UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

Master of Science in Finance
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Performance Evaluation of Green and Conventional Bonds by Common Factor Models

Together with increased sustainable awareness, companies and municipalities all over the world seek funds to conduct Green projects. The rapid growth of interest in sustainability has led to an additional investment opportunity for investors. However, this relatively new topic lacks sufficiently extensive studies concerning Green Bonds performance and investors may therefore struggle to decide whether to include Green Bonds in the portfolio or not. The aim of this thesis was to investigate the performance of Green Bonds compared to conventional bonds using common factor models. Starting off with the CAPM, the model is later expanded with additional factors such as the Fama-French three-factor model, the bond specific Term and Def factors and ultimately ending up with a six-factor model. All models possess relatively high explanatory power and although no statistical significance could be proven, the models suggest that there is no difference in performance between Green- and conventional bonds. Hence, investors are advised to invest in Green Bonds, which possibly entails a positive sustainable image, while the expected return may remain unchanged.

Authors:
Wilhelm Asker
Jens Malm

Supervisor:
Conny Overland

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1. Introduction

1.1 Green Bonds

The importance of being recognized as sustainable oriented has lately increased for investors and companies and is often crucial to become acknowledged and successful. The increased global warming has made people aware that something must be done to reduce the negative impact on the environment. The increasing demands and regulations for sustainable awareness has come to impact the way corporations and investors act. New strategies have been developed to fulfill the new conditions as well as acquire an image of being environmentally friendly (Mathews and Kidney, 2012). As a part of these new strategies, the interest in Socially Responsible Investments (SRI) has increased dramatically in the recent years (Scholtens, 2009). Within the SRI framework one green investment has specifically gained increased popularity, namely the Green Bonds.

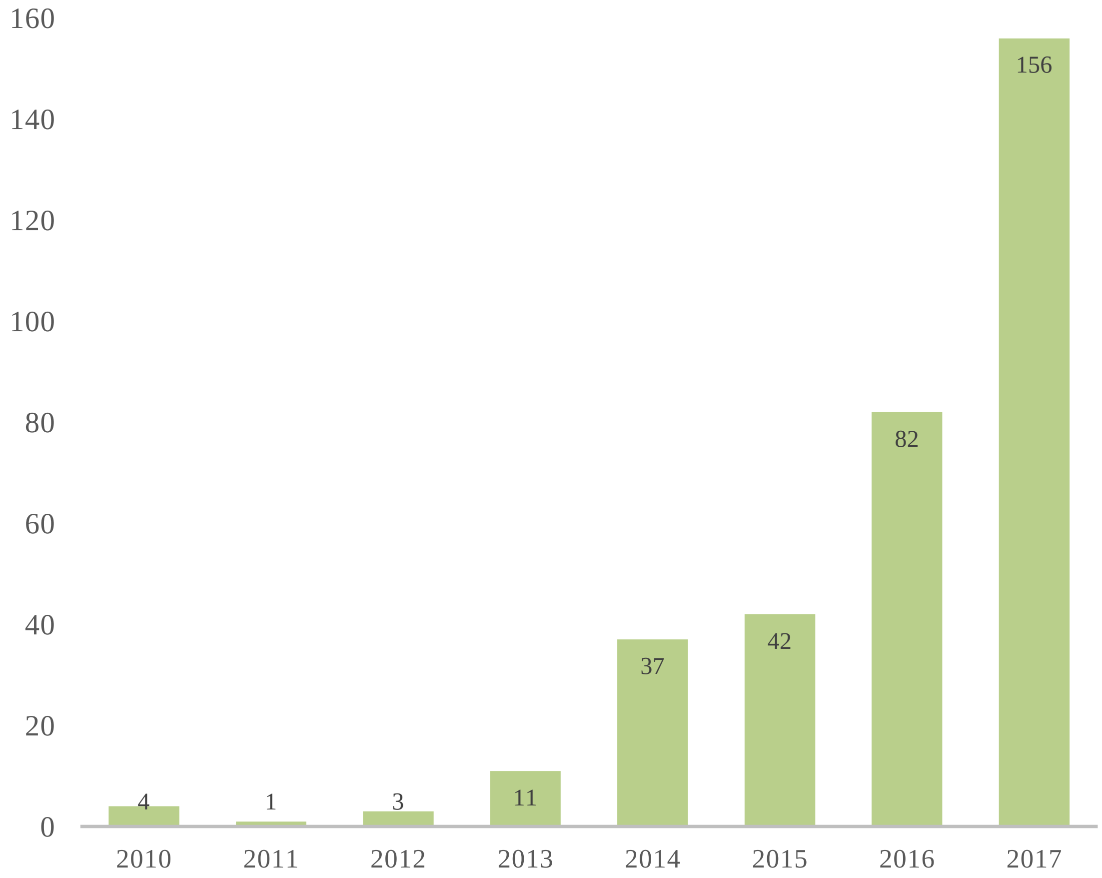
The purpose of Green Bonds is to fund projects that have positive climate and/or environmental benefits. Hence, the proceeds are invested exclusively in green projects, either through securitization, direct exposure in the project or by specifying the use of the proceeds (Barclays, 2015). For instance, Green Bonds could fund projects aimed at energy efficiency, sustainable agriculture, pollution prevention and clean transportation. These characteristics, are what distinguishes Green Bonds from conventional bonds.

1.2 History of Green Bonds

The first issuer of Green Bonds was the World Bank in 2008 and $3.5 billion in debt has been issued by the World Bank since then. There was $35.8 billion worth of Green Bonds outstanding in 2014 and in 2015 there was $41 billion worth of Green Bonds. In mid-October 2017, there was 110$ billion worth of issued Green Bonds (Cheng, 2017).

The interest in a green way of funding projects through bonds has exploded ever since, all over the globe.

Figure 1. Green Bond global market growth (billion USD)



As illustrated in *figure 1*, the Green Bond market has grown rapidly during the last decade, entailing that the availability on the market has increased significantly as company's demand for funding through Green Bonds increases (Mandel, 2015; Schroders, 2015; Kochetygova and Jauhari, 2014).

