds in this index are self-labelled as green and they have no explicit GBP or CBI alignment. To come to an elaborate answer to the research question, the remainder of this research is organized as follows: Section 2 contains a theoretical framework by means of a literature review about green bonds, also the empirical research and the relevance of this research question will be discussed. Subsequently, Section 3 will describe the data used for the research and will contain an elaborate explanation of the relevant concepts. Section 4 contains the research objectives and the methodology. Thereafter, the results obtained through the application of the methodology will be analyzed and discussed in Section 5. In Section 6, several robustness checks will be conducted and discussed, after which Section 7 contains a conclusion with appropriate interpretations of the results and discusses the limitations of this thesis. The final Section will contain a discussion and several directions for future research.

2. Theoretical framework

In this section the most relevant concepts, as well as a summary of existing literature will be discussed. The previously mentioned conceptual ambiguity regarding social responsibility, greenness and responsible investing might not cause problems at first glance. It might mean that the concepts mentioned are studied elaborately, that many people have put their mind to it, and van Vaerenberg (2007) suggests that this is 'a sign of research progress and dynamism'. On the other hand, clarity on different definitions is necessary when aiming to come to a clear conclusion to answer the research question.

2.1 Ethics

Ethics can be defined as the perception of what is right and fair behavior or conduct (Carroll, 1991 & Freeman et al., 1988). While finance relies primarily on the quest for financial return and gain, which can easily become greed (Boatright, 2013), it is expected that only a minor proportion of investors is willing to sacrifice gain when the investment is 'socially responsible'. However, nowadays, it seems that ethical behavior 'sells' and unethical behavior is punished by corporate image loss and shareholder activism. An increasing number of investors is trying to incorporate at least some of the sustainability factors into their decision-making processes. The drivers behind investors' ethical behavior will be explained later on in this Section.

2.2 Corporate social responsibility - CSR

In addition to the previously explained definitions of Davis (1960) and Eells (1961), McWilliams (2015) explains CSR as 'actions of firms that contribute to social welfare, beyond what is required for profit maximization'. As numerous explanations of CSR have been suggested, measurement and theoretical development is challenging.

Companies engaged in corporate social responsibility may gain from a number of benefits as a result of this behavior. Many issuers of green bonds, for example, benefit from positive marketing stories, strengthened reputation, the alignment of CSR with their funding scheme and a more diversified investor base, when they offer a security satisfying investor's objectives to include sustainability in their investment portfolio (Bloomberg New Energy Finance, 2014). The majority of these advantages follow from the fact most people have an investment preference for firms that are reliable, fair, honest, and considerate (Cacioppe et al., 2011). However, the perception of threat to financial returns when considering ethics in investment decisions might be of greater magnitude.

2.3 Environmental, Social and Governance criteria - ESG

The ability of investors to identify drivers of the return and expected risk of investments is considered a crucial aspect in achieving a financial return and evaluating the investments' performance metrics. Certain issues are not assessed by traditional financial metrics and are difficult to measure in monetary terms, however, they do affect the expected financial return and risks of investments, these issues are called environmental, social and governance issues (ESG) (CFA Institute, 2015). The theory of responsible investment is defined as integrating these issues in the investment decision-making process. Munoz-Torres et al. (2004) describe socially responsible investments as investments enabling investors to combine their morals with their financial objectives, these investors combine money and social values in their decision-making. Eccles (2010) states that responsible investment can be defined as integrating the ESG issues in the investors' investment practices with the objective to increase the risk-adjusted financial returns of the investment. Figure 1 shows the ESG factors in detail.

Figure 1: ESG responsibilities in detail

Environmental issues	**Social issues**	**Governance issues**
Climate change and carbon emissions	Customer satisfaction	Board composition
Air and water pollution	Data protection and privacy	Audit committee structure
Biodiversity	Gender and diversity	Bribery and corruption
Deforestation	Employee engagement	Executive compensation
Energy efficiency	Community relations	Lobbying
Waste management	Human rights	Political contributions
Water scarcity	Labor standards	Whistleblower schemes

Source: CFA Institute (2015)

The incorporation of ESG data in investors' decision-making processes and portfolio management is one of the most important trends in the past decade (Verheyden, 2016). Despite this, several reasons complicate the consideration of ESG issues in the investment decision process; ESG issues can often be measured, but it is difficult to assign monetary value to them and the integration into quantitative models is hard. Also, a lot of investors seem to have relatively short term horizons, whereas long-term financial performance is mainly affected by ESG issues. For ESG investing, consistent reporting methods or standards are lacking, and ESG related disclosure is limited and unverified, which makes it difficult to compare investments. Ideally, standardized criteria should be constructed, as the Green Bond Principles (GBP) are criteria for the label for 'green' bonds.

Hoepner (2010) researches firms' ESG ratings and their specific risk and concludes that there exists a significantly negative relationship between these two, although Halbritter (2015) mitigates this finding by taking the rating provider into account, which significantly influences the magnitude and direction of the impact of the rating. The responsible investing landscape is changing; in the past, investing responsibly meant adopting negative screening methods, excluding certain types of investments. When analyzing socially responsible portfolios in 1992-2007, Statman & Glushkov (2009) conclude that the exclusion of socially undesirable products associated with tobacco, gambling, alcohol, military, firearms, and nuclear operations from the portfolio, results in a return disadvantage relative to conventional portfolios. Nowadays, Caplan et al. (2013) argue that an increasing emphasis on research techniques, seeking or encouraging specific characteristics in portfolio companies, has changed the world of responsible investing. Positive screening methods, which means screening for the presence of desirable characteristics associated with corporations rather than for the absence of undesirable characteristics, have become popular. Nofsinger & Varma (2014) conclude that posing ESG criteria on investment decisions dampen downside risk during market crises periods. The reasoning behind this is that corporations exhibiting ESG responsibilities are less likely to suffer from sizeable negative ESG related events and enjoy better relations with communities and governments. Although the debate on the compatibility of ESG criteria with corporate financial performance has continued for academics and practitioners for more than 40 years, Friede et al. (2015) mainly conclude that the vast majority of research they evaluate shows positive findings when investigating the ESG - corporate financial performance relation. This study merges the conclusions of approximately 2,200 different studies, and finds a stable positive correlation patterns between ESG and corporate financial performance in the in primary studies since the mid-1990s.

In summary, this means positive environmental, social, and governance factors have become important over the past years, and as MSCI argues, the term ESG investing can be used interchangeably with sustainable investing and socially responsible investing.

The Environmental responsibility (E)

Russo et al. (1997) find that firms with high scores of environmental performance perform significantly better in terms of financial performance and this relation strengthens with industry growth. In their research, Russo et al. test the resource-based view, a theory which states that firms are represented by a set of different capabilities and resources that could form a source of competitive advantage. The findings suggest that environmental social responsibility is a basis for sustainable competitive advantage. In addition, Dowell et al. (2002) present evidence that multinational firms with poor global environmental standards have much lower market values than firms with strong standards.

The Social responsibility (S)

Despite the fact that investors have been including social criteria into their investment decisions for decades, the social factor in ESG is considered to be the most difficult to measure and is therefore difficult to incorporate in the investment decision-making process. O'Connor (2017) argues that only 14% of 'social' rating products provided by the Global Initiative for Sustainability Reporting target an investor audience (as opposed to 97% of 'environmental' rating products and 80% of 'governance' rating products). The research suggests that either investors are reluctant to believe that these factors will enhance financial returns or that it is primarily the social factors that make ESG challenging to use in investments.

The Governance responsibility (G)

The most recent set of concerns when evaluating the sustainability of a firm involves corporate governance, in which the assessment of the firm's capacity to response to a wide range of relevant stakeholders is incorporated (Moir, 2001). Related to strong corporate governance mechanisms, Bhojraj et al. (2003) identify multiple benefits for bond investors, as effective governance mechanisms decrease the possibility of conflicts of interest between the management of the issuing company and the capital providers. The possibility of misallocation or expropriation of funds can be reduced through effective monitoring of the management's actions. Thereby, improving the firm's disclosures and productivity and forcing management of the issuing company into expanding their planning horizon and thereby avoiding short-termism. As a consequence, the firm's default risk decreases, which is favorable for bondholders.

Although the ESG framework and including ESG in the investment process gained a lot of attention in the past decade, this thesis will only focus on environmental sustainability. It is more difficult to assign monetary value to the social and governance responsibilities and these factors are also more difficult to incorporate in the investment decisions of investors.

2.4 Sustainable Development Goals

Another, more elaborate set of tools to incorporate social responsibility in civil society can be found in the Sustainable Development Goals (SDGs). In September 2015, 17 global goals to end poverty, protect the planet and ensure prosperity for all, were developed. 193 member states of the United Nations approved to pursue efforts to reach the Sustainable Development Goals in 2030. These 17 goals include 169 separate targets and these goals serve as the successors of the, in 2015 ended, Millennium Development Goals (MDGs). The SDGs do not differentiate between developed and developing countries, as the MDGs did; the SDGs apply to all countries. Each goal includes a list of specific targets to be achieved in the 15 years following 2015 (UN, 2015). Sustainable development can be defined as economic growth that is environmentally sound (Sachs, 2006). The SDGs are shown in Figure 2. A more detailed framework can be found in Appendix Figure 1.

Figure 2: Sustainable Development Goals

Criticisms

Critics of the SDGs argue that the expansion of the MDG's eight goals to the SDG's 17 goals would reduce advocacy community's ability to focus attention on any of them. As 169 targets would be impossible to remember, they argue, it would be difficult to create accountability around any of them. Pradhan et al. (2017) argue that the SDGs provide a multidimensional view on development. Therefore, interactions among the SDGs may result in disparate results. They propose a systematic framework in order to assess whether goals create a synergy or a trade-off to each other and they claim the goals cannot be seen as additions to each other. Rather, it should be seen as a synergistic re-enforcement system. As opposed to the first critique, the study finds that within the SDGs framework, there exist more synergies than trade-offs. This also refutes another critique; the fact that some of the goals seem to compete with one another. In contrast, opponents of the SDGs argue that the SDGs are a better version of the MDGs as the SDGs tackle the causes of the problems, while the MDGs only addressed the problems. Also, they state that the interconnectedness of the goals is a positive development, as synergies exist. The costs of achieving the SDGs are also a point of discussion. As the Guardian (2015) argues that ending poverty will cost $1.4 trillion per annum and this is just one of the goals. While estimates vary, the UN Conference on Trade and Development states the achievement of the goals would cost an annual amount of $2.5 trillion, and the Economist estimates the costs at $2 - $3 trillion per year over 15 years, consisting of public and private money.

This is roughly 4% of the world's GDP or approximately 15% of annual global savings (The Economist, 2015). Experts agree that whether achievement of the SDGs is realistic, depends on their implementation.

ESG and SDG

Active ESG engagement and strong management can help channel finance to where it is required in order to achieve the SDGs. While the SDG framework is a more elaborate framework compared to ESG, there is an important difference. ESG only assesses corporate social responsibility, while SDG also encourages civil society to cooperate, however, the two still have many overlapping objectives. Institutions incorporating ESG factors in their business obviously perform better in terms of ESG scores. These ESG scores can be used as an investment indicator and investors can link these ESG scores to broader SDG investing objectives. Busch et al. (2016), argue that the integration of ESG criteria in investors' investment decision-making processes is increasingly gaining popularity, however, concerning organizational reality, an obvious shift towards more sustainable activities and projects seems to remain absent. They state two main challenges. As also explained in the ESG Section, firstly, it is essential that the trustworthiness of the ESG data increases. Secondly, a shift in expectation setting is necessary: investors must focus on the long-term return profile of sustainable investments, rather than expecting short-term returns. As investors' objective in investing is to incorporate SDGs in their investment decisions of investors and these SDGs are due in 2030, this reorientation to the long-term paradigm is more realistic. Nowadays, the incorporation of sustainability in investment decisions is conducted using ESG factors and scores provided by institutions like Sustainalytics, a global player in the ESG research field, who provides ratings for investors. In the near future, however, a shift towards incorporating SDGs into the investment decisions will arise, as an increasing number of institutions, such as Oekom, also research and provide ratings based on SDGs for investors. They have an extensive collection of impact data relating to an institution's products, and production processes and with this data, they assess the institution's positive or negative impacts on the SDGs. The UN's Principles for Responsible Investment report (2017) shows a rising trend of engagement in SDG's incorporation into risk management. The notions of risk and performance have become broader, and the widely endorsed SDG agenda gives investors new language and processes to drive ESG engagement.

2.5 Individual social responsibility - ISR

This concept is not as widely known and researched as CSR; however, it will be important in this thesis. Bénabou et al. (2009) define ISR as the individual behaving prosocially. Prosocial behavior includes all behavior that benefits society and is motivated by three different forces. The first one is intrinsic altruism, people who have a genuine, natural selfless concern for others' well-being, this is an internal motivation factor. More internal motivation factors can be found in a person's social- or self-esteem concerns, the psychology behind this argues that people view their conduct as the definition of what kind of person they are, in the eyes of others, as well as their own eyes. Self-image concerns are important motivators; people act prosocially partly to reassure themselves that they are good people. Thirdly, material incentives play a role in behaving prosocially. Depending on law and regulation of the country the investors live in, they may benefit from tax-deductibility associated with philanthropic behavior. This can be seen as an external motivation factor for prosocial behavior. In addition to the previously mentioned findings by Lewis and Mackenzie that investors are willing to invest their money in line with their morals, Chava (2010) finds evidence that investors expect significantly higher returns on bonds of firms with potential environmental problems. Vice versa, one would expect that investors are prepared to sacrifice a part of their expected return as their investment is socially responsible. In contrast, Rosen (1991) finds that investors are reluctant to sacrifice financial returns in order to achieve socially responsible behavior, although the questioned investors in Rosen's research do value companies involved in socially responsible behavior. Investors may be confronted with an internal conflict with the trade-off between material (financial) gain to investing and their psychological gain when deciding to invest responsibly. Obviously, the premium of investing responsibly must be positive, in order to incentivize investors to involve in socially responsible investments, an even larger positive premium is necessary for the investors who do not have socially responsible investment objectives.

Several researchers argue that the definitions in the field of sustainability seem to differ for every individual (Cacioppe et al., 2011). This research only briefly discusses the controversy over these concepts and shortly discusses the benefits for corporations engaging in sustainable actions. Also, as most research focuses on the public shareholders' role in addressing the climate change problem and changing corporate policy in a more sustainable manner (Scholtens, 2006), this thesis will concentrate on the *individual* investors' impact on this change by researching the effect sustainability has on the performance of bonds. By investigating whether investing sustainably could be more attractive compared to traditional bonds from a financial return perspective, this could potentially move financial flows in a sustainable direction. Financial institutions and investors can be seen as having the crucial role in the allocation of capital through their financing function (Busch et al., 2016). Especially investors' investment decisions can be seen as primary drivers to re-allocating capital towards sustainable investments.

3. Data description

In this section, several important concepts concerning the data used in the research will be explained, as well as the data collection process for the different bond categories, namely traditional bonds and green bonds.

3.1 Bonds

A bond is a fixed income security; it is a contract between the bond issuer, who borrows funds and the bondholder, who lends funds. The issuer is obliged to pay the bondholder in several ways: the interest, called the coupons, on defined dates and the face value on the maturity date. Issuing bonds provides issuers with the opportunity to finance long-term investments for which the existing funds of the issuer are insufficient. Another way to achieve this goal is by issuing stock. The major difference between bonds and stocks is that stockholders buy equity of the issuing company; therefore, they have an ownership stake in the company, whereas bondholders buy debt of the issuing company and thus become creditors of the company, they are lenders. Another difference is that bonds have a pre-specified date at which the face value of the bond is repaid, which is referred to as the maturity date, while stocks usually have an infinite outstanding period.

When comparing stockholders' and bondholders' expectations in terms of financial returns on their investment, the risks involved in the investment must be taken into account. Stockholders benefit when the issuing company performs well, alternatively, they suffer a loss when the company performs poorly. A bonds' coupon payment date is pre-determined, as well as its coupon rate; the bondholder knows what to expect in terms of financial return. Also, in case of corporate bankruptcy, bondholders take priority over stockholders in terms of repayment. Therefore, stocks are considered to be riskier investment securities than bonds in terms of volatility and risk the investor is taking while investing. Fixed income markets are considered to play an essential role in enabling finance to move in the direction of sustainable projects, as they represent the deepest pool of long-term capital. As a result of the growing green bond market, the issuer base and ratings diversity of issuers also grow, not only satisfying investor's growing incorporation of environmental standards in their investment decisions, but potentially also satisfying additional investment considerations, such as social and governance factors.