1.3 Purpose of the Thesis

Although the importance and popularity of Green Bonds is increasing, there is not much empirical information available on the socially responsible investment Green Bond nor not that many empirical studies conducted. Hence, further analysis of this segment is of high interest. This thesis aim is to shed light on the performance of this popular and relatively new investment by applying common factor models of the asset pricing literature. The final results will be evaluated with the purpose to conclude whether there is a financial advantage of investing in Green Bonds or not.

The only factor distinguishing Green Bonds from conventional bonds is the use of proceeds and thus, investors that invest in Green Bonds should not expect significant differences in returns compared to investments in conventional bonds. However, an environmentally friendly image could potentially result in additional value and thus the Green Bond could be seen as a better investment overall. These arguments form the foundation for the hypothesis of this thesis.

1.4 Contribution

Due to the fact that the Green Bond market has boomed significantly during the very recent years, earlier studies have lacked sufficient data. By utilizing this recently available data it is possible to contribute with increased reliability, regarding the performance of Green Bonds. To further increase the reliability of the results, extensions are done to the most common factor models used in the asset pricing theory; starting off with the famous single factor model the Capital Asset Pricing Model, multiple factors are added as well as a control variable in the form of a Green Bond-dummy in order to capture and explain the variability in bond returns. At the same time, the application and explanatory power of these models are evaluated, providing further evidence to the research on bond returns.

1.5 Results

In line with the hypothesis that there is no difference in returns between Green and conventional bonds, Fama-MacBeth regressions on the different factor models show that none of the Green dummy coefficients are statistically significant different from zero, with minimal point estimates of implied yield spreads. Hence, we cannot reject the null hypothesis that there is no difference in returns between Green Bonds and conventional bonds, which indicates that Green and conventional bonds perform equally.

2. Literature Review

2.1 Performance of Sustainable Investments

The Green bonds are found within the sustainable and responsible investments (SRI) segment. The SRI category is still being developed and could explain why there is not much research conducted on the area of financial performance of SRI instruments. Gil-Bazo et al. (2010) find evidence of higher performance of before and after-fee of US SRI fund compared to non-SRI funds, while Xiao et al. (2012) did not find any significant relationship between sustainability and returns.

Ibikunle and Steffen (2015) compared the financial performance of green and conventional investments, although for equity mutual funds, and found no significant difference in the performance of the green mutual funds and the conventional funds.

Derwall and Koedijk (2009) investigate the performance of mutual funds that invest in socially responsible fixed-income securities by measuring how socially responsible bond and balanced funds perform compared to matched samples of conventional funds. Through multi-index performance evaluation models, they conclude that the performance of the average socially responsible investment bond fund was similar to conventional funds. However, the average socially balanced fund outperformed the conventional fund. They further show that the expenses charged by SRI funds does not result in underperformance since the expenses charged by conventional funds match the ones of SRI funds.

Furthermore, research on performance of ethical mutual funds as well as investment style was conducted by Bauer et al. (2004) who show that there are no significant differences between the risk-adjusted returns of ethical and conventional funds.

Edmans (2011) states a theory that suggests that companies whose employees are satisfied with a considered sustainable service position have proven to outperform companies whose employees disagree that the company is working sustainably. If this is true, investments in Green Bond could be financially superior to investments in conventional bonds since the company or government who emitted the bond performs better than other issuers, compared to what the market expects.

2.2 Modelling Bond-Specific Returns

Overall, there is less literature focusing on the modelling of expected returns of bonds compared to the literature focusing on equities and the literature on Green Bond returns is particularly limited. However, the factor differentiating Green Bonds from conventional bonds is the use of proceed, other than that they are no different from conventional bonds. Thus, the same models applied on conventional bonds should be applicable on Green Bonds as well.

Fama and French (1989) investigate expected excess returns on stocks and bonds and find that the expected excess returns on corporate bonds and stocks move together. Furthermore, variables often used to measure default and term spreads in bond returns, can help predict variation in stock returns. Fama and French (1993) identify five risk factors in returns of stocks and bonds. They use the three stock-market factors excess return of the market portfolio, size and book-to-market equity and two bond market factors denoted Def which is related to default risks and the Term factor by (Chen, Roll and Ross, 1986). The Term factor aims to capture interest rate risk and is applied by Chen, Roll and Ross (1986) to the two stage Fama-MacBeth regression by (Fama and MacBeth, 1973). Fama and French (1993) find that these five factors seem to explain average returns on stocks and bonds. The argument is that due to the stock-market factors, the variability of returns of stocks is related to the returns of bonds through shared variation in the factors of the bond market. The importance of including a factor for default is also strengthened by Merton (1973), where he states that the default factor is a major explanatory variable in the pricing of bonds.

The three-factor model by Fama and French (1992) is later used by Elton et al. (2001) to explain whether there is risk premium in corporate bonds spread. Their finding is that systematic risk factors related to expected returns on equity are important in order to explain bond returns as corporate bond spreads systematically vary with the stock market factors (Fama and French, 1993).

3. Method and Theoretical Models

3.1 Modelling Bond Returns

The objective of this paper is to evaluate the yield spread between Green and conventional bonds through common factor models. By adding additional factors to the original single factor Capital Asset Pricing Model, the explanatory power and results will be evaluated in order to see which model explains the variability in bond returns the best. The most suited model will then be applied to rating-based portfolios of bond returns as a robustness test to ensure unbiased results. The hypothesis which the thesis rests upon is formulated as:

$$H_0: The\ yield\ spread\ between\ Green\ Bonds\ and\ conventional\ bonds\ is\ zero$$

$$H_1: The\ yield\ spread\ between\ Green\ Bonds\ and\ conventional\ bonds\ is\ different\ from\ zero$$

In order to capture the variation of returns, many researchers have throughout the previous literature applied multi-factor models which consists of multiple explanatory factors. The multi-factor models have provided high explanatory power, good empirical fit and has been shown to explain a large and significant part of the variability in bond returns. Among the factors that have been proven to possess explanatory power are different bond and stock market factors. As found by numerous researchers, among them Chen, Roll and Ross (1986) and Burmeister and Wall (1986), the time series of individual returns as well as the cross-section of expected returns used in common-stock studies can be explained by the following factors: market returns, default risk, term risk and when there are sudden changes in measurements for economic performance. These factors have been shown to be significant for explaining equity returns, both expected and actual. As such, they should be important in explaining bond returns, Elton et al. (1995).

3.2 Factors

The first factor, the market return, is defined as the excess return on the stock market and can be seen as a measurement of the economic conditions in general. In this thesis, the market return is constructed by an index of aggregate bond returns and this single factor should probably be the best factor in order to explain individual bond returns (Elton et al, 1995). A market index of stock returns should also be the best factor in order to explain the performance of individual stocks, (Elton et al, 1995). The fourth factor which is the factor of sudden changes in measurements for economic performance, could affect the expectations of cash-flows on different kind of bonds and hence bond returns (Ederington and Lee, 1993).

As a large extent of the models used by researchers are based on the single factor Capital Asset Pricing Model developed by Sharpe (1964) and Lintner (1965) and further extended with additional factors, this thesis is inspired by this process and selects the most common factor models in order to evaluate potential differences in yield spread between Green and conventional bonds.

3.3 Capital Asset Pricing Model

The CAPM-model has been constructed to price any capital asset, most of the previous research using the model has been applied on equities. Research with application of CAPM on bonds is limited, even though Engel (1993) tests the CAPM on portfolios of bonds and stocks. Thorsell (2008) argues that data on stock trades are more transparent since the trades are recorded at a stock exchange while bond trading is less transparent due to the existence of over the counter trading. Hence, the availability of data could be one reason why most of the research apply CAPM on equities.

The Sharp-Lintner standard CAPM-model is shown in *equation 1* below.

$$R_{it} - R_{ft} = \alpha_i + \beta_i\left(R_{mt} - R_{ft}\right) + \varepsilon_{it} \qquad \textit{(Eq 1)}$$

Where R_i is the bond return for asset *i*, R_f is the risk-free rate and R_m denotes the market return. In order to distinguish between Green and conventional bonds, a dummy variable is added as a control variable to indicate the effect of being labeled as green. This coefficient, shown in *equation 2*, can be interpreted as the difference in return that an investor can expect when buying a Green Bonds in comparison to buying a conventional bond.

$$R_{it} - R_{ft} = \alpha_i + \beta_m\left(R_{mt} - R_{ft}\right) + \delta_i GreenBond_i + \varepsilon_{it} \qquad \textit{(Eq 2)}$$

3.4 Fama and French Three-Factor Model

The Capital Asset Pricing Model has since its introduction defined researchers as well as the finance industry's view of risk and average returns. However, contradictions have arisen towards the model's main prediction of mean-variance efficiency in the market portfolio. For instance, Banz (1981) find that market equity strengthens the explanatory power of the cross-section of average returns provided by the betas of the market. This stems from the finding that the beta estimates of small and large stocks are not in line with the average returns which are too high for small stocks and too small for large stocks. Additionally, Stattman (1980) and Rosenberg, Reid and Landstein (1985) provide evidence that the ratio of a firm's book value of common equity, BE, to its market value, ME, connected to the average returns on U.S stocks in a positive way. Their findings are further confirmed by Chen, Hamao and Lakonishok (1991) who find that BE/ME provides additional explanatory power in describing the cross-section of average returns on Japanese stocks.

Armed with these findings, Fama and French (1992) extends the original Capital Asset Pricing Model into a multifactor model with two additional factors accounting for size and value. The multifactor asset pricing model identify multiple sources of risk that explain differences in expected returns across assets. The size factor, small minus big or in short SMB, is constructed by creating three portfolios containing small stocks and three portfolios containing large stocks, where size is defined by the stock's market equity. The average return on this portfolio is then calculated by the average return on the three small portfolios minus the average return on the three big portfolios.

The value factor, high minus low or in short HML, is constructed by creating two value portfolios and two growth portfolios, based on the BE/ME ratio. The average return on this portfolio is then defined as the average return on the value portfolios minus the average return on the two growth portfolios.

The two factors SMB and HML consist of daily and global data during the period 2010-2017 retrieved from the Kenneth French website. The SMB- and HML factors are computed by following formulas.

$$SMB_t = \frac{1}{3}\left(R_{t,SG} + R_{t,SN} + R_{t,SV}\right) - \frac{1}{3}\left(R_{t,BG} + R_{t,BN} + R_{t,BV}\right) \quad \text{(Eq 3)}$$

Where $R_{t,SG}$ is the return from small growth firms, $R_{t,SN}$ is the return from small neutral firms, $R_{t,SV}$ is the return from small value firms. $R_{t,BG}$ is the return from big growth firms, $R_{t,BN}$ is the return from big neutral firms and $R_{t,BV}$ is the return from big value firms.

$$HML_t = \frac{1}{2}\left(R_{t,SV} + R_{t,BV}\right) - \frac{1}{2}\left(R_{t,SG} + R_{t,BG}\right) \quad \text{(Eq 4)}$$

Inspired by Elton et al. 2001, the three-factor model developed by Fama and French (1993) is used in order to investigate the yield spread between Green and conventional bonds. The SMB-factor captures differences between small and big companies and the HML-factor shows if there are differences between high value companies and growth companies.

$$R_{it} - R_{ft} = \alpha_i + \beta_m\left(R_{mt} - R_{ft}\right) + \beta_{SMB}SMB_t + \beta_{HML}HML_t + \delta_i GreenBond_i + \varepsilon_{it} \quad \text{(Eq 5)}$$

3.5 Carhart Four-Factor model

Carhart (1997) adds a fourth factor to the original Fama and French three-factor model (1993) in order to capture momentum effects as constructed by Grinblatt, Titman and Wermers (1995) who find that momentum strategies increased the performance significantly compared to investments excluding the momentum strategy. The Carhart model is used by Bauer et al. (2004) to evaluate ethical mutual fund performance.