3.2 Green bonds

The aggregate amount of green bond issuance of corporations and quasi & foreign governments is the second largest in the global green bond universe, while sovereign or sub-sovereign government account for the largest stake. Also, corporations and quasi & foreign governments increasingly attempt to diversify their funding sources and investor base (Kochetygova et al., 2014), therefore, this thesis focuses on corporate bonds and quasi & foreign government bonds. Corporate bonds are bonds issued by corporations and they are considered to have a higher risk compared to government bonds. This is because the corporate issuer's capacity to meet financial commitments can vary significantly, resulting in a wider range of ratings for corporate bonds. Consequently, interest rates for corporate bonds tend to be greater compared to government bonds. In November 2013, Vasakronan was the first corporation to issue a green bond (CBI, 2013). The Swedish property company states that it aims to take further steps towards mobilizing debt capital markets for climate change (Vasakronan, 2016). Quasi-government bonds are issued by the government through various political subdivisions. Most of them are not secured by collateral and do not have government guarantees. Their credit ratings are very high due to extremely low historical default rates. The unique characteristic of green bonds is that the proceeds are invested in projects that generate environmental benefits and, therefore, create the ability to mobilize resources from financial markets for climate change adaptation. Other bond characteristics of green bonds are comparable to those of traditional bonds, except for the fact that green bonds have some additional transaction costs involved, due to the fact that issuers must monitor and report on the usage of the proceeds from the green bond issuance. The previously mentioned corporations' benefits resulting from the issuance of green bonds offset the additional transaction costs of issuers issuing green bonds (CBI, 2017). The Green Bond Principles identify several categories for the use of proceeds of green bonds; renewable energy (this is the most developed segment), energy efficiency, low carbon transport, sustainable water, waste and pollution, agriculture and forestry, climate adaptation. The CBI argues that investors benefit from the fact that well-understood and well-managed projects reduce the exposure to risk of the investment and investing in green bonds results in deeper engagement with the issuers' management on green causes. However, the credibility of the issues is very important. A system of environmental due diligence is necessary, as specialist expertise is needed and it is costly for individual investors to assess the 'greenness' themselves. The 'greenness' of a bond is assessed by the issuer and whether a green bond is assigned to the green bond label by the Climate Bonds Standards depends on whether the bond meets the Green Bond Principles. In 2017, almost 25% of the climate-aligned bond universe consisted of labelled green bonds ($221bn) (CBI, 2017).

From January 1st, 2014 until April 30th, 2018, all bonds from the BofA ML Green Bond Index were extracted from Bloomberg, this gives 5,985 bonds to start with. These bonds are considered 'green', when the issuer either self-labels its bond as 'green' or identifies it as an environmental sustainability-oriented bond issue with clear additional statements about the commitment to deploy funds towards projects and activities in the Green Bond Principles use of proceeds categories. As the data is monthly and multiple bonds stay in the index for more than one month, this number does not contain unique bonds solely. The research period is chosen as Phil Galdi[5] argues that in 2013 the amount issued of green bonds exceeded the aggregate issued amount of the six years before,

[5] Head of Bank of America Merrill Lynch Global Bond Index Research

which is significant, however, in 2014 this volume more than doubled. Supranational issuers with an AAA-rating initially dominated the BofA ML Green Bond Index, and the first qualifying green corporate issuer entered the market in November 2013. In 2014, the contribution of corporate issuers grew and in November 2014, one-third of the index capitalization consisted of corporate issuers. This is also an argument for the chosen research period starting in 2014, as corporate issues improve the diversity of the index. With the development of corporate green bond issuers, whose bonds are included in the index, the average credit rating of the index decreased to AA2, adding incremental spread (Galdi, 2014). For bonds to qualify for the index, the use of proceeds must be entirely used for activities or projects promoting the mitigation of climate change or plans for adapting to climate change. When an issuer of general debt is active in the green industry, this does not mean the bonds issued by this issuer automatically apply as green bonds, therefore, these bonds are not included in the index. Debt of corporate and quasi-government issuers are included in the index, while securitized and collateralized securities are excluded. Qualifying securities must have a fixed coupon schedule, at least one-month remaining term to final maturity as of the rebalancing date, and a minimum of 18 months to the maturity date at the issue date. The bond is also required to have an investment grade rating, which is based on the average rating of the three rating agencies, taking the Moody's, Standard & Poor's and Fitch's ratings for the calculation. The index excludes issues lower than €250 million, £100 million and $250 million. The exclusion of all currencies but the United States dollar (USD), the Euro (EUR) and the British Pound (GBP) is chosen as this simplifies the research and focuses on a particular part of the developed markets' green bonds. These selection criteria reduce the number of green bonds by nearly 22 percent to 4,695 green bonds. Compliance with the GBP on the use of proceeds is only credible when 100% of the proceeds are aligned with the green categories previously mentioned. However, Bloomberg does not require additional reporting on project selection or management of proceeds for the bond to be included. As the International Capital Market Association argues in their Summary of Green Fixed Income Indices Providers report, the Green Bond index has no explicit GBP or CBI alignment. The green bond selection process can be found in Table 1. The analysis starts with an initial set of 5,985 green bonds. As a result of the filtering, the green bond dataset includes 4,694 bonds.

Table 1 - Green Bond selection process

Selection of Green Bonds from the Bank of America Merrill Lynch Green Bond Index

Selection criteria		Number of bonds
Time period	January 1st 2014 - April 30th 2018	5,985
Currency	Excluding anything but USD, EUR, GBP	4,695
No information	Eliminate bonds with no data on maturity	4,694
Total		4,694

3.3 Traditional bonds

When comparing traditional bonds to green bonds, the main difference lies in the fact that the proceeds an issuer receives from issuing traditional bonds can be used for any investment in the operations of the corporation. Two different indices will be used and subtracted from Bloomberg to match to the green bonds from the BofA ML Green Bond Index. For the selection of these indices, it is necessary to use indices matching the Green Bond Selection of only USD, EUR and GBP, therefore, the Barclay's Corporate & Government Master Index (B0A0) is chosen for the USD part and the Pan-Europe (PE00) part of the Global Broad Market Index (GBMI) is chosen for the EUR and GBP part. Both indices include corporates and quasi & foreign government organizations. The Barclay's Corporate & Government Master Index shows 452,544 bonds and the Pan-Europe index shows an initial number of bonds for the chosen research period of 278,021 bonds. Again, note that these numbers do not include unique bonds only, as this is monthly data and bonds tend to stay in an index for longer than one month, there will be duplicates. The exclusion of bond issues lower than $250 million, €250 million and £100 million is applied, as well as the filter on sector level: corporates and quasi & foreign governments. The traditional bond selection process can be found in Table 2.

Table 2 - Traditional Bond selection process

Selection of Traditional Bonds from the Pan-Europe (PE00) and Barclay's Corporate & Government Master Index (B0A0)

Selection criteria		Number of bonds
Time period	January 1st 2014 - April 30th 2018	730,565
Currency	Excluding anything but USD, EUR, GBP	728,605
Minimum value	Excluding < $250 mn, €250 mn, £100 mn	728,605
Composite rating	Investment grade	728,605
Sector Level	Corporates & Quasi and Foreign Governments	647,817
No information	Eliminate bonds with no data on maturity	647,816
Total		647,816

3.4 Descriptive statistics

In this section, the distribution of green bonds regarding several characteristics of the dataset will be discussed and visualized. Table 3 shows the distribution of green bonds split out per year, sector level 1, currency and composite rating. Sector level 1 is the first level of the four-tier BofA ML bond index schedule that classifies issuer's sectors. Level 1 designates the sector asset class. A matching procedure is conducted to match each green bond to a comparable traditional bond. From this, 2,015 pairs of matched bonds are obtained. The matching procedure will be explained in detail in Section 4.1.

Table 3 - Distribution of green bonds

Distribution of green bonds by several bond characteristics: panel (a) gives information on the distribution of the 2,015 green bonds according to the year, note that 2018 only ranges from January 1st to April 30th. Panel (b) gives a division per sector level 1, panel (c) shows by currency and panel (d) by composite rating. Each panel shows the number of bonds and the percentage of the category of the whole sample.

(a) By year	N°	%
2014	169	8%
2015	297	15%
2016	539	27%
2017	744	37%
2018	266	13%
Total	*2,015*	*100%*
(b) By sector level 1	**N°**	**%**
Quasi & Foreign Government	1,210	60%
Corporate	805	40%
Total	*2,015*	*100%*
(c) By currency	**N°**	**%**
USD	1,022	51%
EUR	943	47%
GBP	50	2%
Total	*2,015*	*100%*
(d) By composite rating	**N°**	**%**
AAA	1,006	50%
AA1	176	9%
AA2	52	3%
AA3	81	4%
A1	148	7%
A2	260	13%
A3	186	9%
BBB1	60	3%
BBB2	43	2%
BBB3	2	0%
Total	*2,015*	*100%*

Panel (a) shows that more than one third of the data sample's green bonds are from 2017. Regarding the number of green bonds in the index from 2014 to 2017, one can conclude that this index is growing as an increasing number of green bonds are included. It is common knowledge that the global green bond market is growing and thus, this increasing amount of green bonds in the BofA ML Green Bond Index is not surprising. Also, the labelled green bond market has grown within the green bond universe, unfortunately, this cannot be derived from the Table, nor from the data sample used in this thesis. From panel (b), the division of Bloomberg's defined sector level 1 shows that the data sample is predominantly issued by quasi & foreign government institutions. This is in line with the latest CBI report (2017). As previously mentioned, this is because corporations started entering the green bond market in 2014, while government-related institutions and banks started issuing green bonds in 2007 already. The distribution according to currency can be found in panel (c), it shows that just over half of the sample is comprised of United States Dollar issues (51%). 46% of the sample is comprised of Euros and only a small part of the sample of British Pounds; the sample is mainly comprised of USD and EUR issues. In the global green bond market, CBI argues that the USD and EUR currencies account for nearly 50 percent of the global green bond issuance, and the Chinese yuan accounts for 32 percent. As we only included USD, EUR and GBP denominated bonds, this shows that the sample used in this research is representative for the USD, EUR and GBP segment of the global green bond market (CBI, 2017). Note that the currency of a bond refers to the bond's denomination and it is independent of the country of the issuer. The same conclusion as of that of sector level 1 can be drawn from panel (d), the distribution in composite rating, predominantly AAA rated institutions issue green bonds in this data sample and it is only recently that the average composite rating of this index decreased, as corporations started issuing green bonds, which were included in the index. Other green bond indices come to the same conclusion, the Global Green Bond Index shows a AAA dominated universe (30%), the AA rated institutions in the index account for 18% compared to 16% in the sample this research uses. A rated institutions account for 25% compared 29% in this sample. Lastly, BBB accounts for 15% in the Global Green Bond Index, whereas in this sample 5% of the included institutions have a BBB rating (MSCI Environmental Finance, 2018). In summary, the entire green bond data sample is comprised of investment grade bonds. The data sample includes bonds ranging from prime to lower medium grade bonds; all in the investment grade universe. This means that the issuer's capacity to meet financial commitments ranges from the extremely strong to adequate, from which the bond's creditworthiness can be derived.

In Table 4 the distribution based on country of issuance, a more detailed sector level and the term to maturity is shown. Almost 25 percent of green bonds is issued by a supranational, abbreviated to SNAT in the country panel of Table 4. Two or more governments can create a supranational, which is an entity with international accords, with the objective is to incentivize member countries to create economic development. After this, Germany, France, and the United States are large green bond-issuing countries. The supranationals and these three countries account for 66 percent of the green bond sample issuance. Sector level 4 is the fourth level of the four-tier BofA ML bond index sector classification schema, it designates the sector sub-category. Regarding sector level 4, the supranationals account for the most substantial stake (29 percent), followed by the banking sector (26 percent) and the government guaranteed sector (14 percent), these three account for almost 70 percent. Overall, from these tables, it can be concluded that the supranationals play an essential role in the green bond issuance. Similar statistics are found by Zerbib (2018), who argues that government-related bonds, national and supranational agencies account for 30% of the total labeled green bond market, and 32% are bonds issued by financial institutions. Of the term to maturity, which is calculated from the 24th of May, 2018 until the maturity date, almost 20 percent of the green bonds in the sample have matured at this base date, showed by a negative term to maturity. The vast majority of nearly 60 percent has a short-term to maturity from the base date, which is defined as 0 to 5 years. More than 20 percent have a medium-term to maturity from the base date (5 to 10 years) and only a negligible amount of bonds exceed the 10 years to maturity, they are considered to have a long term to maturity. These year segments are chosen following the CBI report (2017).

Considering the characteristics of the green bond sample data as presented below and discussed, multiple characteristics seem in line with the global green bond market (the increase in green bonds over the years, the sector level distribution, both sector level 1 and sector level 4, the currencies, the composite rating and the term to maturity). This makes the dataset representative for the global green bond market, enables to draw conclusions from and is reliable enough for testing posed hypotheses.

Table 4 - Distribution of green bonds

Distribution of green bonds by several bond characteristics: panel (a) gives information on the country* of issuance of the 2,015 green bonds and panel (b) gives a division per sector level 4. Panel (c) shows the term to maturity calculated from May 24th, 2018. Each panel shows the number of bonds and the percentage of the category of the whole sample.

(a) By country*		N°	%
AU	Australia	12	1%
CA	Canada	54	3%
CN	People's Republic of China	56	3%
DE	Germany	381	19%
ES	Spain	13	1%
FI	Finland	4	0%
FR	France	282	14%
GB	United Kingdom	3	0%
IT	Italy	7	0%
JP	Japan	49	2%
KR	Republic of Korea	36	2%
NL	Netherlands	175	9%
NO	Norway	90	4%
PL	Poland	1	0%
SE	Sweden	43	2%
SNAT	**	457	23%
US	United States	213	11%
XB	Brownland	126	6%

(b) By sector level 4	N°	%
Agency	210	10%
Auto Loans	11	1%
Banking	521	26%
Electric-Integrated	129	6%
Foreign Sovereign	1	0%
Government Guaranteed	274	14%
Local-Authority	132	7%
Non-Electric Utilities	60	3%
REITs	52	3%
Supranational	586	29%
Tech Hardware & Equipment	31	2%

(c) Term to maturity (from 5/24/2018)			
Matured	<0 years	375	19%
Short	0-5 years	1,183	59%
Medium	5-10 years	419	21%
Long	10+ years	38	2%

* NATO country codes used

** SNAT country stands for supranational

3.5 Index

An index can be defined as a market-capitalization-weighted basket of a fixed set of securities, and it serves as an aggregate measure of investment performance that corrects for non-recurring events of individual components to identify economy-wide drivers of the market (Lo, 2015). As previously mentioned, a comparison between the green bond universe from the BofA ML Green Bond Index and comparable traditional bonds will be made. The performance of these bonds will be measured utilizing total return, excess return, and the Sharpe ratio.

There are several important limitations of comparability between traditional bond indices and green bond indices (Kochetygova, 2014); the green bonds' aggregate outstanding amount in the research period differs significantly and disables the investor to draw conclusions concerning bond performance from. The fact that the currency mix in the green bond indices in the research period has been unstable, also creates a comparison problem, as this could add volatility to the index. The credit rating distribution differs significantly and differences in the maturity profile of the index complement this concern. To overcome these limitations, a comparison on individual bond level will be made. The currency distribution comparison can be found in the descriptive statistics tables previously shown, as well as the credit rating distribution.

3.6 PE00 index & B0A0 index

The Pan-Europe Broad Market Index is one of the indices used to find a match to each individually selected green bond in the Green Bond Index. This index keeps track of the investment grade debt's performance denominated in a European currency and publicly issued in the Eurobond or European domestic markets, including securitized and collateralized securities, as well as sovereign, corporate, and quasi-government securities. The US Corporate & Government Index keeps track of the investment grade debt's performance denominated in the US dollar and publicly issued in the US domestic market, including US agency, US Treasury, corporate, supranational, and foreign government securities. This index enables to find a match to US Dollar bonds in the Green Bond Index. Qualifying securities must have an investment grade rating, based on the average rating of the three rating agencies, taking the Moody's, Standard & Poor's and Fitch's ratings for the calculation. The remaining term to the maturity date must be one year for qualifying securities, moreover, a fixed coupon schedule and a minimum of 18 months to the maturity date at the issue date are required. For US Treasuries, the B0A0 index requires at least $1 billion as the outstanding amount and for all other securities, this amount is a minimum of $250 million. The PE00 index requires callable perpetual securities to be at least one year from their first call date in order to qualify. When fixed-to-floating rate securities are at least one year from the last call prior to the date the bond transforms from a fixed to a floating rate security and are callable within the fixed rate period, these also qualify. As this index is a European index, it will qualify for matching to the Euro (€) and British Pound (£) bonds in the Green Bond Index. For the B0A0 index applies that original issue zero coupon bonds are included in the Index, but bills, inflation-linked debt and strips are excluded. Also, the qualifying coupon securities' outstanding amounts are not reduced by any portions that have been stripped. As these indices have many overlapping criteria to which bonds qualify as a member of the index, and these criteria also match to those of the Green Bond Index, matching between these three indices seems valid.

3.7 Total return

The definition of the performance variable as stated in the first hypothesis; total return is explained in this section. Total return is a yield measure for which it is essential to make an assumption about the reinvestment rate. It is computed by adding the total coupon payments plus interest to the projected price at the maturity date, and dividing this number by the amount invested. This metric is obtained monthly from Bloomberg. Total return is calculated with this formula:

$$Total\ return = \frac{sum\ of\ all\ coupons + interest + principal\ fluctuation}{amount\ invested} \cdot 100\% \quad (1)$$

The monthly contribution of sustainability to the total return of traditional bonds is defined as follows:

$$\delta\ TR = TR\ sustainable\ bonds\ -\ TR\ traditional\ bonds \quad (2)$$

This measure will later be referred to as total return differential. For the hypothesis regarding total return to hold, this equation must be positive. In formula:

$$\delta\ TR > 0 \quad (3)$$

Concerning total return, there are two different types of analyzing this metric; horizon analysis, for the assessment of the performance by means of the total return over a specified investment period, and horizon return, which refers to when the investment horizon is used in the calculation of the total return. A drawback of using total return as a performance measure is that it requires assumptions about future yields, the reinvestment rate, as well as to think in terms of an investment horizon, these assumptions need to be made by the investor, which is a difficult task.

3.8 Excess return

Another performance indicator will be used to assess the contribution of sustainability to traditional corporate bonds; this is the excess return. This metric is also obtained monthly from Bloomberg. Excess return is calculated as follows:

$$Excess\ return = R - R_b \qquad (4a)$$

$$Excess\ return = R - R_{rf} \qquad (4b)$$

Where:

R: total return of the security (%)

R_b: return of the benchmark (%)

R_{rf}: risk-free rate (%)

During the month, the cash flows of the fair value government securities are discounted by the corresponding spot rates derived from the par coupon fair value yield curve. Each bond's total return is calculated in the hedge basket and multiplied by the bond's initial weight. The bond's total return minus the sum of the weighted hedge security total returns is calculated to arrive at the excess return (Bloomberg, 2018); the total return percentage of a risk-matched basket of governments is subtracted from the total return percentage of a bond. For the synthetic securities used for this calculation the corresponding denominated currency of the bond is taken into account. The hedge basket and the bond are matched using effective duration at six key points on the curve: 6-month, 2-year, 5-year, 10-year, 20-year, and 30-year (Bloomberg, 2018).

The contribution of sustainability to the excess return of traditional bonds will be defined as follows:

$$\delta\ ER = ER\ sustainable\ bonds - ER\ traditional\ bonds \qquad (5)$$

This measure will later be referred to as excess return differential. For the hypothesis regarding excess return to hold, this equation must be positive. In formula:

$$\delta\ ER > 0 \tag{6}$$

3.9 Sharpe ratio

As previously explained, the Sharpe ratio is a more elaborate metric for assessing performance; it adjusts the return for the risk of the security. Following Consolandi et al. (2008), who argue that the Sharpe ratio shows a two-dimensional performance metric, the Sharpe ratio will be included in the research, as the return in excess of the risk-free rate divided by the risk involved in the investment is measured. When the expected returns of the bonds do not have a normal distribution, the Sharpe ratio can show incorrect values. This is when there is skewness or Kurtosis in the distribution of the variables (Johnson & Soenen, 2003). In Section 4.2 the skewness and Kurtosis of all variables will be checked. For this research, it is essential to differentiate the systematic risks, which exist in the bond market and impact the risk profile of most securities, from the unsystematic risks that impact the individual securities and have a negligible effect on a diversified portfolio (Litterman, 1991). In order words, especially when comparing individual bonds incorporating a risk metric is important. The Sharpe ratio in formula:

$$Sharpe\ ratio = \frac{r_p - r_f}{\sigma_p} \tag{7}$$

Where:

r_p is the expected return

r_f is the risk-free rate of return

σ_p is the standard deviation of return

The contribution of sustainability to the Sharpe ratio of traditional bonds will be defined as follows:

$$\delta\ SR = SR\ sustainable\ bonds - SR\ traditional\ bonds \tag{8}$$

This measure will later be referred to as Sharpe ratio differential. For the third hypothesis to hold, the Sharpe ratio differential must be positive, in formula:

$$\delta\ SR > 0 \tag{9}$$

When comparing ethical to non-ethical funds, Statman et al. (1993) used the Sharpe ratio to evaluate the performance of 31 ethical funds to 62 non-ethical funds of equal asset size. The findings show that ethical funds performed better than traditional funds, although the difference was not statistically significant (Statman et al., 1993). Also, Kreander et al. (2005) evaluate the Sharpe ratio of funds considered to be ethical compared to a matched counterpart and find that ethical funds depicted a higher value than their comparable equivalent fund in the case of 17 funds. However, also in this research, the result of the ethical fund outperformance of a mean of 0.034 was not significant.

4. Empirical methodology

4.1 Matching

A data sample from Bloomberg of the green bond universe will be used and matched to traditional bonds. Following Zerbib (2017) and Renneboog et al. (2008), the matching method will be applied. This is a useful technique for analyzing the intrinsic value of a specialized financial instrument and will be conducted using several bond characteristics: issuer, currency, and maturity. Matching is a statistical technique to assess the impact of a treatment by comparing the treated and non-treated observations in an observational study, in this case the 'treatment' is whether the nature of the bond is considered green or not. The OECD (2015) states that when an issuer issues both green bonds and traditional bonds, the characteristics of these green bonds are identical to those of similar traditional bonds. These characteristics include the yield at the issue date and the credit-worthiness of the bond. This 'flat-pricing', the fact that issuers are not able to realize pricing advantages through green bonds, can be explained by the fact that investors are unwilling to pay a premium simply for the ability to invest 'green' (Bloomberg New Energy Finance, 2014). This OECD (2015) statement is queried in this thesis.

All bond issues lower than €250 million, £100 million and $250 million are automatically excluded. Also, bonds with missing information on their maturity date, currency and ISIN code are excluded. After these criteria, 4,694 green bonds remain in the research.

The traditional bond sample is selected from the PE00 and B0A0 indices. The sample is filtered by the following dates: January 1st, 2014 until April 30th, 2018 to ensure matching possibilities with the green bonds extracted from Bloomberg.

Certain assumptions need to be made to be able to conduct matching. The issuer and currency of the green bond and traditional bond must be identical, however, for the term to maturity a range of one year is assumed to be acceptable. Thus, the traditional bond maturity may differ from that of the green bond by six months at most. Therefore, the remaining term of the bond in years is calculated with two decimal places and half a year will be added and subtracted to this number to create a range. Note that also bonds with a remaining term of a number below 0 can be included in the data sample. These are bonds that are matured, the maturity date is in the past, and these can be included as long as they can be matched to a traditional bond with a similar term to maturity.

A unique code for every green bond is created including TICKER[6], currency, and maturity. With this unique code, the traditional bond indices will be searched to find a match. After a match has been found, the green bond ISIN code and the traditional bond ISIN code will be compared, as it might be the case that the green bond unique code found an exact match in the traditional bond universe. This can be possible as the green bond can also be included in one of the traditional bond indices. Therefore, the ISIN[7] codes cannot be the same. After assuring the green bonds did not match to themselves in the traditional bond index, 2,015 green bonds were matched to 2,015 traditional bonds. This reduces the initial green bond data sample by 66 percent. An example of several green bond-traditional bond matches can be found in Appendix 1.

There are several ways to code variables, one of them is to use dummy variables, it means the baseline category is coded with a zero, and the other category with a one. In this case, the traditional bond sample is coded with a zero and the green bond sample with a one.

[6] TICKER symbol: the letters that identify a company's securities, this is unique for every company

[7] ISIN code: International Securities Identification Number, this is unique for every security and consists of a two or three letter prefix identifying the country of the issuer, followed by a nine digit national security ID and a check digit

4.2 Variables

Utilizing STATA for statistical tests, first, the dependent variables will be summarized, and the two main ways in which the distribution of these variables can deviate from the normal distribution will be analyzed. The lack of symmetry, skewness, and the pointiness of the distribution, Kurtosis will be analyzed. In a normal distribution, skewness and Kurtosis show values of zero. The summarized results of this analysis are shown in Table 5 and Appendix 2.

Table 5 - Summary Statistics

Panel (a) provides a summary of the statistics of the green bond sample, panel (b) for the traditional bond sample and panel (c) for the total sample. The statistics considered are N for number of observations, mean, standard deviation, minimum value, median, maximum value, skewness and Kurtosis.

Bond Class	Total Return	Excess Return	Sharpe ratio
(a) Green			
N	2,015	2,015	2,015
Mean	0.081	0.058	0.185
St.Dev.	0.701	0.365	1.109
Min	-5.218	-3.204	-6.679
Median	0.042	0.032	0.110
Max	4.592	2.617	6.508
Skewness	-0.382	-0.036	0.210
Kurtosis	11.712	16.100	9.684
(b) Traditional			
N	2,015	2,015	2,015
Mean	0.348	-0.045	-0.059
St.Dev.	1.155	0.431	1.074
Min	-5.897	-4.198	-5.771
Median	0.260	0.000	0.000
Max	5.544	1.370	3.548
Skewness	-0.355	-3.107	-1.445
Kurtosis	8.659	22.962	9.536
(c) Total			
N	4,030	4,030	4,030
Mean	0.215	0.007	0.063
St.Dev.	0.965	0.403	1.098
Min	-5.897	-4.198	-6.679
Median	0.120	0.017	0.060
Max	5.544	2.617	6.508
Skewness	-0.190	-1.982	-0.557
Kurtosis	10.519	21.578	9.810

Skewness measures the degree of asymmetry of the distribution of the probability of a random variable about its mean. When utilizing these variables for the statistical tests, normality in the distribution of these variables is assumed. A normal distribution shows that the data is symmetric about the mean and has a skewness of zero. Thus, the variables must have a skewness close to zero. As shown in Table 5, most of the variables have a skewness close to zero, only the variable excess return of the traditional bonds (Excess Return of panel (b)) is skewed to the left. This is shown by its negative skewness of -3.107. Negatively skewed means that many scores are gathered at the tighter end and the tail points towards the more negative part of the axis of the distribution graph. A method to overcome this skewness is winsorizing; this is a transformation of the statistics to limit extreme values to reduce the effect of spurious outliers. However, as the maximum skewness only has a value of -3.107, and this is caused by one case showing a value of -4, as shown in Appendix 2, winsorizing does not seem necessary. Also, because the data is matched, winsorizing would imply losing not one observation (the outlier), but two, which would be a waste of the data. Another metric to assess the distribution of the variables is Kurtosis. Kurtosis measures the tailedness of the probability distribution of a random variable, the degree to which scores are gathered at the ends of the distribution graph, known as the tails. A positive Kurtosis has many observations in the tails and has high pikes, while a negative Kurtosis has relatively thin tails and tends to be flatter than the normal distribution. Although the Kurtosis is slightly high for some of the variables, also for this metric no correction to the variables will be made. These conclusions can also be drawn from the histograms of the variables in Appendix 2.

In Appendix 3, several boxplots can be found. A boxplot is a five-number summary of a variable showing its minimum, first quartile, median, third quartile, and maximum. It is an overview of the distribution of the data, shown in a commonly used manner. Even though no legitimate conclusions can be drawn from these boxplots, it seems that for total return the median of the traditional bonds is higher than for the green bonds, the total return of the traditional bonds also has a wider range of observations. For excess return the boxplots seem almost equal, although the excess returns median of the green bonds seems slightly higher than that for the traditional bonds. Here, the green bonds seem to have a wider range of observations, except for the one case in the excess returns traditional bond sample of approximately -4, the previously mentioned outlier. For the

Sharpe ratio a slightly higher metric for green bonds can be expected, as the median is a little bit higher for green bonds than for traditional bonds, again the green bonds seem to have a broader range of observations. In the case of total returns, these conclusions are in contrast with the hypothesis of a positive total return differential; however, the excess return and Sharpe ratio hypotheses are in line with these findings.

4.3 Paired t-tests

The paired t-test is conducted for the comparison between green bonds with their matched traditional bonds for the complete research period on the individual bond level. The formula used for the t-test is:

$$t = \frac{mean\ of\ differences}{standard\ error\ of\ differences} \quad (10)$$

$$t = \frac{\bar{d}}{SE\ (\bar{d})} \quad (11)$$

Where:

$\bar{d}$: the mean difference

$SE\ (\bar{d})$: the standard error of the differences

Under the null hypothesis of the t-test, this t-statistic follows a t-distribution with n-1 degrees of freedom. Using t-distribution tables to compare the t-value to the t_{n-1} distribution gives the p-value of the paired t-test and will allow drawing conclusions from (Shier, 2004). With a paired t-test two population means can be compared. There are two samples, in which the observations of the one sample can be matched to the observations of the other sample. In this case, a comparison of two different methods of 'treatment' will be made, and the 'treatment' is the nature of the bond, namely green or traditional. The hypotheses of the t-test are as follows:

H_0: mean difference = 0

H_{a1}: mean difference ≠ 0

H_{a2}: mean difference > 0

H_{a3}: mean difference < 0

For this test to be valid, several assumptions need to be checked. The first assumption is that the dependent variable (total return, excess return or Sharpe ratio) should be continuous, this means measured at the interval or ratio level. In this case, we have ratio variables; the independent variables are interval variables. This means that the variables have a zero point, indicating there is none of that variable. The second assumption is that the independent variable should consist of two categorical, related groups or matched pairs, the latter is true for this research. The non-existence of significant outliers in the differences between the pairs is assumed in the third assumption. Significant outliers reduce the accuracy of the results, as they have a negative effect on the paired t-test. Assumption four is that the differences need to be approximately normally distributed, thus, no extreme outliers. As discussed in the previous section and shown in Table 5 and Appendix 2, assumptions three and four hold in this case and therefore, the paired t-test can be used to draw conclusions from for this research. The total return, excess return and Sharpe ratio will be compared. For a two-tailed t-test the boundaries for significant differences are as follows: if $t > 1.96$ and if $t < -1.96$ the differences are significant.

After this comparison, a comparison per year (2014-2018), per sector level 1 (corporate or quasi & foreign government), per currency (USD, GBP, EUR), per rating (AAA – BBB3) will be analyzed and discussed.

4.4 Regression analysis

Consequently, a more elaborate analysis will be performed, using regression analysis. Before these tests can be conducted, the data must be transformed into panel data. Panel data allows to control for variables that are time-varying but not change across entities, or variables that cannot be observed. Therefore, panel data resolves individual heterogeneity. Panel data allows for multilevel or hierarchical modeling, as variables can be included at different levels of analysis. In this case the entity or panel is ‘pair’ and this is ‘balanced’, which means that all pairs have complete data. This is not surprising as all bonds with non-complete information were removed from the data sample. The methodology uses a fixed-effects model, this is a model used to explore the impact of time-varying variables. Fixed-effects models analyze the relationship between predicting variables (the independent variables) and dependent variables within an entity. In this case, the entity is a matched pair of bonds. An assumption of the fixed-effects model is that the predictor variables; the independent variables may be influenced by each entity having its own individual characteristics. When using fixed-effects models it is also assumed that the either the independent, or the dependent variables are impacted or biased by something within the data and controlling for this effect is necessary. Hereby, the assumption of the correlation between entity's error term and the independent variables is explained. By using fixed-effects models the effect of the time-invariant characteristics are removed, thereby making it possible to assess the net effect of the predictors on the outcome variable. Fixed-effects model assume another important characteristic; the time-invariant characteristics are unique to the individual and should not be correlated with other individual characteristics. As each entity is different, the entity's constant and error term, capturing individual characteristics, should not be correlated with the others. When a correlation between the error terms exists, the fixed-effects models results are not suitable for drawing conclusions, as these results may be incorrect. The formula for a fixed-effects regression is:

$$Y_{it} = \alpha_i + \beta_1 X_{it} + \cdots + \beta_k X_{kt} + u_{it} \quad (12)$$

Where:

Y_{it} is the dependent variable, i depicts the entity and t is the time

α_i is the unknown intercept for each entity (n entity-specific intercepts)

$\beta_1$is the coefficient for the corresponding independent variable

X_{it} is one independent variable

u_{it} is the error term

The βs in the formula indicate how much Y changes when X changes by one unit and are referred to as the coefficients of the regressors. When including the previously mentioned Dummy to distinguish between the nature of the bond, either green or traditional, the formula becomes:

$$Y_{it} = \alpha_i + \beta_1 X_{it} + \cdots + \beta_k X_{kt} + \gamma_1 DUMMY_1 + u_{it} \quad (13)$$

Where:

γ_1 is the coefficient for the binary repressor (dummy for nature of the bond)

$DUMMY_1$ is the dummy for the nature of the bond, namely green or traditional, since this is a binary variable, in this model n-1 dummies are included.

Again, the γ in the formula is the coefficient indicating how much Y changes when the DUMMY becomes one; when the bond is considered green. The fixed-effects regression model is used to check the paired t-test results and to add more meaning to the conclusion; regressions allow to include control variables, while t-tests do not.

4.5 Control variables

Following Becker's (2005) recommendations regarding usage of control variables, a brief explanation for the reason behind each selected control variable and why this variable could be a biasing factor is necessary. This is to assure the inclusion of the control variables is supported by prior evidence, a logical reason, or both. When the control variables are uncorrelated with the dependent variable and they are included in the in analysis, this will reduce the power of the tests. Control variables are nothing more than independent variables; they are included in the regression in the same way, only the interpretation is different. They are included in research to increase statistical power, reduce error terms, and eliminate the possibility of alternative explanations for the results (Becker, 2005). In this fixed-effects regression model, composite credit rating and effective duration will be used as control variables. As the repeated measures design cannot be performed using a t-test, the regression analysis will be used.