The momentum factor is denoted WML and it captures the differences between companies that has performed well, in terms of market value growth, in the previous time period compared to recent poor performing companies. The Carhart model is shown in *equation 6*.

$$R_{it} - R_{ft} = \alpha_i + \beta_m\left(R_{mt} - R_{ft}\right) + \beta_{SMB}SMB_t + \beta_{HML}HML_t + \beta_{WML}WML_t + \delta_i GreenBond_i + \varepsilon_{it} \quad \text{(Eq 6)}$$

3.6 Def and Term Factor Model

Fama and French (1993) extend their asset pricing model tests (Fama and French, 1992) by incorporating bond returns as an additional asset to be explained. Since changes in interest rates is an identified risk factor in bond returns and to account for this risk factor, Fama and French apply a factor denoted Term which is defined as the difference between the monthly long-term government bond return and the one-month Treasury bill. The motivation for the application of the Treasury bill rate is that it will act as a proxy of the general level of expected returns on bonds. Hence, how the long-term bond returns deviate from the expected returns due to changes in interest rates will be proxied by the Term factor. In this paper the Term factor is constructed by using the Citi World Government Bond Index with daily returns during the period 2010-2017 to proxy for the long-term government bond.

Another identified risk-factor of bond returns is the probability of default. When changes in financial conditions that affect the probability of default occurs this risk needs to be accounted for. To proxy for the default risk a Def factor is constructed by calculating the difference between the return on a market portfolio of long-term corporate bonds and the long-term government bond return. In order to construct a proxy for the Def factor the Bloomberg Barclays Global aggregate corporate total return index is used as a proxy for the long-term corporate bonds daily returns and the Citi World Government Bond Index is used as a proxy for the long-term government bond.

Chen et al. (1986) argue that changes in interest rate as well as changes in default probability for companies should be factors to use in order to explain value premiums for bonds, which intuitively makes sense. Therefore, a Term factor is added that captures differences in return when the interest rate changes defined as the difference between long-term government bond and one-month treasury bills. Further, a Def factor is added which is defined as the difference between a portfolio of long-term corporate bonds and the government bond return. In this model, the market factor is removed, and the factors Def and Term are included in the model in order to isolate the model solely to bond specific risk factors as inspired by Fama and French (1989).

$$R_{it} - R_{ft} = \alpha_i + TERM_t + \beta_{DEF} DEF_t + \delta_i GreenBond_i + \varepsilon_{it} \qquad \textit{(Eq 7)}$$

3.7 Fama and French Extended Three-Factor Model

To establish a model that incorporates a wider spectrum of effects, the bond specific Def and Term factors are added to the stock specific three-factor model. The outcome is the five-factor model, listed in *equation 8*.

$$R_{it} - R_{ft} = \alpha_i + \beta_m\left(R_{mt} - R_{ft}\right) + \beta_{SMB}SMB_t + \beta_{HML}HML_t + \beta_{TERM}TERM_t + \beta_{DEF}DEF_t + \delta_i GreenBond_i + \varepsilon_{it} \qquad \text{(Eq 8)}$$

In order to to capture further potential effects, the momentum-factor is added to the five-factor model, leading to the most extensive model in this thesis, the six-factor model shown below.

$$R_{it} - R_{ft} = \alpha_i + \beta_m\left(R_{mt} - R_{ft}\right) + \beta_{SMB}SMB_t + \beta_{HML}HML_t + \beta_{WML}WML_t + \beta_{TERM}TERM_t + \beta_{DEF}DEF_t + \delta_i GreenBond_i + \varepsilon_{it} \qquad \text{(Eq 9)}$$

3.8 Fama-MacBeth Regression

In order to explain asset returns, risk factors are commonly used in the asset pricing research. The Fama-MacBeth two step approach by Fama and MacBeth (1973) is a widely used method for investigating how multi-factors explain asset returns or portfolios. It is primarily used when big cross-sectional data is processed which is simultaneously observed for a period of time. The application of the Fama and MacBeth approach on bonds is among others supported by Lin, Wang & Wu (2011) who apply the Fama and MacBeth regression to test individual bonds. In the first step the goal is to determine the different factor exposures of the portfolio returns. The procedure of the first step is to regress each portfolio return against one or more of the factor time series. Thus, in the first step each factor exposure, denoted β, is retrieved from conducting *n* number of regressions on each one of the *m* factors. The procedure gives following regressions.

$$R_{it} - R^f = a_{i1} + \beta_{i1} f_{1t} + \cdots + \beta_{ik} f_{kt} + \varepsilon_{it} \qquad \text{(Eq 10)}$$

where beta is the time series coefficient of the regression and alpha the intercept. Each bond is represented by *i*, while *k* represents each factor and *t* each time point.

In the second step, cross-sectional regressions of the portfolio or asset returns against the obtained factor exposures at each point in time is conducted. This results in a time series of risk premium coefficients for each of the factors in the model and then the average of these risk premium coefficients for each factor is calculated. The average risk premium is calculated in order to be able to quantify the expected premium for a unit exposure to each of the risk factors across time.

Expressed in equation form, *k* denotes the number of cross-sectional regressions of the returns on the *i* first stage obtained factor exposures which is denoted β and where λ is the factor coefficient representing factor *k*.

$$R_{it} - R^f = \alpha_{i1} + \lambda_{1t} \beta_{i1} + \cdots + \lambda_{kt} \beta_{ik} + \varepsilon_{it} \qquad \text{(Eq 11)}$$

3.9 Portfolio Formation for the Five-Factor Regression Based on Ratings

In order to improve the accuracy of the beta estimates, Blume (1970), Friend and Blume (1970), Black, Jensen and Scholes (1972), Fama and French (2004) group securities into portfolios. The argument is that the market betas and expected returns interact in the same way in portfolios as they do individually. Thus, CAPM is applicable to describe portfolio returns as well. Grouping the securities into portfolios will also reduce the problem of the critical errors in variables, which could arise when conducting cross-sectional regressions of averages returns on betas, Fama and French (2004). Furthermore, evidence show that depending on the rating, corporate bonds possess different characteristics. (Elton et al. 2001; Fama & French, 1993; Huang & Huang 2002). It was also found that bonds with lower rating and stocks behave to a high degree in similar ways.

Following these arguments, the green and conventional bonds are grouped into 5 rating-based portfolios. The plus and minus signs of the respective rating grade are not accounted for in the portfolio formation, thus, BBB+ is sorted in the BBB portfolio, following (Fama and French, 1993). The first portfolio consists of AAA and AA-rated bonds, the second contains A-rated bonds, the third BBB-rated bonds, the fourth portfolio denoted LG, contains low grade bonds and the last portfolio contains no info or no rating bonds. Then, in each portfolio, a green dummy variable is once again included in order to control for Green Bonds and then the five-factor Fama-MacBeth regression is applied to each portfolio.

Table 1. Distribution of ratings

Rating-based portfolios and number of bonds

Portfolio	Number of bonds
AAA & AA	130
A	129
BBB	131
LG	40
No info or rating	570

4. Data

4.1 Bonds

Data on historical prices and yields of both Green Bonds and conventional bonds has been collected from Bloomberg alongside information regarding each bonds' S&P rating and currency. Most factors used are downloaded from Kenneth French's database-website, while the Term and Def factors have been created based on global interest and corporate bond indices from Bloomberg. Returns for bonds and currencies are calculated and used for the analysis. All calculations and regressions are conducted in Matlab which is the most convenient software since the Fama-MacBeth-method with more than 1000 bonds in up to 2000 time points demands a huge amount of regressions and database management. The data starts from 2010/01/01 when the first registered Green Bonds were issued, however most of the Green Bonds are issued within the last recent years.

Since the Green Bond is a relatively new financial instrument, most of the Green Bonds were issued during recent years and therefore the scope has been broadened to include Green Bonds worldwide. Thus, this further allows the thesis to incorporate a global perspective. The global scope comes with issues such as differences in data concerning non-trading days. Therefore, matching algorithms have been created and applied on all bonds as well as on the factors and the risk free rate. The global perspective further requires currency adjustments as the bonds are expressed in different currencies. All bond prices have therefore been converted to USD in order to correct for exchange rate returns. USD is considered the most convenient currency since roughly half of the Green- and conventional bonds are listed in USD, additionally, all data of the factors are retrieved in USD.

Several bonds lack proper information regarding yield and have therefore been excluded. Certain criteria were specified in the data import process such as interest rate structure, in order to strengthen the comparability of the bonds. Daily returns are used for bonds issued at least one year ago to compare with the returns of Green Bonds. An index containing conventional bonds, covered bonds and treasury bonds is used as a market proxy in the models.

There are big differences in geographical distribution between Green Bonds and the conventional bonds, which is due to differences in how far countries have advanced with sustainability. This has led to over and under representations of countries in our study. For instance, Sweden as a country is considered ahead when it comes to sustainability and Sweden represents 31 of the Green Bonds in the Green Bond data sample, while none of the conventional bonds that were randomized turned out to be Swedish. USA on the other hand, represents roughly half of the Green Bonds as well as the conventional bonds and contributes to balancing out the geographical distribution.

4.2 Green Bond Dataset

The 'Fixed Income' function in Bloomberg is used to retrieve all bond information, where the data is filtered with the following search criterias:

Table 2. Green Bond filtrering

Class	Corporate or Government
Security status	Bonds: Active
Use of proceed	Project finance or investment
S&P Rating	AAA-R
Region	Global
Issue Date	01/01/2007-12/31/2017
Matches	597

As it turns out, Bloomberg has no data regarding 38 of the Green bonds and 57 of the Green Bonds lack data regarding the yield. This adds up to total of 502 Green bonds with an average of 524 trading days.

4.3 Conventional Bond Dataset

The search criterias for conventional bonds was similar to the Green Bonds filtering, as shown in the table below.

Table 3. Conventional bond filtering

Class	Corporate or Government
Security status	Bonds: Active
Use of proceed	Green Bond
S&P Rating	AAA-R
Region	Global
Issue Date	01/01/2007-12/31/2017
Matches	10 131

In order to somewhat equalize the sample sizes for Green-and conventional bonds, a similar amount of conventional bonds on which data is available, is selected randomly. The random selection is conducted by assigning a random term to each conventional bond and sort them according to the random term. This lead to a final set of 505 conventional bonds with an average of 771 trading days.

4.4 Risk-Free Rate

Since the bonds in the dataset are globally distributed, daily global risk-free rate provided by Kenneth French's website are used to represent the risk-free rate, (French, 2017).

4.5 Fama French Factors

Data on the Fama French factors as well as the momentum factor is retrieved from Kenneth French's website in daily format (French, 2017). The first factor is HML (high minus low), which captures the differences between firms with strong cash flows compared to growth firms. SMB (small minus big) on the other hand focuses on differences between big market cap firms and small firms. The momentum factor is constructed as lagged returns (12 and 2 trading days respectively) and can hence compare stocks with differences in momentum.

4.6 Bond Factors

The first bond specific factor used is the Def factor (default risk changes), which captures how changes in default risk affect bond performance. It is constructed as the difference between the long-term corporate bond return and the long-term government bond return. The returns from

Bloomberg Barclays Global Aggregate Corporate Total Return Index Value Unhedged is retrieved from Bloomberg as the long-term corporate bond returns and the returns of Citi World Government Bond Index as the long-term government bond returns. The second bond specific factor is the Term factor (interest rate changes), where the effect of interest rate changes on the bond prices are captured. The term factor used is constructed by the difference between the Citi World Government Bond Index and the one-month Treasury bill.

4.7 Bond Market

Throughout the Capital Asset Pricing Model literature, the excess stock market return has been the most heavily applied factor to define the market portfolio. Fama and French (1993) provides motivation for this application with the argument that if markets are integrated, one single model that explains equity returns should also explain bond returns.