Composite rating will be used as control variable in the regression analysis, as Zerbib (2017) finds this variable to be a major driver of the green bond premium. The rating scheme is transformed into a numerical variable showing a value of 1 for AAA-rated bonds and 10 for BBB3-rated bonds. As previously mentioned, the composite rating is based on the average rating of the three rating agencies, taking the Moody's, Standard & Poor's and Fitch's ratings for the calculation. This sample only includes investment grade bonds. Based on each rating agency's criteria, the entity's ability to meet their financial commitments is assessed with this credit rating.

As effective duration can differ within a bond match, it will used as a control variable and included in the regression model. Duration is defined as the sensitivity of the percentage bond price change to changes in interest rates (Lyuu, 2008). In other words, duration measures the risk of changes in interest rate levels. Two bonds may have the same maturities, but the sensitivity to interest rate changes may differ when, for example, the coupon rate of the bonds is different. Investors can diversify their portfolio with differing maturities, but they can also diversify with regard to possible volatility to bond price movements as interest rate change, thus, price sensitivities. With longer duration, the bond's sensitivity to interest rate changes increases. Consequently, a portfolio with a duration, which is lower than the duration of the benchmark will outperform the benchmark when interest rates are increasing and will underperform when interest rates are decreasing. This volatility measure can be used to assess the bond's exposure to risk. A change in interest rates fundamentally changes supply and demand of money and thereby influences many assets, liabilities, securities and money markets within an economy. The current interest rate volatility, with regard to unusually low interest rates in Europe, financial markets facing a high degree of uncertainty due to exchange rate volatility, or events such as an increasing budget deficit, makes the relevance to research the degree of sensitivity of the bond's exposure to this risk grow. The duration for bonds that have embedded options is called effective duration. The fact that expected cash flows will change when interest rates change is taken into account in this metric. It is calculated as follows:

$$Effective\ duration = \frac{(P_1 - P_2)}{(2 \cdot P_0 \cdot Y)} \qquad (13)$$

Where:

P_1: the price of the bond with a decrease in yield by Y percent

P_2: the price of the bond with an increase in yield by Y percent

P_0: the bond's original price per $100 worth of face value

Y: the estimated change in yield used to calculate P_1 and P_2

5. Results

The application of the methodology allows to test for the existence and significance of a total return differential ($\delta\ TR$), the excess return differential ($\delta\ ER$) and the Sharpe ratio differential ($\delta\ SR$) between green and traditional bonds, mainly due to their difference in nature.

5.1 Total return t-test results

The output of a paired t-test shows useful descriptive statistics; the mean, standard deviation, standard errors and t-values and thereby contributes to the analysis of the two compared groups. This test calculates the differences between the two dependent variables (the green bond total return and the traditional bond total return in this case) and shows the mean of that differential. When looking at the mean column, the bonds characterized by being green show a lower mean than the traditional bonds (0.081 < 0.348). The mean difference between the two is -0.267 with a standard error of the mean of 0.029 and a standard deviation of 1.301. The t-test takes the mean difference of zero as the null-hypothesis, as can be derived from Table 6, it shows H_0: mean(diff) = 0. The t-value of -9.2062 is smaller than the threshold of -1.96 and therefore, the t-value is significant, and the null hypothesis of equal means can be rejected. This means that there exists a difference between the means of the two variables that is statistically significant. This conclusion can also be derived from the p-value associated with the alternative hypothesis of H_a: mean(diff) != 0, which is smaller than 0.05 (Pr(|T| > |t|) = 0.0000). The mean difference, in this case, is smaller than zero, namely -0.267; this means the total return differential is negative, from which can be concluded that the traditional bonds have higher total returns than the green bonds and the hypothesis regarding total returns can be rejected, as $\delta\ TR < 0$, instead of the hypothesized $\delta\ TR > 0$.

Table 6 - Paired t-test Total Return

This table provides the results of the paired t-test of Total Return. The statistics considered are number of observations, mean, standard error, standard deviation and the 95% confidence interval. The t-value and degrees of freedom, as well as the different hypotheses concering this test are shown.

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Total Return Green Bonds	2,015	0.081	0.016	0.701	0.051	0.112
Total Return Traditional Bonds	2,015	0.348	0.026	1.155	0.298	0.399
Difference	2,015	-0.267	0.029	1.301	-0.324	-0.210

mean(diff) = mean(TRRGREN - TRRTRAD)		t = -9.2062
Ho: mean(diff) = 0		degrees of freedom = 2014
Ha: mean(diff) < 0	Ha: mean(diff) != 0	Ha: mean(diff) > 0
Pr(T < t) = 0.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 1.0000

5.2 Excess return t-test results

When analyzing the paired t-test results of the excess returns in Table 7, the means show that the green bonds depict a higher mean than the traditional bonds (0.058 > -0.045). The mean difference is 0.103 with a standard error of 0.012 and standard deviation of 0.535. The null hypothesis of the mean difference of zero can be rejected, as the t-value exceeds the threshold (8.6510 > 1.96), and the alternative hypothesis of the mean difference differing from zero shows a significant p-value (Pr(|T| > |t|) = 0.0000), therefore, this alternative hypothesis is accepted. A significant outperformance of the excess return of the green bond sample compared to the excess return of the traditional bond sample can be concluded. The mean of the green bonds exceeds the traditional bonds with 0.103; thus, the excess return differential is positive ($\delta\ ER > 0$) and the second hypothesis can be accepted.

Table 7 - Paired t-test Excess Return

This table provides the results of the paired t-test of Excess Return. The statistics considered are number of observations, mean, standard error, standard deviation and the 95% confidence interval. The t-value and degrees of freedom, as well as the different hypotheses concering this test are shown.

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf	Interval]
Excess Return Green Bonds	2,015	0.058	0.008	0.365	0.042	0.074
Excess Return Traditional Bonds	2,015	-0.045	0.010	0.431	-0.064	-0.026
Difference	2,015	0.103	0.012	0.535	0.080	0.126

mean(diff) = mean(ExcessRtnGREN - ExcessRtnTRAD)		t = 8.6510
Ho: mean(diff) = 0		degrees of freedom = 2014
Ha: mean(diff) < 0	Ha: mean(diff) != 0	Ha: mean(diff) > 0
Pr(T < t) = 1.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 0.0000

5.3 Sharpe ratio t-test results

The means of the Sharpe ratio in the t-test results in Table 8 show that the mean of the green bonds has outperformed the mean of the traditional bonds (0.185 > -0.059), with a mean difference of 0.244. This mean difference has a standard error of 0.032 and a standard deviation of 1.415. The t-value of the Sharpe ratio paired t-test shows an amount of 7.7357, this exceeds the threshold of 1.96 and is, therefore, a significant outcome. Again, this conclusion can be verified by looking at the p-value of the alternative hypothesis, which assumes that the mean difference differs from zero (Pr(T > t) = 0.0000). The null hypothesis of a mean difference of zero can be rejected, and the alternative hypothesis of a mean difference not being zero can be accepted. The mean difference is significant with an amount of 0.244, and the Sharpe ratio differential is therefore positive. This means the third hypothesis, $\delta\ SR > 0$, can be accepted and when comparing Sharpe ratios, green bonds outperform traditional bonds. Recall that a higher Sharpe ratio depicts a higher risk-adjusted excess return and thus, a higher performance.

Table 8 - Paired t-test Sharpe Ratio

This table provides the results of the paired t-test of Sharpe Ratio. The statistics considered are number of observations, mean, standard error, standard deviation and the 95% confidence interval. The t-value and degrees of freedom, as well as the different hypotheses concering this test are shown.

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf	Interval]
Sharpe Ratio Green Bonds	2,015	0.185	0.025	1.109	0.137	0.233
Sharpe Ratio Traditional Bonds	2,015	-0.059	0.024	1.074	-0.106	-0.012
Difference	2,015	0.244	0.032	1.415	0.182	0.306

mean(diff) = mean(SHARPEGREN - SHARPETRAD)		t = 7.7357
Ho: mean(diff) = 0		degrees of freedom = 2014
Ha: mean(diff) < 0	Ha: mean(diff) != 0	Ha: mean(diff) > 0
Pr(T < t) = 1.0000	Pr(T > t) = 0.0000	Pr(T > t) = 0.0000

5.4 Total return regression results

When analyzing the fixed effects regression model with the dependent variables as mentioned in the hypothesis, the green bond performance compared to traditional bond performance is shown in Table 9. For this fixed effects regression the following formula is used:

$$Total\ return_{it} = \alpha_i + \gamma_1 DUMMY_1 + u_{it} \qquad (14)$$

Table 9 - Regression results

This table shows the results of the fixed effects regression model with dependent variables: total return, excess return and Sharpe ratio between green and traditional bonds. In this table, three regression are performed. Dummy is 1 for green bonds and 0 for traditional bonds.

Variables	(1) Total return	(2) Excess return	(3) Sharpe ratio
Dummy	-0.267***	0.103***	0.244***
	(0.029)	(0.012)	(0.032)
Constant	0.348***	-0.045***	-0.059**
	(0.021)	(0.009)	(0.024)
Observations	4,030	4,030	4,030
Number of Pair	2,015	2,015	2,015

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

The values depicted by 'Dummy' demonstrate what happens to the dependent variable in the top row when 'Dummy' becomes one instead of zero. In the first regression, the total return decreases by 0.267 when the 'Dummy' becomes one, and this means when the bond is green, the total return decreases by 0.267. The asterisks (*) depict the significance level, where the Dummy of total return shows three asterisks, the value is significant at the 99% confidence interval. The standard errors are shown between brackets, and this value is very close to zero. The average difference between the observed values compared to the regression line are showed by the standard errors. The smaller the values for this metric, the better; this illustrates smaller distances to the regression line. Analyzing standard errors has the advantage of showing the precision of the model's usage of the dependent variable used for predictions of the model. The constant term is the value at which the regression line crosses the y-axis, and for the first regression, the constant is also significant at the 99% confidence interval. These findings are in contrast with the hypothesis concerning total returns, as $\delta\, TR < 0$. The second and third regression results will be discussed in the excess return and Sharpe ratio regression results sections.

The conclusions from the first three regressions are equal to those of the t-test conclusions. Only the total return hypothesis is rejected, the excess return and Sharpe ratio hypotheses are accepted. As explained in the methodology section, the control variables composite rating and effective duration will be included to see if these variables influence the conclusions.

Table 10 - Regression results with control variables

This table shows the results of the fixed effects regression model with dependent variables: Total return, Excess return and Sharpe ratio between green and traditional bonds. In this table, three regressions are performed. Dummy is 1 for green bonds and 0 for traditional bonds. Composite Rating and Effective Duration are control variables in this regression. Composite Rating is a numerical variable ranging from 1 (AAA) to 10 (BBB3)

Variables	(1) Total return	(2) Excess return	(3) Sharpe ratio
Dummy	-0.255***	0.115***	0.271***
	(0.030)	(0.012)	(0.033)
Composite Rating	0.035	0.001	0.013
	(0.024)	(0.010)	(0.026)
Effective Duration	0.118***	0.071***	0.178***
	(0.037)	(0.015)	(0.041)
Constant	-0.280	-0.367***	-0.887***
	(0.185)	(0.076)	(0.200)
Observations	4,030	4,030	4,030
R-squared	0.046	0.046	0.038
Number of Pair	2,015	2,015	2,015

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Concerning Table 10, the fixed effects regression formula is:

$$Total\ return_{it} = \alpha_i + \beta_1 Composite\ Rating_{1t} + \beta_2 Effective\ Duration_{2t} + \gamma_1 DUMMY_1 + u_{it} \quad (15)$$

The first regression shows a negative 'Dummy' again; total returns decrease by 0.255 (significant at 99% confidence level) when the bond is green compared to when the bond is traditional. When looking at composite rating, this rating is coded to a numerical value ranging from 1 for AAA-rated bonds to 10 for BBB3-rated bonds. When the value of composite rating increases by 1 (meaning the rating decreases by one level), the total return increases by 0.035. This is logical, as investing in a lower rated bond includes more risk-taking and therefore, a higher return is expected. However, the variable is not significant. When effective duration increases by one, total return is increased by 0.118 (significant at the 99% confidence interval). The constant for this regression is not significant and also has a high standard error.

5.5 Excess return ratio regression results

For this regression the following formula is used:

$$Excess\ return_{it} = \alpha_i + \gamma_1 DUMMY_1 + u_{it} \qquad (16)$$

Table 9 also shows the results of this regression. When the 'Dummy' variable in this regression becomes one, when the bond is characterized as being green, the excess return increases with 0.103, which is statistically significant at the 99% confidence interval. Also, this value has a small standard error. The constant is also statistically significant at the 99% confidence interval and has an even lower standard error. This means the hypothesis concerning the excess return can be accepted as the green bond excess return outperforms the traditional bond excess return ($\delta\ ER$ >0).

When analyzing the regression with control variables (Table 10), the formula used is:

$$Excess\ return_{it} = \alpha_i + \beta_1 Composite\ Rating_{1t} + \beta_2 Effective\ Duration_{2t} + \gamma_1 DUMMY_1 + u_{it} \qquad (17)$$

The 'Dummy' is positive as in the regression without control variables, it still is significant at the 99% confidence interval, and it has a small standard error. Therefore, the excess return of a green bond is 0.115 higher than that of a traditional bond. The composite rating is not significant and of a negligible magnitude. Effective duration, however, is significant at the 99% confidence interval and shows that increasing this variable by 1 unit increases the excess return by 0.071 (small standard error again). The constant in this regression is negative and significant at the 99% confidence interval.

5.6 Sharpe ratio regression results

Analyzing the results of the Sharpe ratio regression in Table 9, the fixed effects regression formula is:

$$Sharpe\ ratio_{it} = \alpha_i + \gamma_1 DUMMY_1 + u_{it} \qquad (18)$$

The ratio increases with 0.244 (significant at the 99% significance interval) when the bond is green compared to when the bond is traditional, depicted by the coefficient of the Dummy. The risk-adjusted excess return for green bonds is 0.244 higher than for traditional bonds. A small standard error depicts the precision of this regression. The significant constant at the 95% confidence interval also shows a small standard error. From these findings, the hypothesis concerning Sharpe ratio can be accepted, as $\delta\ SR > 0$.

When including the control variables composite rating and effective duration in Table 10, the formula becomes:

$$Sharpe\ ratio_{it} = \alpha_i + \beta_1 Composite\ Rating_{1t} + \beta_2 Effective\ Duration_{2t} + \gamma_1 DUMMY_1 + u_{it} \qquad (19)$$

In this case, the 'Dummy' stays positive and shows that the green bonds outperform the traditional bonds by 0.271 units of Sharpe ratio (significant at the 99% confidence interval). Composite rating is not significant and small. Effective duration shows that an increase of 1 increases the Sharpe ratio by 0.178 (significant at the 99% confidence interval). The constant is statistically significant and negative.

5.7 Economic and financial intuition

The green bond total return and excess return findings of this research seem to be in line with these performance indicator findings of the whole green index (ICE Data Services, 2018). As the excess return for green bonds is higher than the total return for green bonds, the outperformance of excess return of the green bonds compared to the traditional bonds could have been expected. Also, as the excess returns of green bonds outperform the excess returns of traditional bonds, the outperformance of the green bonds' Sharpe ratio can be expected as the Sharpe ratio is an extension of the excess return.

Regarding composite rating, even though the results are not significant, it is logical that the total return and excess return increase as the composite rating code increases. The code range contained numbers from 1 to 10, AAA coded by 1 and BBB by 10. Thus, the higher the coded composite rating, the lower the credit rating. As a lower credit rating implies taking more risk while investing in these bonds, a higher total return and excess return could be expected. This is because investors would not accept an unchanged return when the risks involved in investing in such a bond would increase.

When looking at effective duration, a metric taking the risk of changes in interest rate levels into account is assessed. When the duration is longer, the bond's sensitivity to interest rate changes increases. Consequently, a portfolio with a duration which is lower than the duration of the benchmark will outperform the benchmark when interest rates are increasing and will underperform when interest rates are decreasing. The US Federal funds rate has been increasing during the research period and the European interest rates have been decreasing during the research period. The positive relation between the effective duration and the total return, excess return and Sharpe ratio could have been expected, ceteris paribus. The fact that the sample consists of bond that are USD, EUR and GBP denominated influences the results and makes the results difficult to interpret.

6. Robustness checks

Concerning the paired t-tests, Appendices 4 - 12 show the results of the paired t-tests performed with a division per year, sector level 1, currency and composite rating.