However, this argument is contradicted by Elton, Gruber and Blake (1995) who states that in a single factor model, an index of aggregate bond returns will serve as the optimal factor in order to explain individual bond returns. Following this, the MSCI World Bond Index collected from Bloomberg is used as a proxy for the bond market portfolio and will be used to capture the common variation in bond returns. From the MSCI World Bond Index, daily returns during the period 2010-2017 is retrieved.

5. Results and Analysis

This section is divided into several parts where each model's results are analyzed separately and compared later. All statistical tests are analyzed with a set significance level of 5%. As shown in the descriptive table below, the average yearly returns for Green Bonds and conventional bonds are similar, with a difference of 27 basis points.

Table 4. Descriptive statistics

	Green Bonds	Conventional bonds
Number of Bonds	502	505
Average yearly return	5.12%	5.29%
Average days since issue date	530	774
	Overall Statistics	
Time period	2010-01-01 to 2017-12-31	
Average risk-free rate during the period	0.06%	

5.1 Fama-MacBeth Regression of The Capital Asset Pricing Model

As shown in the table 5, the Green dummy variable has a small negative coefficient of -0.5 basis points. Hence, the point estimate shows negligible small tendencies of lower returns for Green Bonds compared to conventional bonds. However, the t-value of -0.258 suggests that the coefficient is not statistically significant different from zero at a 5% significance level and hence neither Green Bonds nor conventional bonds can be confirmed as outperforming the counterpart using the CAPM model.

The pricing error of the model is of low magnitude of 3.9 basis points, a value below the average risk-free rate during the period of 6.0 basis points. However, the pricing error is positive and has a corresponding t-value of 3.96, showing that the pricing error is statistically significant on an 5% significance level. The risk premium from exposure to the market factor is positive and significantly different from zero on an 5% significance level. The model has an R^2 adjusted-value of 0.315 which shows that most of the variability in the model is still unexplained and thus, the model should be extended with additional factors for further analysis.

Table 5. CAPM Results

	α	δ GREEN	λ mkt
Coefficient	0.039	-0.005	0.415
t-value	3.956	-0.258	9.411
	***		***

R^2	Adjusted R^2	P-value
0.326	0.315	0.011

Table 5 presents the results of the two-stage Fama-MacBeth regression of bond returns as explained by the single-factor Capital Asset Pricing Model. The λ represents the average risk premium associated with exposure to the market factor from the cross-sectional regression in the second stage. All individual bond returns are regressed each day of the time period and then explained by the beta coefficients retrieved in the time series regression in the first stage. The t-statistics are expressed in parentheses. The δ represents the dummy variable controlling for the differences in returns between Green Bonds and conventional bonds. The R^2 of the Fama-MacBeth regression of the single factor Capital Asset Pricing Model is the proportion of the variation in the model that can be explained by the model. In order to adjust for the natural increasing explanatory power of adding additional factors, the adjusted R^2 is calculated. The P-value shows the significance of the entire model.

5.2 Fama-MacBeth Regression of the Def-Term Bond Factor Model

As shown in the table 6, the Green dummy variable has a negative coefficient of -0.6 basis points decreasing from -0.5 basis point in the Capital Asset Pricing Model. A t-value of -0.363 indicates as before that no distinguishable differences can be concluded regarding the yield spread between Green and conventional bonds. The pricing error of the model increases but remains low and significant at 5.5 basis points with a corresponding t-value of 4.94. The average risk premium from exposure to the default probability factor is negative with a coefficient of -45 basis points and statistically significantly different from zero on an 5% significance level. The Term factor however, is positive with a coefficient of 20.7 basis points which indicates that investors or corporations should expect a positive risk premium as compensation for the exposure to the term-risk factor. However, the coefficient is on the other hand not statistically significant. The model has an R^2 adjusted value of 0.255 which is of lower magnitude compared to the CAPM-model, however it suggests that the bond specific factor Def is able to explain bond returns. Furthermore, Fama and French (1989) reports R^2 values ranging from 0.00 to 0.45, although for rating based portfolios. As such, the model generated R^2 should not be considered abnormal and additionally, both the Def factor and Term factor are significant which is in line with their result that these factors provide significant information about the expected returns of bonds as implied by the majority of their t-statistics.

Table 6. Def-Term Results

	α	**δ GREEN**	**λ DEF**	**λ TERM**
Coefficient	0.055	-0.006	-0.451	0.206
t-value	4.945	-0.363	-2.765	3.023
	***		***	***

R^2	**Adjusted R^2**	**P-value**
0.273	0.255	0.023

Table 6 presents the results of the two-stage Fama-MacBeth regression of bond returns explained by solely the bond specific factors Def and Term, where Def captures the effect on the bond returns that comes from changes in default risk and Term captures the effect coming from changes in interest rate Each λ represents the average risk premium associated with exposure to the Def and Term factor. The t-statistics are expressed in parentheses. The δ represents the dummy variable controlling for the differences in returns between Green Bonds and conventional bonds. The R^2 of the Fama-MacBeth regression of the single factor Capital Asset Pricing Model is the proportion of the variation in the model that can be explained by the model. In order to adjust for the natural increasing explanatory power of adding additional factors, the adjusted R^2 is calculated. The P-value shows the significance of the entire model.

5.3 Fama-MacBeth Regression of the Three-Factor Fama-French Model

This model is an extension of the CAPM-model, where the stock market specific factors SMB and HML are added as inspired by Elton et al (2001). As shown in the table 7, the Green dummy variable is unaffected from the Def-Term model at -0.6 basis points. The t-value for the Green dummy is -0.289 and hence not statistically significantly different from zero. The pricing error decreases to 3.05 basis points while remaining significant at a t-value of 3.1. The t-statistics of the risk premium coefficients for the market factor, SMB and HML are 14.850, 5.328 and -4.542 respectively which means that all of factors are significantly different from zero on an 5% significance level. The risk premium of the market factor is consistently positive which is in line with the basis of theory (Elton et al, 2001). The positive SMB-coefficient suggests that a positive risk premium should be expected for exposure to the SMB risk factor. The HML coefficient however is negative and implies that the factor is negatively related to returns. This was also found in the regression on corporate and government bonds with low maturity in the study by (Elton et al, 2001), although they concluded that overall, the HML factor is positively related to bond returns. As such, the negative HML-coefficient was unexpected. The model has an adjusted R^2 value of 0.533 which is a large increase in explanatory power compared to the earlier models.