6.1 Total return

When analyzing Appendix 4, the total return t-tests are divided per year. For 2014, the mean difference is exactly zero with a standard error of 0.014 and a standard deviation of 0.177. As the t-value of -0.0048 does not exceed -1.96 or 1.96, the mean difference is not significant and thus, for 2014, no conclusion can be drawn from the t-test. For 2015, the total return differential is negative and significant (t-value of -11.9040 exceeds the threshold), the total return of the traditional bonds outperforms the total return of the green bonds and the hypothesis concerning total returns can be rejected. For 2016, the total return differential is also negative, but not significant (t-value of -1.103 does not exceed the threshold), no further conclusion can therefore be drawn. For 2017, a positive total return mean differential appears, which is also significant (t-value of 9.1971 exceeds the threshold), the hypothesis concerning total return can be accepted for the 2017 data sample. For 2018, the total return mean differential is again positive, but not significant (t-value of 0.9284 does not exceed the threshold) and no further conclusions can be drawn from this. A reason for the fact that this outcome is not significant might be the relatively small amount of observations. The division by sector level 1 shows that both corporate and quasi & foreign government type of institutions have a negative total return differential, which is significant in both cases (t-values of -5.4234 and -7.4890, respectively). Concerning the currency division, USD shows a negative significant total return mean differential (t-value of -16.9998), whereas EUR shows a positive, but not significant differential (t-value of 1.5348). The GBP universe shows a negative significant total return mean differential. When dividing the data sample by composite rating the AAA results will be discussed separately, but the results of AA1, AA2 and AA3 will be clustered, as well as A1, A2, A3 and BBB1, BBB2 and BBB3. AAA shows a negative significant total return mean differential (t-value of -10.2807). The AA universe predominantly shows a positive significant differential, the A universe predominantly shows a negative significant differential, as well as the BBB universe.

6.2 Excess return

With regard to the robustness check of the excess return variable and the division of the data sample per year, for 2014 it appears that the excess return mean differential is negative, but not significant (t-value of 0.8118 does not exceed the threshold). The relatively small amount of observations might be the reason for this non-significance. The same conclusion can be drawn for 2015 with a t-value of 1.6417. For 2016, however, the excess return mean differential shows a significant positive coefficient, the t-value of 11.4139 shows that the green bond sample seems to outperform the traditional bond sample when analyzing excess returns. For 2017 and 2018, the excess return mean differential is positive but not significant (t-values of 1.5598 and 0.3899, respectively). The division by sector level 1 shows that both corporate and quasi & foreign government type of institutions have a positive and significant excess return mean differential, with t-values of 7.0350 and 5.1250, respectively. Concerning the currency division, all three currencies, USD, EUR and GBP show positive and significant excess return mean differentials (t-values of 6.8709, 5.6842 and 2.8987, respectively). When dividing the data sample by composite rating the AAA results will be discussed separately, but the results of AA1, AA2 and AA3 will be clustered, as well as A1, A2, A3 and BBB1, BBB2 and BBB3. AAA shows a positive significant excess return mean differential (t-value of 3.8991). The AA universe, as well as the A universe and the BBB universe show predominantly positive and significant differentials.

6.3 Sharpe ratio

For the Sharpe ratio robustness check, 2014 shows a negative Sharpe ratio mean differential, which is not significant (t-value of -1.9094). 2015, 2016 and 2017 show positive Sharpe ratio mean differentials, while all three are also significant (with t-values of 2.3782, 9.6865, and 3.1763, respectively). This means the green bond data sample outperforms the traditional bond data sample in these three years. For 2018, however, the Sharpe ratio mean differential is negative, but not significant (the t-value of -0.8060 does not exceed the threshold). The division by sector level 1 shows that both corporate and quasi & foreign government type of institutions have a positive and significant excess return mean differential, with t-values of 6.0659 and 4.8582, respectively. Concerning the currency division, all three currencies, USD, EUR and GBP show positive and significant Sharpe ratio mean differentials (t-values of 5.3935, 5.4901 and 3.0951). When dividing the data sample by composite rating the AAA results will be discussed separately, but the results of AA1, AA2 and AA3 will be clustered, as well as A1, A2, A3 and BBB1, BBB2 and BBB3. AAA shows a positive significant Sharpe ratio mean differential. The AA universe shows a positive mean differential, but only one out of three cases this differential is significant, the A universe shows a positive and in all three cases significant differential, while the BBB universe shows a predominantly positive significant differential.

6.4 Summary

In summary, concerning total return, the paired t-test without division of the characteristics showed a statistically significant traditional bond outperformance compared to the green bonds. When analyzing the t-test result per year, this conclusion is only supported by the results of one year, namely 2015, this year's t-value was the highest, but there was also a positive significant total return differential. This makes the first conclusion slightly ambiguous. The divisions by sector level 1 and currency support the first conclusion entirely. The division by composite rating does not change the first conclusion, the results per rating cluster are ambiguous, however with a tendency in the direction of negative significant.

Summarizing the excess return results, the excess return differential was positive and significant in the first t-test, the division per year partly supports this conclusion, mainly by the 2016 result of a significant positive differential. The green bond data sample outperforms the traditional bond data sample with regard to excess returns. The divisions by sector level 1 and currency support the first conclusion concerning excess returns entirely. The division by composite rating endorses the first conclusion; the results seem to have a substantial tendency to positive significant.

When analyzing the Sharpe ratio results, the first t-test shows a significant outperformance of the green bond data sample compared to the traditional bond data sample, the summarized results of the divided t-tests endorse this conclusion. Three out of five years showing a significant positive Sharpe ratio differential in favor of the green bond data sample. The divisions by sector level 1 and currency support the first conclusion concerning the Sharpe ratio entirely. The division by composite rating supports the first conclusion, as almost all results show positive significant coefficients.

In summary, all three conclusions concerning the dependent variables remain the same as before the robustness checks or are even supported. The total return hypothesis is rejected, while both the excess return and Sharpe ratio hypotheses are accepted.

6.5 Regression robustness check

The most common characteristics of bonds to evaluate are duration, coupon, maturity, market sectors and credit quality, all of these characteristics are included in this research, except for coupon. As a robustness check, the control variable 'face value' is added to the regression of total return, excess return and Sharpe ratio with the control variables composite rating and effective duration. The face value of a security represents its nominal value stated by the issuer. At the bond's maturity date this principle amount should be paid to the bondholder. For capitalization-weighted indices, the face value of the constituent is equal to the total amount outstanding of the bond issue. As the face value within a matched pair of a green bond and a traditional bond can differ, this control variable is included. The results of these regressions are shown in Appendix 13. For all three of the regressions, the face value control variable shows a significant effect on the dependent variables of 99% confidence level of 0.000, as face value increases by 1 unit, the dependent variables neither increase nor decrease. This seems logical as increasing face value by 1 unit means either $1, €1 or £1, which is too small to have a real influence on the dependent variables. The remaining variables continue to have approximately the same size and magnitude as in the regressions without face value as control variable. This result is surprising as Zerbib (2017) finds that using the issued amount as control variable reveals that the issued amount is a major driver of the green bond premium.

7. Conclusion

Conclusion

In a world in which the battle against climate change is the talk of the town, financial markets are trying to foster environmental transition. Proponents and opponents widely express their opinions about this development, while investors seem to have the key to driving the re-allocation of capital towards sustainable investments. In this thesis, the green bond premium is quantified, conducting a matching procedure, in which 2,015 green bonds are matched to their most comparable traditional bonds. The magnitude and significance of the three main performance variables; total return, excess return and Sharpe ratio differentials, are evaluated. The differentials are defined as the performance measure of the green bonds minus the performance measure of the traditional bonds. For all three of the performance measures, the differential is hypothesized to be greater than zero. Several conclusions can be drawn from the results. The contribution of sustainability to the performance of traditional bonds is positive in terms of the excess returns and the Sharpe ratio. Specifically, the excess return differential, as well as the Sharpe ratio differential show significant positive results, when analyzed through a paired t-test, as well as when analyzed through a fixed effects regression model. These results are robust for different time periods, sector levels, currencies, composite ratings and other bond characteristics. This means the second and third hypotheses are accepted.

In contrast, the total return of traditional bonds seems to outperform the total return of green bonds, the total return differential is negative, and this result is also robust for different time periods, sector levels, currencies, composite ratings and other bond characteristics. This means the first hypothesis is rejected.

As the excess returns and the Sharpe ratio exclude the distortion of the performance of bonds by excluding the benchmark's return or risk-free rate and measure the excess return per unit of risk, the excess return and Sharpe ratio results outweigh the results of the total return metric. Also, the total return metric only provides a useful performance metric with one possible set of market conditions, this endorses the conclusion that the excess return and Sharpe ratio results give a more elaborate view on the bond's performance.

To summarize the answer to the research question:
'To what extent does sustainability contribute to bond performance?'

This research seems to find evidence for a positive contribution of sustainability to traditional bond performance, measured with three different performance metrics. The results seem to be robust for various definitions of the concepts used and different performance indicators. The objective to quantify the green bond premium is achieved. Regarding the excess returns and the Sharpe ratio, the contribution of sustainability is 0.103 and 0.244, respectively. In terms of total return, the contribution of sustainability is negative; -0.267.

Contribution to the literature and implications for key stakeholders

As the financial return of a bond investment can be seen as the ultimate criterion for investing in a particular asset, with these findings, individual investors can be sure to obtain a positive significant excess return and Sharpe ratio to their investment in green bonds. This means investors without a specific responsible investing objective could also become interested in investing in green bonds. With these conclusions, an increase in green bond demand is expected. With the knowledge of the advantages associated with issuing green bonds for issuing institutions, these institutions might become more prone to issue green bonds than to issue traditional bonds. Consequently, the global green bond market is expected to increase. Moreover, decision makers' assessment of responsible investment policies can now be supported by empirical evidence. This evidence can be seen as a leap towards mobilizing capital in a sustainable direction. The governmental subsidies for philanthropic behavior and large amounts of public stimulus for steering capital towards environmentally sustainable projects, complement this development.

Limitations

The appropriate metrics for measuring performance depend on the investor's objective. Choosing the right quantitative tools is important, however, it is essential have a clear understanding of these tools and their limitations. Relying on randomly selected metrics could result in non-effective investment decisions, which cause suboptimal financial returns. Therefore, this thesis includes three different metrics, total return, the most general measure, excess return, which takes the influence of market conditions into account and the Sharpe ratio, which takes the risk of a security into account. Even though these performance metrics are carefully chosen, some limitations to this research will be discussed in this section.

The issue date of green bonds and traditional bonds is neglected, thereby, the bond's age is neglected. This could be a possible limitation. It might be the case that a bond with a relatively long term to maturity that is approaching its maturity date has been compared to a short-term bond that has been issued recently. As a result, this does not take the influence of the yield of the bonds into account, which influences the total return. With a possible distortion of the total return conclusions as a result. The bond's age could be included in future research utilizing a matching procedure including the term to maturity from issue date to maturity date, instead of base date to maturity date only, as is used in this thesis.

When encountering the trade-off between the number of matched bonds and quality of these matches, this thesis only includes three main criteria in the matching process. These are the issuing institution, the currency and the remaining term to maturity. By choosing to match with the criterion of the same issuer, this implies also assuring an exact match on composite rating and sector. By only including the mentioned criteria, a high number of matched bonds is the result. Alternatively, more criteria could be included, as the previously mentioned bond's age and a more elaborate term to maturity definition. Also, the liquidity of the bond could be taken into account. However, Houweling et al. (2005) argue that the age of a bond can be used to represent the bond's liquidity. Posing more criteria to the matched procedure would result in a smaller amount of matched pairs, but a more qualitative set would be created. In this case, it is chosen to pose a smaller amount of criteria, resulting in a larger amount of matched pairs and thus, more observations.

The drawback of a fixed-effects regression model is that it does not control for time-varying unobserved variables. The fixed-effects regression model also does not control for the effects of omitted time-invariant variables that have time-varying effects. However, in the existence of these time-invariant variables, interactions of these variables with time could be included to estimate their time-varying effects. The fixed-effect regression model assures that the effects of stable characteristics are controlled for, whether they are measured or not. However, the effects of these variables are not estimated. Conversely, fixed-effects models are less vulnerable to omitted variable bias, which results in falsely leaving out one or more variables. When facing the trade-off between bias and efficiency, fixed-effects models have higher standard errors than random effects models, as the former discard a lot of information, but the omitted variable bias in controlled for in the fixed-effects regression model, by having individuals serve as their own controls (William, 2015).

The International Capital Market Association argues in their Summary of Green Fixed Income Indices Providers report that the Green Bond Index used in this dataset has no explicit GBP or CBI alignment. Bloomberg tags bonds with their 'green bond' label in the use of proceeds field when an issuer either self-labels its bond as 'green' or identifies it as an environmental sustainability-oriented bond issue with clear additional statements about the commitment to deploy funds towards projects and activities in the Green Bond Principles use of proceeds categories. Therefore, it is unknown whether the green bonds in this dataset are 'CBI labelled' green bonds or whether they comply with the GBP. Moreover, it is not officially checked whether the proceeds of the investment are actually used for green projects. It would be interesting to research what the contribution to the performance of traditional bonds is when the matched green bond is an officially labelled green bond. This would increase the transparency and integrity in the market and would force more green bond issuers to obtain the labelled classification.

Even though a lot of effort has been put into the construction of the dataset used in this thesis, there is room for improvement. This thesis only researches the USD, EUR and GBP universe of the BofA ML Green Bond Index; excluding all the other currencies significantly decreased the dataset and limited the ability to draw conclusions from for the remainder of the green bond market, apart from the USD, EUR and GBP universe. The possibility of unobserved variables influencing the results also still exists. Including more variables in the models used could significantly increase the explanatory power of the models and provide new insights.

8. Discussion

Some may argue that the growing attention of investors and financial institutions for the financial market's force to induce socially responsible behavior could be only a hype. Opponents of green bond's potential impact argue that institutions issuing green bonds use marketing tricks to convince themselves and investors that significant impact can be made when investing responsibly. They also question whether the bonds issued are actually green enough. Research in the direction of green bond classification and the evaluation of self-labelled green bonds by issuers would be interesting.

A possible direction for future research could be investigating convexity. Duration only measures market risk; thereby, measures the effect of a parallel yield curve shift. Convexity also measures yield curve risk and market volatility; the former measures the effect of a shift in the shape or slope of the yield curve, while the latter takes historical and expected market volatility into account.

The implications for investment management can be found in the fact that total return optimization may not necessarily be the only objective of investment portfolios, the investment manager should include five important steps in the process; setting the objectives of the investment, deciding on the investment policy, deciding on the selection of a portfolio strategy, as well as selecting assets and the assessment of the performance of the investment. According to the strategy of the institution, the type and magnitude of green bonds can be included in the portfolio.

Advice on how to incorporate green bonds in the portfolio of investment managers, and what the impact of green bonds on a portfolio's diversification can also contribute to the literature. Multiple portfolio managers argue that the incorporation into portfolios is difficult. While data from institutions on responsible investing can be challenging to put into context, and no go-to source providing easily comparable data in a universally accepted standard exists, Snider (2016) argues that the development of training and a standard information database is essential.

Using another definition of risk-adjusted return, such as the Information ratio, could be an extension of this research. This is a similar performance measure as the Sharpe ratio, but uses a selected benchmark to subtract from the total return instead of the risk-free rate of return. The Sharpe ratio calculates the outperformance of the investment compared to the risk-free rate, and thereby adjusts for risk, while the information ratio measures the investment's performance consistency.

The incorporation of ESG factors in investment decisions could be researched in the future, as well as an SDG framework research. By means of a similar methodology as the one applied in this thesis, this thesis could be extended by investigating the social bond premium, or the corporate governance bond premium. Thereby, taking more elaborate sustainability or ethics definitions into account and incorporating these in the research question. Considering this, including non-ethical bonds in the research, bonds issued by institutions involved in tobacco, gambling, alcohol, military, firearms, and nuclear operations, and comparing the non-ethical bonds, to the ethical bonds, issued by institutions taking ESG factors and the SDG framework into account, would be interesting.

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Appendix

Figure 1: Sustainable Development Goals

1	End poverty in all its forms everywhere
2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
3	Ensure healthy lives and promote well-being for all at all ages
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5	Achieve gender equality and empower all women and girls
6	Ensure availability and sustainable management of water and saniation for all
7	Ensure access to affordable, reliable, sustainable and modern energy for all
8	Promote sustained inclusive and sustainable economic growth, full and productive employment and decent work
9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10	Reduce inequality within and amoung countries
11	Make cities and human settlements inclusive, safe, resilient and sustainable
12	Ensure sustainable consumption and production patterns
13	Take urgent action to combat climate change and its impacts
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forsts, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

* Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change

Source: The 2030 Agenda for Sustainable Development - UN - 2015

Appendix 1 - Green bond - Traditional bond match examples

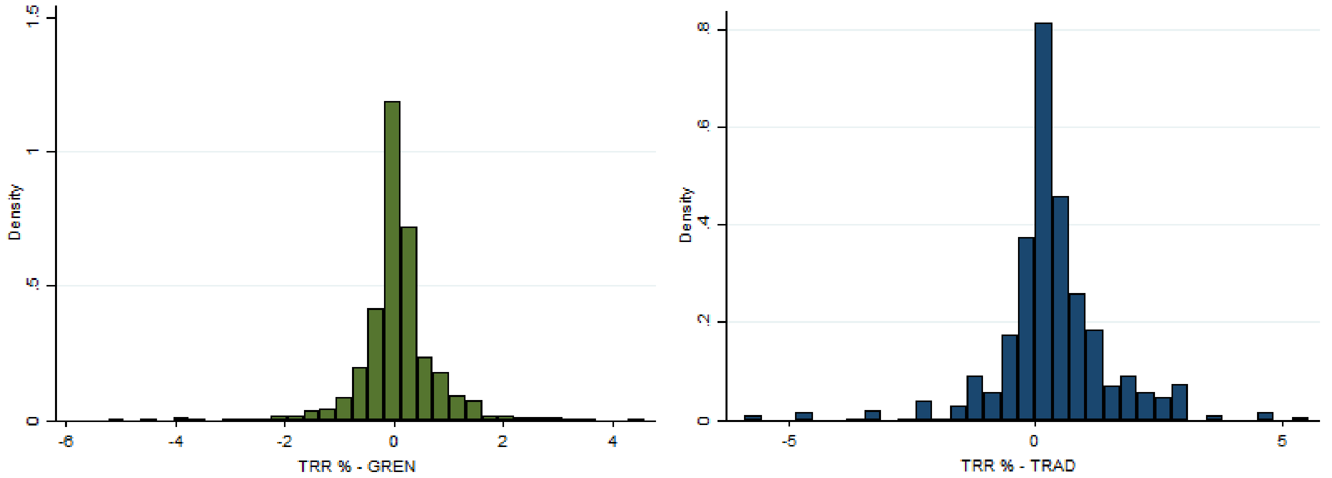
This table provides the results of the matching procedure. The statistics considered are pair number, year, ISIN, TICKER, Currency, Maturity date, Term to Maturity (calculated from 24/5/2018), Sector Level 1, Coupon, Face value, Total Return, Excess Return, Sharpe Ratio and Composite Rating. Note that these matches are randomly selected from the data sample and that the difference between the term to maturity of the pair is never exceeding 6 months (<0.5)

Pair	Year	ISIN	TICKER	Currency	Maturity date	Term to maturity	Sector Level 1	Coupon	Face value	Total Return	Excess Return	Sharpe ratio	Composite Rating
1	2014	US45950VCP94	IFC	USD	11/15/2016	-1.52	Quasi & Foreign Government	0.63	1000	0.266	-0.128	-0.871	AAA
1	2014	US45950KBQ22	IFC	USD	11/23/2016	-1.50	Quasi & Foreign Government	1.13	3000	0.270	-0.126	-0.551	AAA
2	2014	US500769GF56	KFW	USD	10/15/2019	1.39	Quasi & Foreign Government	1.75	1500	0.000	0.000	0.000	AAA
2	2014	US500769DJ06	KFW	USD	6/17/2019	1.07	Quasi & Foreign Government	4.88	3000	0.813	-0.080	-0.586	AAA
3	2015	FR0011637586	EDF	EUR	4/27/2021	2.93	Corporate	2.25	1400	0.767	-0.085	-0.562	A1
3	2015	XS0409749206	EDF	EUR	1/25/2021	2.68	Corporate	6.25	2000	0.571	-0.096	-0.666	A1
4	2015	XS1083955911	NEDWBK	EUR	7/3/2019	1.11	Quasi & Foreign Government	0.63	500	0.410	0.010	0.066	AA1
4	2015	XS0820548716	NEDWBK	EUR	8/23/2019	1.25	Quasi & Foreign Government	1.63	1500	0.397	-0.009	-0.062	AA1
5	2016	US30216BER96	EDC	USD	1/30/2017	-1.31	Quasi & Foreign Government	0.88	300	0.241	-0.032	-0.103	AAA
5	2016	US30216BEX64	EDC	USD	5/15/2017	-1.02	Quasi & Foreign Government	1.00	1000	0.360	-0.025	-0.079	AAA
6	2016	US06051GEZ81	BAC	USD	11/21/2016	-1.50	Corporate	1.35	500	0.247	0.036	0.115	A3
6	2016	US06050TKN18	BAC	USD	3/15/2017	-1.19	Corporate	5.30	2000	0.060	-0.250	-0.793	A3
7	2017	XS1083955911	NEDWBK	EUR	7/3/2019	1.11	Quasi & Foreign Government	0.63	500	-0.024	0.270	0.919	AAA
7	2017	XS0820548716	NEDWBK	EUR	8/23/2019	1.25	Quasi & Foreign Government	1.63	1500	-0.037	0.275	0.964	AAA
8	2017	XS1502438820	RABOBK	EUR	10/11/2021	3.39	Corporate	0.13	500	-0.610	0.088	0.300	AA3
8	2017	XS0256967869	RABOBK	EUR	6/7/2021	3.04	Corporate	4.38	1250	-0.451	0.124	0.435	AA3
9	2018	US62630CAH43	KUNTA	USD	9/21/2021	3.33	Quasi & Foreign Government	1.38	500	-0.830	0.040	0.083	AA1
9	2018	US62630CAK71	KUNTA	USD	3/15/2022	3.81	Quasi & Foreign Government	2.38	1000	-0.889	0.122	0.311	AA1
10	2018	US865622BY94	SUMIBK	USD	10/20/2020	2.41	Corporate	2.45	500	-0.705	-0.142	-0.294	A2
10	2018	US865622BV55	SUMIBK	USD	7/23/2020	2.17	Corporate	2.65	1000	-0.352	0.133	0.340	A2

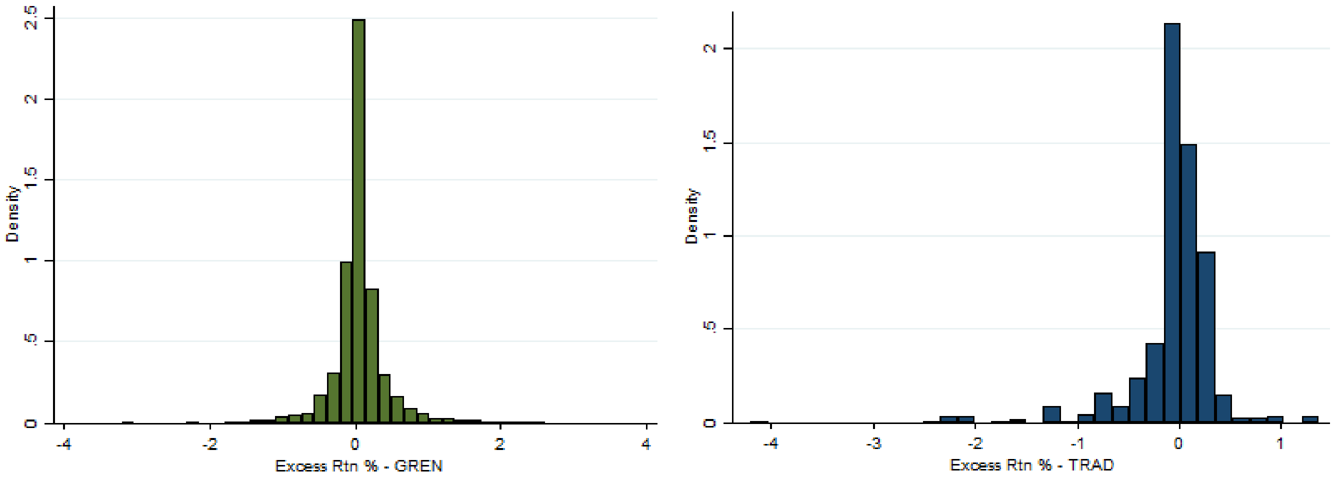
Appendix 2 - Histograms of Total Return Green Bonds vs. Traditional Bonds

A histogram is an accurate representation of the distribution of numerical data. It is an estimate of the probability distribution of a continuous variable. Its objective is to roughly assess the probability distribtuion of a given variable by depicting the frequencies of observations occuring in certain ranges of values

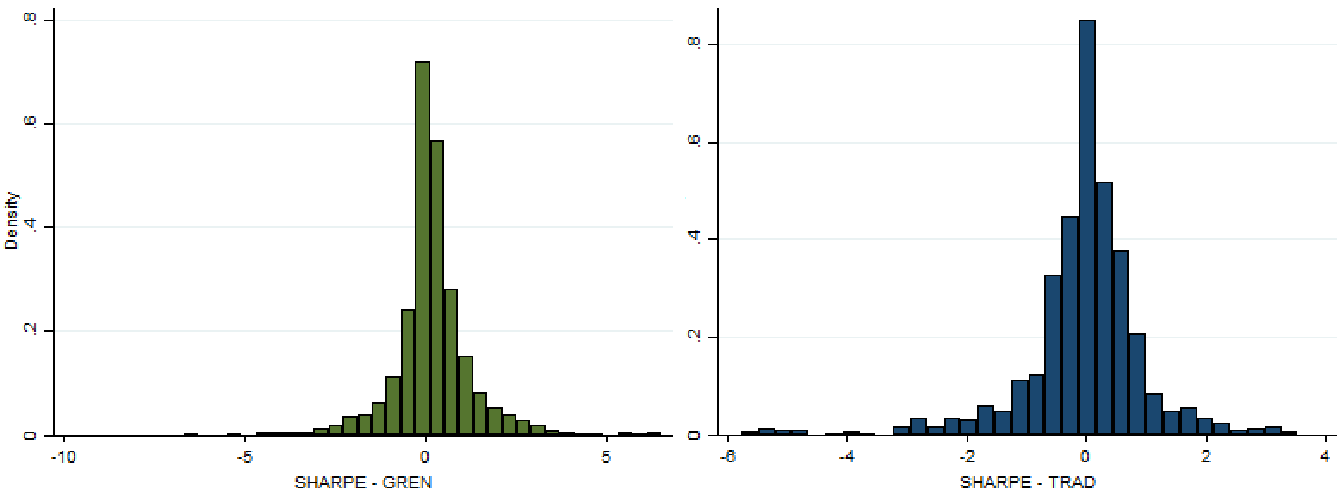
(a) Total Return Histograms



(b) Excess Return Histograms



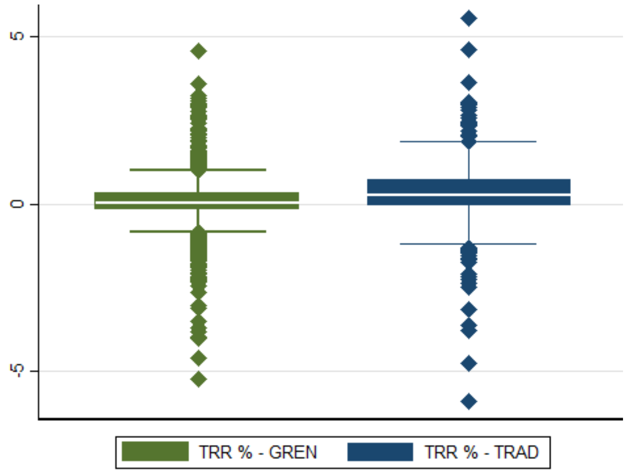
(c) Sharpe Ratio Histograms



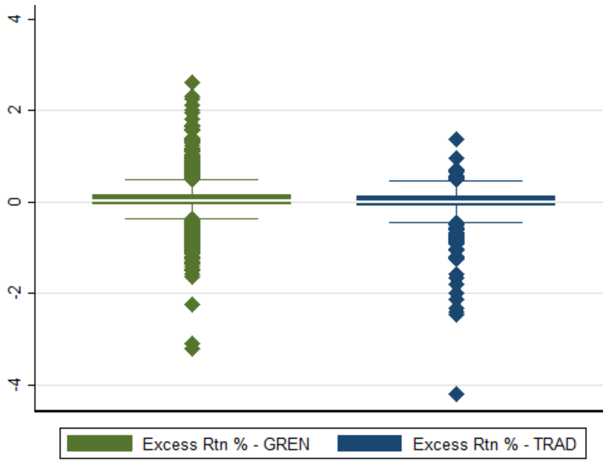
Appendix 3 - Boxplot of Total Return Green Bonds vs. Traditional Bonds

A boxplot is a method for graphically depicting groups of numerical data through their quartiles. Boxplots are non-parametric, they display variation in samples of a statistical population without making any assumptions of the underlying statistical distribution. The spacing between the different parts of the box indicate the degree of dispersion (spread) and skewness in the data and show outliers.

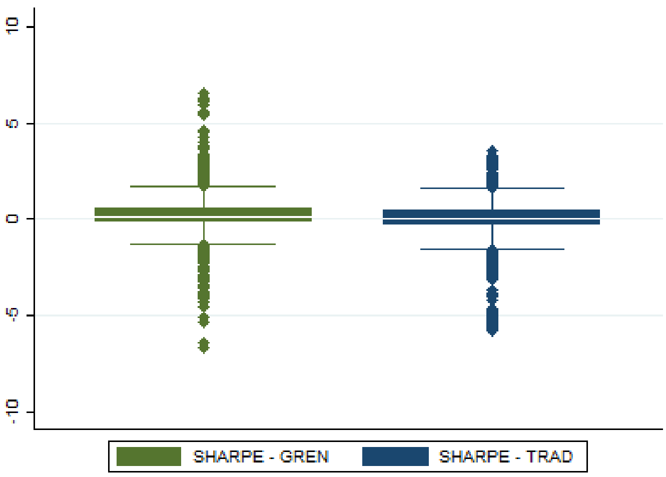
(a) Total Return Boxplot



(b) Excess Return Boxplot



(c) Sharpe Ratio Boxplot



Appendix 4 - Paired t-test Total Return - Robustness check

This table provides the results of the paired t-test of Total Return. The statistics considered are number of observations, mean, standard error, standard deviation and the 95% confidence interval. The t-value and degrees of freedom, as well as the different hypotheses concering this test are also shown. This table shows the division of the t-test results per year. For all t-tests holds that the mean(diff) = mean(TRRGREN - TRRTRAD) and Ho: mean(diff) = 0.

Variable	Year	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]		t-value	degrees of freedom	Ha: mean(diff) < 0	Ha: mean(diff) != 0	Ha: mean(diff) > 0
Total Return Green Bonds	2014	169	0.251	0.035	0.452	0.182	0.319					
Total Return Traditional Bonds	2014	169	0.251	0.032	0.419	0.187	0.314					
Difference	2014	169	0.000	0.014	0.177	-0.027	0.027	t = -0.0048	168	Pr(T < t) = 0.4981	Pr(|T| > |t|) = 0.9962	Pr(T > t) = 0.5019
Total Return Green Bonds	2015	297	0.049	0.039	0.665	-0.026	0.125					
Total Return Traditional Bonds	2015	297	0.928	0.062	1.075	0.805	1.050					
Difference	2015	297	-0.878	0.074	1.271	-1.023	-0.733	t = -11.9040	296	Pr(T < t) = 0.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 1.0000
Total Return Green Bonds	2016	539	0.133	0.037	0.853	0.061	0.205					
Total Return Traditional Bonds	2016	539	1.236	0.040	0.929	1.158	1.315					
Difference	2016	539	-1.103	0.055	1.266	-1.211	-0.996	t = -20.2290	538	Pr(T < t) = 0.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 1.0000
Total Return Green Bonds	2017	744	0.112	0.023	0.620	0.068	0.157					
Total Return Traditional Bonds	2017	744	-0.308	0.038	1.043	-0.383	-0.233					
Difference	2017	744	0.420	0.046	1.246	0.331	0.510	t = 9.1971	743	Pr(T < t) = 1.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 0.0000
Total Return Green Bonds	2018	266	-0.181	0.041	0.676	-0.263	-0.100					
Total Return Traditional Bonds	2018	266	-0.202	0.041	0.665	-0.282	-0.121					
Difference	2018	266	0.020	0.022	0.356	-0.023	0.063	t = 0.9284	265	Pr(T < t) = 0.8230	Pr(|T| > |t|) = 0.3540	Pr(T > t) = 0.1770

Appendix 5 - Paired t-test Excess Return - Robustness check

This table provides the results of the paired t-test of Excess Return. The statistics considered are number of observations, mean, standard error, standard deviation and the 95% confidence interval. The t-value and degrees of freedom, as well as the different hypotheses concering this test are also shown. This table shows the division of the t-test results per year. For all t-tests holds that the mean(diff) = mean(ExcessRtnGREN - ExcessRtnTRAD) and Ho: mean(diff) = 0.