Table 7. Three-Factor Results

	α	**δ GREEN**	**λ mkt**	**λ SMB**	**λ HML**
Coefficient	0.030	-0.006	0.751	0.104	-0.106
t-value	3.912	-0.289	14.850	5.328	-4.542
	***		***	***	***

R^2	**Adjusted R^2**	**P-value**
0.546	0.533	0.001

Table 7 presents the results of the two-stage Fama-MacBeth regression of bond returns as explained by the Fama and French three-factor model. Each λ represents the average risk premium spread *associated with exposure to the market factor, the size factor (SMB) and the book-to-market factor (HML). The t-statistics are expressed in parentheses. The δ represents the dummy variable controlling for the differences in returns between Green Bonds and conventional bonds. The R^2 of the Fama-MacBeth regression of the single factor Capital Asset Pricing Model is the proportion of the variation in the model that can be explained by the model. In order to adjust for the natural increasing explanatory power of adding additional factors, the adjusted R^2 is calculated. The P-value shows the significance of the entire model.*

5.4 Fama-MacBeth Regression of the Carhart Four-Factor Model

The Carhart model is a further extension of the Capital Asset Pricing Model where the momentum effect is added as a factor in order to capture the effect among stocks that have performed differently in previous time periods, Carhart (1997). An initial notation is that the Momentum coefficient has a t-value of -3.228 and is hence statistically significant on a 5% level, however, the coefficient is relatively small with a value of -3.9 basis points.

The remaining factors already included in the three-factor model are more or less unaffected by the inclusion of the momentum factor. The consistency of the positive risk premium of the market risk factor still holds as well as the direction of the coefficients of the SMB and the HML factor. Looking at the adjusted R^2, it is clear that the explanatory power is not significantly improved, advancing a few percentage points to 0.558.

Table 8. Carhart Results

	α	**δ GREEN**	**λ mkt**	**λ SMB**	**λ HML**	**λ WML**
Coefficient	0.031	-0.003	0.698	0.139	-0.110	-0.039
t-value	4.124	-0.174	12.139	4.914	-5.003	-3.228
	***		***	***	***	***

R^2	**Adjusted R^2**	**P-value**
0.573	0.558	0.000

Table 8 presents the results of the two-stage Fama-MacBeth regression of bond returns as explained by the Carhart four-factor model. Each λ represents the average yield spread associated with exposure to the respective factor, the size factor (SMB), the book-to-market factor (HML) and the momentum factor. The t-statistics are expressed in parentheses. The δ represents the dummy variable controlling for the differences in returns between Green Bonds and conventional bonds. The R^2 of the Fama-MacBeth regression of the single factor Capital Asset Pricing Model is the proportion of the variation in the model that can be explained by the model. In order to adjust for the natural increasing explanatory power of adding additional factors, the adjusted R^2 is calculated. The P-value shows the significance of the entire model.

5.5 Fama-MacBeth Regression of the Five-Factor Model

In the five-factor model, the previous bond and stock specific models are integrated into one model, where the two bond specific Def and Term factors are added to the original Fama-French model in order to account for both the stock factors and the bond factors. This procedure is inspired by Fama and French (1993) who states these five factors seem to explain average returns of stocks and bonds well. The dummy coefficient for Green Bonds has now changed to a positive coefficient but still exhibits a negligible small value. As in the previous results, the coefficient is not statistically significant since the t-value is 0.064 which implies that no outperformance can be proven for neither Green- nor conventional bonds.

The pricing error of the model is 2.2 basis points with a corresponding t-value of 3.01 indicating that the pricing error is statistically significant. The Def factor shows a negative coefficient of -65.4 basis points and has a corresponding t-value of -7.68 and the coefficient is hence statistically significant different from zero. This indicates that one can expect lower yield of bonds when the probability of default increases. The coefficient of the Term factor is 0.40 with a t-value of 9.104 and hence statistically significant. This provides evidence that positive changes in interest rate increase returns from bonds. The adjusted R^2 further increases from 0.573 from the Carhart model to 0.68 in the five-factor model, confirming that the inclusion of the two bond factors increases the explanatory power of bond returns.

Table 9. Five-Factor Model Results

	α	δ GREEN	λ mkt	λ SMB	λ HML	λ DEF	λ TERM
	0,0221	0,002	0,540	0,017	-0,018	-0,654	0,3999
Five Factor Model	3,0074	0,064	13,566	1,1552	-3,042	-7,677	9,1042
	***		***		***	***	***

R^2	R^2 Adjusted	P-value
0,690	0,680	0,000

Table 9 presents the results of the two-stage Fama-MacBeth regression of bond returns explained by the five-factor model. Each λ represents the average risk premium associated with exposure to the market factor, the size factor (SMB), the book-to-market factor (HML), the term spread (TERM) and the default factor (DEF). The t-statistics are expressed in parentheses. The δ represents the dummy variable controlling for the differences in returns between Green Bonds and conventional bonds. The R^2 of the Fama-MacBeth regression of the single factor Capital Asset Pricing Model is the proportion of the variation in the model that can be explained by the model. In order to adjust for the natural increasing explanatory power of adding additional factors, the adjusted R^2 is calculated. The P-value shows the significance of the entire model.

5.6 Fama-MacBeth Regression of the Six-Factor Model

Including the momentum factor to the five-factor model turns out to increase the coefficient of the Green bond dummy from 0.2 to 0.4 basis points, but it remains statistically insignificant with a t-statistic of 0.01. The pricing error remains at the same magnitude with a coefficient of 2.3 basis points and is still statistically significant at a 5% significance level.