Variable	Year	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]		t-value	degrees of freedom	Ha: mean(diff) < 0	Ha: mean(diff) != 0	Ha: mean(diff) > 0
Excess Return Green Bonds	2014	169	0.035	0.014	0.177	0.008	0.062					
Excess Return Traditional Bonds	2014	169	0.045	0.012	0.156	0.021	0.068					
Difference	2014	169	-0.009	0.012	0.150	-0.032	0.013	t = -0.8118	168	Pr(T < t) = 0.2090	Pr(|T| > |t|) = 0.4181	Pr(T > t) = 0.7910
Excess Return Green Bonds	2015	297	0.004	0.016	0.270	-0.027	0.035					
Excess Return Traditional Bonds	2015	297	-0.027	0.010	0.177	-0.047	-0.007					
Difference	2015	297	0.031	0.019	0.323	-0.006	0.068	t = 1.6417	296	Pr(T < t) = 0.9491	Pr(|T| > |t|) = 0.1017	Pr(T > t) = 0.0509
Excess Return Green Bonds	2016	539	0.039	0.018	0.408	0.004	0.073					
Excess Return Traditional Bonds	2016	539	-0.283	0.023	0.528	-0.328	-0.238					
Difference	2016	539	0.322	0.028	0.654	0.266	0.377	t = 11.4139	538	Pr(T < t) = 1.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 0.0000
Excess Return Green Bonds	2017	744	0.125	0.014	0.372	0.098	0.152					
Excess Return Traditional Bonds	2017	744	0.092	0.015	0.420	0.061	0.122					
Difference	2017	744	0.034	0.022	0.588	-0.009	0.076	t = 1.5598	743	Pr(T < t) = 0.9404	Pr(|T| > |t|) = 0.1192	Pr(T > t) = 0.0596
Excess Return Green Bonds	2018	266	-0.015	0.025	0.404	-0.064	0.033					
Excess Return Traditional Bonds	2018	266	-0.022	0.022	0.363	-0.065	0.022					
Difference	2018	266	0.006	0.016	0.260	-0.025	0.038	t = 0.3899	265	Pr(T < t) = 0.6515	Pr(|T| > |t|) = 0.6970	Pr(T > t) = 0.3485

Appendix 6 - Paired t-test Sharpe ratio - Robustness check

This table provides the results of the paired t-test of Sharpe ratio. The statistics considered are number of observations, mean, standard error, standard deviation and the 95% confidence interval. The t-value and degrees of freedom, as well as the different hypotheses concering this test are also shown. This table shows the division of the t-test results per year. For all t-tests holds that the mean(diff) = mean(SHARPE-GREN - SHARPE-TRAD) and Ho: mean(diff) = 0.

<table>
<tr><th>Variable</th><th>Year</th><th>Obs</th><th>Mean</th><th>Std. Err.</th><th>Std. Dev.</th><th colspan="2">[95% Conf. Interval]</th><th>t-value</th><th>degrees of freedom</th><th>Ha: mean(diff) < 0</th><th>Ha: mean(diff) != 0</th><th>Ha: mean(diff) > 0</th></tr>
<tr><td>Sharpe ratio Green Bonds</td><td>2014</td><td>169</td><td>0.233</td><td>0.080</td><td>1.042</td><td>0.075</td><td>0.391</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sharpe ratio Traditional Bonds</td><td>2014</td><td>169</td><td>0.373</td><td>0.082</td><td>1.067</td><td>0.211</td><td>0.535</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>2014</td><td>169</td><td>-0.140</td><td>0.073</td><td>0.955</td><td>-0.285</td><td>0.005</td><td>t = -1.9094</td><td>168</td><td>Pr(T < t) = 0.0290</td><td>Pr(|T| > |t|) = 0.0579</td><td>Pr(T > t) = 0.9710</td></tr>
<tr><td>Sharpe ratio Green Bonds</td><td>2015</td><td>297</td><td>0.055</td><td>0.063</td><td>1.093</td><td>-0.070</td><td>0.180</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sharpe ratio Traditional Bonds</td><td>2015</td><td>297</td><td>-0.146</td><td>0.057</td><td>0.985</td><td>-0.259</td><td>-0.034</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>2015</td><td>297</td><td>0.202</td><td>0.085</td><td>1.462</td><td>0.035</td><td>0.369</td><td>t = 2.3782</td><td>296</td><td>Pr(T < t) = 0.9910</td><td>Pr(|T| > |t|) = 0.0180</td><td>Pr(T > t) = 0.0090</td></tr>
<tr><td>Sharpe ratio Green Bonds</td><td>2016</td><td>539</td><td>0.054</td><td>0.049</td><td>1.143</td><td>-0.043</td><td>0.151</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sharpe ratio Traditional Bonds</td><td>2016</td><td>539</td><td>-0.571</td><td>0.043</td><td>0.990</td><td>-0.655</td><td>-0.487</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>2016</td><td>539</td><td>0.625</td><td>0.065</td><td>1.498</td><td>0.498</td><td>0.752</td><td>t = 9.6865</td><td>538</td><td>Pr(T < t) = 1.0000</td><td>Pr(|T| > |t|) = 0.0000</td><td>Pr(T > t) = 0.0000</td></tr>
<tr><td>Sharpe ratio Green Bonds</td><td>2017</td><td>744</td><td>0.401</td><td>0.039</td><td>1.065</td><td>0.324</td><td>0.478</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sharpe ratio Traditional Bonds</td><td>2017</td><td>744</td><td>0.226</td><td>0.036</td><td>0.994</td><td>0.154</td><td>0.298</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>2017</td><td>744</td><td>0.175</td><td>0.055</td><td>1.504</td><td>0.067</td><td>0.283</td><td>t = 3.1763</td><td>743</td><td>Pr(T < t) = 0.9992</td><td>Pr(|T| > |t|) = 0.0016</td><td>Pr(T > t) = 0.0008</td></tr>
<tr><td>Sharpe ratio Green Bonds</td><td>2018</td><td>266</td><td>-0.039</td><td>0.069</td><td>1.119</td><td>-0.175</td><td>0.096</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sharpe ratio Traditional Bonds</td><td>2018</td><td>266</td><td>0.006</td><td>0.070</td><td>1.144</td><td>-0.132</td><td>0.144</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>2018</td><td>266</td><td>-0.046</td><td>0.057</td><td>0.927</td><td>-0.158</td><td>0.066</td><td>t = -0.8060</td><td>265</td><td>Pr(T < t) = 0.2105</td><td>Pr(|T| > |t|) = 0.4210</td><td>Pr(T > t) = 0.7895</td></tr>
</table>

Appendix 7 - Paired t-test Total Return - Robustness check

This table provides the results of the paired t-test of Total Return. The statistics considered are number of observations, mean, standard error, standard deviation and the 95% confidence interval. The t-value and degrees of freedom, as well as the different hypotheses concering this test are also shown. This table shows the division of the t-test results per sector level 1 (* Q & FG stands for Quasi & Foreign Government) and currency (USD, EUR, GBP), ETC, for all t-tests holds that the mean(diff) = mean(TRRGREN - TRRTRAD) and Ho: mean(diff) = 0.

<table>
<tr><th>Variable</th><th>Sector Level 1</th><th>Obs</th><th>Mean</th><th>Std. Err.</th><th>Std. Dev.</th><th>[95% Conf.</th><th>Interval]</th><th>t-value</th><th>degrees of freedom</th><th>Ha: mean(diff) < 0</th><th>Ha: mean(diff) != 0</th><th>Ha: mean(diff) > 0</th></tr>
<tr><td>Total Return Green Bonds</td><td>Corporate</td><td>805</td><td>0.122</td><td>0.022</td><td>0.638</td><td>0.077</td><td>0.166</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total Return Traditional Bonds</td><td>Corporate</td><td>805</td><td>0.324</td><td>0.034</td><td>0.953</td><td>0.258</td><td>0.390</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>Corporate</td><td>805</td><td>-0.202</td><td>0.037</td><td>1.057</td><td>-0.275</td><td>-0.129</td><td>t = -5.4234</td><td>804</td><td>Pr(T < t) = 0.0000</td><td>Pr(|T| > |t|) = 0.0000</td><td>Pr(T > t) = 1.0000</td></tr>
<tr><td>Total Return Green Bonds</td><td>Q & FG*</td><td>1,210</td><td>0.055</td><td>0.021</td><td>0.739</td><td>0.013</td><td>0.096</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total Return Traditional Bonds</td><td>Q & FG*</td><td>1,210</td><td>0.364</td><td>0.037</td><td>1.273</td><td>0.293</td><td>0.436</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>Q & FG*</td><td>1,210</td><td>-0.310</td><td>0.041</td><td>1.439</td><td>-0.391</td><td>-0.229</td><td>t = -7.4890</td><td>1,209</td><td>Pr(T < t) = 0.0000</td><td>Pr(|T| > |t|) = 0.0000</td><td>Pr(T > t) = 1.0000</td></tr>
<tr><td></td><td>Currency</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total Return Green Bonds</td><td>USD</td><td>1,022</td><td>0.065</td><td>0.021</td><td>0.663</td><td>0.025</td><td>0.106</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total Return Traditional Bonds</td><td>USD</td><td>1,022</td><td>0.645</td><td>0.030</td><td>0.962</td><td>0.586</td><td>0.704</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>USD</td><td>1,022</td><td>-0.580</td><td>0.034</td><td>1.091</td><td>-0.647</td><td>-0.513</td><td>t = -16.9998</td><td>1021</td><td>Pr(T < t) = 0.0000</td><td>Pr(|T| > |t|) = 0.0000</td><td>Pr(T > t) = 1.0000</td></tr>
<tr><td>Total Return Green Bonds</td><td>EUR</td><td>943</td><td>0.097</td><td>0.024</td><td>0.747</td><td>0.049</td><td>0.144</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total Return Traditional Bonds</td><td>EUR</td><td>943</td><td>0.024</td><td>0.042</td><td>1.275</td><td>-0.057</td><td>0.106</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>EUR</td><td>943</td><td>0.072</td><td>0.047</td><td>1.442</td><td>-0.020</td><td>0.164</td><td>t = 1.5348</td><td>942</td><td>Pr(T < t) = 0.9374</td><td>Pr(|T| > |t|) = 0.1252</td><td>Pr(T > t) = 0.0626</td></tr>
<tr><td>Total Return Green Bonds</td><td>GBP</td><td>50</td><td>0.120</td><td>0.073</td><td>0.518</td><td>-0.027</td><td>0.267</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total Return Traditional Bonds</td><td>GBP</td><td>50</td><td>0.373</td><td>0.099</td><td>0.699</td><td>0.174</td><td>0.572</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>GBP</td><td>50</td><td>-0.253</td><td>0.104</td><td>0.732</td><td>-0.461</td><td>-0.045</td><td>t = -2.4403</td><td>49</td><td>Pr(T < t) = 0.0092</td><td>Pr(|T| > |t|) = 0.0183</td><td>Pr(T > t) = 0.9908</td></tr>
</table>

Appendix 8 - Paired t-test Excess Return - Robustness check

This table provides the results of the paired t-test of Excess Return. The statistics considered are number of observations, mean, standard error, standard deviation and the 95% confidence interval. The t-value and degrees of freedom, as well as the different hypotheses concering this test are also shown. This table shows the division of the t-test results per sector level 1 (* Q & FG stands for Quasi & Foreign Government) and currency (USD, EUR, GBP), ETC, for all t-tests holds that the mean(diff) = mean(ExcessRtnGREN - ExcessRtnTRAD) and Ho: mean(diff) = 0.

Variable	Sector Level 1	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]		t-value	degrees of freedom	Ha: mean(diff) < 0	Ha: mean(diff) != 0	Ha: mean(diff) > 0
Excess Return Green Bonds	Corporate	805	0.113	0.015	0.432	0.084	0.143					
Excess Return Traditional Bonds	Corporate	805	-0.046	0.019	0.552	-0.084	-0.008					
Difference	Corporate	805	0.160	0.023	0.644	0.115	0.204	t = 7.0350	804	Pr(T < t) = 1.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 0.0000
Excess Return Green Bonds	Q & FG*	1,210	0.021	0.009	0.307	0.004	0.039					
Excess Return Traditional Bonds	Q & FG*	1,210	-0.044	0.009	0.327	-0.063	-0.026					
Difference	Q & FG*	1210	0.065	0.013	0.444	0.040	0.090	t = 5.1250	1209	Pr(T < t) = 1.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 0.0000
	Currency											
Excess Return Green Bonds	USD	1,022	0.047	0.008	0.261	0.031	0.063					
Excess Return Traditional Bonds	USD	1,022	-0.043	0.011	0.351	-0.065	-0.022					
Difference	USD	1022	0.090	0.013	0.419	0.064	0.116	t = 6.8709	1021	Pr(T < t) = 1.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 0.0000
Excess Return Green Bonds	EUR	943	0.071	0.015	0.458	0.042	0.100					
Excess Return Traditional Bonds	EUR	943	-0.049	0.017	0.514	-0.082	-0.016					
Difference	EUR	943	0.120	0.021	0.648	0.078	0.161	t = 5.6842	942	Pr(T < t) = 1.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 0.0000
Excess Return Green Bonds	GBP	50	0.048	0.018	0.124	0.013	0.083					
Excess Return Traditional Bonds	GBP	50	-0.002	0.007	0.046	-0.015	0.011					
Difference	GBP	50	0.050	0.017	0.123	0.015	0.085	t = 2.8987	49	Pr(T < t) = 0.9972	Pr(|T| > |t|) = 0.0056	Pr(T > t) = 0.0028

Appendix 9 - Paired t-test Sharpe ratio - Robustness check

This table provides the results of the paired t-test of Sharpe ratio. The statistics considered are number of observations, mean, standard error, standard deviation and the 95% confidence interval. The t-value and degrees of freedom, as well as the different hypotheses concering this test are also shown. This table shows the division of the t-test results per sector level 1 (* Q & FG stands for Quasi & Foreign Government) and currency (USD, EUR, GBP), ETC, for all t-tests holds that the mean(diff) = mean(SHARPE-GREN - SHARPE-TRAD) and Ho: mean(diff) = 0.

Variable	Sector Level 1	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]		t-value	degrees of freedom	Ha: mean(diff) < 0	Ha: mean(diff) != 0	Ha: mean(diff) > 0
Sharpe ratio Green Bonds	Corporate	805	0.345	0.046	1.295	0.255	0.434					
Sharpe ratio Traditional Bonds	Corporate	805	-0.004	0.045	1.290	-0.093	0.085					
Difference	Corporate	805	0.348	0.057	1.629	0.236	0.461	t = 6.0659	804	Pr(T < t) = 1.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 0.0000
Sharpe ratio Green Bonds	Q & FG*	1,210	0.079	0.027	0.951	0.025	0.133					
Sharpe ratio Traditional Bonds	Q & FG*	1,210	-0.095	0.026	0.901	-0.146	-0.045					
Difference	Q & FG*	1,210	0.174	0.036	1.248	0.104	0.245	t = 4.8582	1,209	Pr(T < t) = 1.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 0.0000
	Currency											
Sharpe ratio Green Bonds	USD	1,022	0.134	0.027	0.861	0.081	0.187					
Sharpe ratio Traditional Bonds	USD	1,022	-0.065	0.028	0.907	-0.120	-0.009					
Difference	USD	1,022	0.198	0.037	1.176	0.126	0.271	t = 5.3935	1,021	Pr(T < t) = 1.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 0.0000
Sharpe ratio Green Bonds	EUR	943	0.242	0.044	1.346	0.156	0.328					
Sharpe ratio Traditional Bonds	EUR	943	-0.055	0.041	1.255	-0.135	0.025					
Difference	EUR	943	0.297	0.054	1.664	0.191	0.404	t = 5.4901	942	Pr(T < t) = 1.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 0.0000
Sharpe ratio Green Bonds	GBP	50	0.152	0.051	0.360	0.049	0.254					
Sharpe ratio Traditional Bonds	GBP	50	-0.009	0.020	0.139	-0.048	0.030					
Difference	GBP	50	0.161	0.052	0.367	0.056	0.265	t = 3.0951	49	Pr(T < t) = 0.9984	Pr(|T| > |t|) = 0.0032	Pr(T > t) = 0.0016

Appendix 10 - Paired t-test Total Return - Robustness check

This table provides the results of the paired t-test of Total Return. The statistics considered are number of observations, mean, standard error, standard deviation and the 95% confidence interval. The t-value and degrees of freedom, as well as the different hypotheses concering this test are also shown. This table shows the division of the t-test results per composite rating, note that this metric is based on an average of Moody's, S&P and Fitch. For all t-tests holds that the mean(diff) = mean(TRRGREN - TRRTRAD) and Ho: mean(diff) = 0.

Variable	Composite Rating	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]	t-value	degrees of freedom	Ha: mean(diff) < 0	Ha: mean(diff) != 0	Ha: mean(diff) > 0
Total Return Green Bonds	AAA	1,006	0.056	0.024	0.755	0.009	0.103					
Total Return Traditional Bonds	AAA	1,006	0.501	0.038	1.197	0.427	0.575					
Difference	AAA	1,006	-0.445	0.043	1.373	-0.530	-0.360	t = -10.2807	1,005	Pr(T < t) = 0.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 1.0000
Total Return Green Bonds	AA1	176	0.008	0.047	0.620	-0.084	0.101					
Total Return Traditional Bonds	AA1	176	0.013	0.055	0.729	-0.095	0.122					
Difference	AA1	176	-0.005	0.057	0.761	-0.118	0.108	t = -0.0843	175	Pr(T < t) = 0.4665	Pr(|T| > |t|) = 0.9329	Pr(T > t) = 0.5335
Total Return Green Bonds	AA2	52	0.086	0.139	1.004	-0.193	0.366					
Total Return Traditional Bonds	AA2	52	-1.226	0.308	2.222	-1.845	-0.608					
Difference	AA2	52	1.312	0.363	2.614	0.584	2.040	t = 3.6196	51	Pr(T < t) = 0.9997	Pr(|T| > |t|) = 0.0007	Pr(T > t) = 0.0003
Total Return Green Bonds	AA3	81	0.032	0.053	0.474	-0.072	0.137					
Total Return Traditional Bonds	AA3	81	-0.073	0.096	0.867	-0.265	0.118					
Difference	AA3	81	0.106	0.098	0.878	-0.088	0.300	t = 1.0827	80	Pr(|T| > |t|) = 0.2822	Pr(|T| > |t|) = 0.2822	Pr(T > t) = 0.1411
Total Return Green Bonds	A1	148	0.143	0.044	0.540	0.055	0.231					
Total Return Traditional Bonds	A1	148	0.273	0.052	0.638	0.170	0.377					
Difference	A1	148	-0.130	0.058	0.700	-0.244	-0.016	t = -2.2627	147	Pr(T < t) = 0.0126	Pr(|T| > |t|) = 0.0251	Pr(T > t) = 0.9874
Total Return Green Bonds	A2	260	0.140	0.043	0.693	0.056	0.225					
Total Return Traditional Bonds	A2	260	0.463	0.061	0.985	0.343	0.584					
Difference	A2	260	-0.323	0.071	1.146	-0.463	-0.183	t = -4.5428	259	Pr(T < t) = 0.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 1.0000
Total Return Green Bonds	A3	187	0.104	0.037	0.512	0.030	0.178					
Total Return Traditional Bonds	A3	187	0.112	0.059	0.807	-0.004	0.229					
Difference	A3	187	-0.008	0.069	0.948	-0.145	0.128	t = -0.1207	186	Pr(T < t) = 0.4520	Pr(|T| > |t|) = 0.9040	Pr(T > t) = 0.5480
Total Return Green Bonds	BBB1	60	0.114	0.094	0.726	-0.074	0.301					
Total Return Traditional Bonds	BBB1	60	0.269	0.132	1.022	0.005	0.533					
Difference	BBB1	60	-0.155	0.156	1.210	-0.468	0.157	t = -0.9939	59	Pr(T < t) = 0.1622	Pr(|T| > |t|) = 0.3243	Pr(T > t) = 0.8378
Total Return Green Bonds	BBB2	43	0.313	0.119	0.783	0.072	0.554					
Total Return Traditional Bonds	BBB2	43	1.550	0.220	1.442	1.106	1.994					
Difference	BBB2	43	-1.237	0.225	1.475	-1.691	-0.783	t = -5.5017	42	Pr(T < t) = 0.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 1.0000
Total Return Green Bonds	BBB3	2	0.709	0.709	1.002	-8.294	9.711					
Total Return Traditional Bonds	BBB3	2	0.003	0.031	0.044	-0.391	0.397					
Difference	BBB3	2	0.706	0.740	1.046	-8.691	10.102	t = 0.9540	1	Pr(T < t) = 0.7425	Pr(|T| > |t|) = 0.5150	Pr(T > t) = 0.2575

Appendix 11 - Paired t-test Excess Return - Robustness check

This table provides the results of the paired t-test of Excess Return. The statistics considered are number of observations, mean, standard error, standard deviation and the 95% confidence interval. The t-value and degrees of freedom, as well as the different hypotheses concering this test are also shown. This table shows the division of the t-test results per composite rating, note that this metric is based on an average of Moody's, S&P and Fitch. For all t-tests holds that the mean(diff) = mean(ExcessRtnGREN - ExcessRtnTRAD) and Ho: mean(diff) = 0.

<table>
<tr><th>Variable</th><th>Composite Rating</th><th>Obs</th><th>Mean</th><th>Std. Err.</th><th>Std. Dev.</th><th colspan="2">[95% Conf. Interval]</th><th>t-value</th><th>degrees of freedom</th><th>Ha: mean(diff) < 0</th><th>Ha: mean(diff) != 0</th><th>Ha: mean(diff) > 0</th></tr>
<tr><td>Excess Return Green Bonds</td><td>AAA</td><td>1,006</td><td>0.012</td><td>0.009</td><td>0.292</td><td>-0.006</td><td>0.031</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Excess Return Traditional Bond</td><td>AAA</td><td>1,006</td><td>-0.026</td><td>0.007</td><td>0.212</td><td>-0.039</td><td>-0.013</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>AAA</td><td>1,006</td><td>0.038</td><td>0.010</td><td>0.310</td><td>0.019</td><td>0.057</td><td>t = 3.8991</td><td>1,005</td><td>Pr(T < t) = 0.9999</td><td>Pr(|T| > |t|) = 0.0001</td><td>Pr(T > t) = 0.0001</td></tr>
<tr><td>Excess Return Green Bonds</td><td>AA1</td><td>176</td><td>0.039</td><td>0.019</td><td>0.256</td><td>0.001</td><td>0.077</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Excess Return Traditional Bond</td><td>AA1</td><td>176</td><td>-0.034</td><td>0.041</td><td>0.550</td><td>-0.116</td><td>0.048</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>AA1</td><td>176</td><td>0.073</td><td>0.047</td><td>0.622</td><td>-0.019</td><td>0.166</td><td>t = 1.5631</td><td>175</td><td>Pr(T < t) = 0.9401</td><td>Pr(|T| > |t|) = 0.1198</td><td>Pr(T > t) = 0.0599</td></tr>
<tr><td>Excess Return Green Bonds</td><td>AA2</td><td>52</td><td>0.185</td><td>0.088</td><td>0.634</td><td>0.009</td><td>0.361</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Excess Return Traditional Bond</td><td>AA2</td><td>52</td><td>-0.696</td><td>0.136</td><td>0.983</td><td>-0.970</td><td>-0.422</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>AA2</td><td>52</td><td>0.881</td><td>0.184</td><td>1.329</td><td>0.511</td><td>1.251</td><td>t = 4.7784</td><td>51</td><td>Pr(T < t) = 1.0000</td><td>Pr(|T| > |t|) = 0.0000</td><td>Pr(T > t) = 0.0000</td></tr>
<tr><td>Excess Return Green Bonds</td><td>AA3</td><td>81</td><td>0.076</td><td>0.035</td><td>0.317</td><td>0.006</td><td>0.146</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Excess Return Traditional Bond</td><td>AA3</td><td>81</td><td>0.082</td><td>0.038</td><td>0.343</td><td>0.006</td><td>0.158</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>AA3</td><td>81</td><td>-0.006</td><td>0.031</td><td>0.283</td><td>-0.069</td><td>0.056</td><td>t = -0.2036</td><td>80</td><td>Pr(T < t) = 0.4196</td><td>Pr(|T| > |t|) = 0.8392</td><td>Pr(T > t) = 0.5804</td></tr>
<tr><td>Excess Return Green Bonds</td><td>A1</td><td>148</td><td>0.087</td><td>0.031</td><td>0.379</td><td>0.026</td><td>0.149</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Excess Return Traditional Bond</td><td>A1</td><td>148</td><td>0.001</td><td>0.026</td><td>0.318</td><td>-0.051</td><td>0.053</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>A1</td><td>148</td><td>0.086</td><td>0.039</td><td>0.473</td><td>0.009</td><td>0.163</td><td>t = 2.2203</td><td>147</td><td>Pr(T < t) = 0.9860</td><td>Pr(|T| > |t|) = 0.0279</td><td>Pr(T > t) = 0.0140</td></tr>
<tr><td>Excess Return Green Bonds</td><td>A2</td><td>260</td><td>0.132</td><td>0.026</td><td>0.427</td><td>0.080</td><td>0.184</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Excess Return Traditional Bond</td><td>A2</td><td>260</td><td>-0.011</td><td>0.024</td><td>0.392</td><td>-0.059</td><td>0.037</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>A2</td><td>260</td><td>0.143</td><td>0.034</td><td>0.550</td><td>0.076</td><td>0.210</td><td>t = 4.1890</td><td>259</td><td>Pr(T < t) = 1.0000</td><td>Pr(|T| > |t|) = 0.0000</td><td>Pr(T > t) = 0.0000</td></tr>
<tr><td>Excess Return Green Bonds</td><td>A3</td><td>187</td><td>0.088</td><td>0.029</td><td>0.398</td><td>0.031</td><td>0.146</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Excess Return Traditional Bond</td><td>A3</td><td>187</td><td>-0.173</td><td>0.056</td><td>0.770</td><td>-0.284</td><td>-0.062</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>A3</td><td>187</td><td>0.261</td><td>0.057</td><td>0.778</td><td>0.149</td><td>0.374</td><td>t = 4.5969</td><td>186</td><td>Pr(T < t) = 1.0000</td><td>Pr(|T| > |t|) = 0.0000</td><td>Pr(T > t) = 0.0000</td></tr>
<tr><td>Excess Return Green Bonds</td><td>BBB1</td><td>60</td><td>0.099</td><td>0.078</td><td>0.605</td><td>-0.057</td><td>0.256</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Excess Return Traditional Bond</td><td>BBB1</td><td>60</td><td>-0.185</td><td>0.039</td><td>0.304</td><td>-0.264</td><td>-0.107</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>BBB1</td><td>60</td><td>0.285</td><td>0.076</td><td>0.590</td><td>0.132</td><td>0.437</td><td>t = 3.7360</td><td>59</td><td>Pr(T < t) = 0.9998</td><td>Pr(|T| > |t|) = 0.0004</td><td>Pr(T > t) = 0.0002</td></tr>
<tr><td>Excess Return Green Bonds</td><td>BBB2</td><td>43</td><td>0.241</td><td>0.090</td><td>0.589</td><td>0.060</td><td>0.422</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Excess Return Traditional Bond</td><td>BBB2</td><td>43</td><td>0.405</td><td>0.074</td><td>0.487</td><td>0.255</td><td>0.555</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>BBB2</td><td>43</td><td>-0.164</td><td>0.109</td><td>0.712</td><td>-0.383</td><td>0.055</td><td>t = -1.5088</td><td>42</td><td>Pr(T < t) = 0.0694</td><td>Pr(|T| > |t|) = 0.1388</td><td>Pr(T > t) = 0.9306</td></tr>
<tr><td>Excess Return Green Bonds</td><td>BBB3</td><td>2</td><td>0.844</td><td>0.844</td><td>1.194</td><td>-9.880</td><td>11.568</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Excess Return Traditional Bond</td><td>BBB3</td><td>2</td><td>-0.263</td><td>0.541</td><td>0.765</td><td>-7.137</td><td>6.611</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Difference</td><td>BBB3</td><td>2</td><td>1.107</td><td>0.303</td><td>0.429</td><td>-2.743</td><td>4.957</td><td>t = 3.6535</td><td>1</td><td>Pr(T < t) = 0.9150</td><td>Pr(|T| > |t|) = 0.1701</td><td>Pr(T > t) = 0.0850</td></tr>
</table>

Appendix 12 - Paired t-test Sharpe ratio - Robustness check

This table provides the results of the paired t-test of Sharpe ratio. The statistics considered are number of observations, mean, standard error, standard deviation and the 95% confidence interval. The t-value and degrees of freedom, as well as the different hypotheses concering this test are also shown. This table shows the division of the t-test results per composite rating, note that this metric is based on an average of Moody's, S&P and Fitch. For all t-tests holds that the mean(diff) = mean(SHARPEMGREN - SHARPEMTRAD) and Ho: mean(diff) = 0.

Variable	Composite Rating	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]		t-value	degrees of freedom	Ha: mean(diff) < 0	Ha: mean(diff) != 0	Ha: mean(diff) > 0
Sharpe ratio Green Bonds	AAA	1,006	0.051	0.028	0.899	-0.004	0.107					
Sharpe ratio Traditional Bonds	AAA	1,006	-0.060	0.022	0.699	-0.103	-0.016					
Difference	AAA	1,006	0.111	0.031	0.995	0.049	0.172	t = 3.5337	1,005	Pr(T < t) = 0.9998	Pr(|T| > |t|) = 0.0004	Pr(T > t) = 0.0002
Sharpe ratio Green Bonds	AA1	176	0.158	0.063	0.830	0.035	0.282					
Sharpe ratio Traditional Bonds	AA1	176	-0.003	0.103	1.360	-0.205	0.199					
Difference	AA1	176	0.161	0.115	1.525	-0.066	0.388	t = 1.4018	175	Pr(T < t) = 0.9186	Pr(|T| > |t|) = 0.1627	Pr(T > t) = 0.0814
Sharpe ratio Green Bonds	AA2	52	0.507	0.270	1.949	-0.036	1.050					
Sharpe ratio Traditional Bonds	AA2	52	-1.621	0.318	2.295	-2.260	-0.982					
Difference	AA2	52	2.128	0.467	3.365	1.191	3.065	t = 4.5590	51	Pr(T < t) = 1.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 0.0000
Sharpe ratio Green Bonds	AA3	81	0.246	0.097	0.874	0.052	0.439					
Sharpe ratio Traditional Bonds	AA3	81	0.180	0.105	0.944	-0.029	0.389					
Difference	AA3	81	0.066	0.095	0.858	-0.124	0.255	t = 0.6883	80	Pr(T < t) = 0.7534	Pr(|T| > |t|) = 0.4933	Pr(T > t) = 0.2466
Sharpe ratio Green Bonds	A1	148	0.276	0.095	1.158	0.088	0.464					
Sharpe ratio Traditional Bonds	A1	148	0.068	0.079	0.965	-0.089	0.224					
Difference	A1	148	0.209	0.103	1.252	0.005	0.412	t = 2.0255	147	Pr(T < t) = 0.9777	Pr(|T| > |t|) = 0.0446	Pr(T > t) = 0.0223
Sharpe ratio Green Bonds	A2	260	0.417	0.075	1.214	0.269	0.565					
Sharpe ratio Traditional Bonds	A2	260	0.035	0.062	1.002	-0.087	0.157					
Difference	A2	260	0.382	0.092	1.486	0.201	0.564	t = 4.1460	259	Pr(T < t) = 1.0000	Pr(|T| > |t|) = 0.0000	Pr(T > t) = 0.0000
Sharpe ratio Green Bonds	A3	187	0.244	0.089	1.216	0.069	0.419					
Sharpe ratio Traditional Bonds	A3	187	-0.161	0.112	1.532	-0.382	0.060					
Difference	A3	187	0.405	0.123	1.684	0.162	0.648	t = 3.2916	186	Pr(T < t) = 0.9994	Pr(|T| > |t|) = 0.0012	Pr(T > t) = 0.0006
Sharpe ratio Green Bonds	BBB1	60	0.232	0.249	1.927	-0.266	0.730					
Sharpe ratio Traditional Bonds	BBB1	60	-0.439	0.123	0.952	-0.685	-0.193					
Difference	BBB1	60	0.671	0.251	1.942	0.169	1.173	t = 2.6756	59	Pr(T < t) = 0.9952	Pr(|T| > |t|) = 0.0096	Pr(T > t) = 0.0048
Sharpe ratio Green Bonds	BBB2	43	0.757	0.266	1.747	0.220	1.295					
Sharpe ratio Traditional Bonds	BBB2	43	1.158	0.192	1.256	0.771	1.544					
Difference	BBB2	43	-0.401	0.310	2.034	-1.027	0.226	t = -1.2912	42	Pr(T < t) = 0.1019	Pr(|T| > |t|) = 0.2037	Pr(T > t) = 0.8981
Sharpe ratio Green Bonds	BBB3	2	2.960	2.960	4.186	-34.653	40.574					
Sharpe ratio Traditional Bonds	BBB3	2	-0.219	1.653	2.337	-21.216	20.778					
Difference	BBB3	2	3.179	1.308	1.849	-13.437	19.795	t = 2.4309	1	Pr(T < t) = 0.8758	Pr(|T| > |t|) = 0.2485	Pr(T > t) = 0.1242

Appendix 13 - Regression results with control variables

This table shows the results of the fixed effects regression model with dependent variables: total return, excess return and Sharpe ratio between green and traditional bonds. In this table, three regression are performed. Dummy is 1 for green bonds and 0 for traditional bonds. Next to Composite Rating and Effective Duration, in this table also Face Value is added as a control variable. Composite Rating is a numerical variable ranging from 1 (AAA) to 10 (BBB3)

Variables	(1) Total return	(2) Excess return	(3) Sharpe ratio
Dummy	-0.074**	0.099***	0.232***
	(0.037)	(0.015)	(0.041)
Composite Rating	0.031	0.002	0.013
	(0.024)	(0.010)	(0.026)
Effective Duration	0.154***	0.068***	0.170***
	(0.037)	(0.015)	(0.041)
Face Value	0.000***	-0.000*	-0.000
	(0.000)	(0.000)	(0.000)
Constant	-0.740***	-0.326***	-0.790***
	(0.191)	(0.079)	(0.210)
Observations	4,030	4,030	4,030
R-squared	0.076	0.047	0.039
Number of Pair	2,015	2,015	2,015

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1