The inclusion of the momentum factor has no noticeable effects on the other factors. The momentum factor itself turns out to have a t-statistic of -3.426 and a coefficient of -0.023 (-2.3 basis points). All the coefficients of the factors are significant except for SMB, controlling for value effects, even though it shows a small positive point estimated coefficient.

Table 10. Six-Factor Results

	α	δ GREEN	λ mkt	λ SMB	λ HML	λ DEF	λ TERM	λ WML
Coefficient	0.022	0.004	0.498	0.002	-0.023	-0.690	0.388	-0.023
t-value	3.089	0.010	13.259	2.523	-3.623	-7.930	9.076	-3.426
	***		***		***	***	***	***

R^2	Adjusted R^2	P-value
0.713	0.702	0.000

Table 10 presents the results of the two-stage Fama-MacBeth regression of bond returns explained by the six-factor model. Each λ represents the average risk premium associated with exposure to the market factor, the size factor (SMB), the book-to-market factor (HML) the momentum factor, the Term spread factor (TERM) and the default factor (DEF). The δ represents the dummy variable controlling for the differences in returns between Green Bonds and conventional bonds. The R^2 of the Fama-MacBeth regression of the single factor Capital Asset Pricing Model is the proportion of the variation in the model that can be explained by the model. In order to adjust for the natural increasing explanatory power of adding additional factors, the adjusted R^2 is calculated. The P-value shows the significance of the model.

5.7 Comparison Among Models

With the intention to find the best possible common factor model to explain the difference in bond returns between Green and conventional bonds, seven different common factor models are tested. In terms of explanatory power, it is clear that the model increases when it is extended from the original Capital Asset Pricing Model. The Term and Def factors are statistically significant factors that contribute to explain bond returns, further, these two factors alone get an adjusted R^2 of 25.5%. Regarding the more stock specific factors, it is displayed that both the SMB and HML factor are statistically significant factors in the three-factor model. Alongside the bond market factors, they exhibit an adjusted R^2 value of 53.3%, which means that they explain more than half of the variability in the model.

Looking at the even further extension of adding a momentum factor, no significant differences in terms of explanatory power are detected. Even though the factor turns out to be statistically significant at a 5% significance level, it does not contribute enough to the explanatory power of the model. Therefore, the most balanced model in terms of factors and explanatory power for bond returns is the five-factor model.

As the most balanced and effective model among the seven different factor models has now been established, the five-factor model is further used and applied on rating-based portfolios as a robustness test. The motivation for this is to try to reduce potential bias and strengthen the reliability of the results.

5.8 Five-Factor Model on Rating-Based Portfolios

Table 11 presents the results of the two-stage Fama-MacBeth regression on rating-based portfolios as explained by the five-factor model. Each λ represents the average risk premium associated with exposure to the market factor, the excess bond market returns from MSCI World Bond Index, the size factor (SMB), the book-to-market factor (HML), the Term spread (Term) and the default factor (Def). The t-statistics are expressed in parentheses. The δ represents the dummy variable controlling for the differences in returns between Green Bonds and conventional bonds. The R^2 of the Fama-MacBeth regression of the single factor Capital Asset Pricing Model is the proportion of the variation in the model that can be explained by the model. In order to adjust for the natural increasing explanatory power of adding additional factors, the adjusted R^2 is calculated. The P-value shows the significance of the entire model.

Table 11. Rating Portfolio Results

Rating	α	δ GREEN	λ mkt	λ SMB	λ HML	λ DEF	λ TERM	R^2	Adjusted R^2	P-value
	0.023	0.002	0.953	0.043	0.086	-0.533	0.348	0.913	0.891	0.000
AAA	2.851	0.320	26.802	1.317	1.445	-4.574	6.109			
	***		***			***	***			
	0.028	0.008	-0.118	0.093	-0.131	-0.256	0.321	0.657	0.640	0.169
A	5.558	0.923	-2.776	4.307	-22.396	-13.675	10.287			
	***		***	***	***	***	***			
	0.031	0.001	0.254	0.068	0.014	-0.776	0.421	0.767	0.755	0.016
BBB	2.130	0.293	3.522	2.529	0.484	-13.394	21.596			
	**		***	***		***	***			
	0.042	-0.001	0.040	0.016	0.020	-0.270	0.098	0.423	0.411	0.253
LG	2.210	-0.266	2.946	0.299	0.500	-4.964	3.535			
	**		***			***	***			
	0.038	0.002	0.538	0.127	-0.059	-0.396	0.260	0.664	0.652	0.000
NA/NR	2.424	0.382	12.295	3.776	-4.496	-6.359	7.913			
	***		***	***	***	***	***			

Applying the five-factor model with a Fama MacBeth two stage approach to the five different rating-based portfolios generates statistically significant pricing errors. The green dummy variables however are statistically insignificant for the five portfolios, and their corresponding coefficients are very small. This is in line with the negligibly small values previously generated by the other regression models. The market coefficients remain statistically significant throughout the portfolios as well as the Term and Def factors.

The previously found pattern of a negative coefficient for the Def factor and a positive coefficient for the Term factor is also consistent for all the portfolios. The SMB-coefficient is positive for all portfolios, however it is only significant for the A, BBB and NA/NR portfolios. The HML-coefficient exhibits a negative value whenever it is significant which occurs in the A and NA/NR portfolios.

Grouping the bonds into rating-based portfolios seems to strengthen the explanatory power for the AAA portfolio with an adjusted R-squared of 0.891 and for the BBB portfolio with an adjusted R-squared of 0.755. However, the other portfolios possess lower adjusted R^2 compared to the five-factor model regression on individual securities. The adjusted R^2 of the low grade portfolio is particularly low at 0.411.

6. Discussion

The result of focus in this thesis, the Green dummy coefficient, is clearly consistent throughout our different models with regards of the magnitude and the insignificance as determined by the t-values. The highest absolute t-value is 0.363 as estimated by the Def-Term model. This is well below 1.96 that is needed for statistically significance at the 5%-level, which is considered the lowest level possible. After grouping the bonds in portfolios based on ratings, the highest attained t-value is observed for the A-rating portfolio with a t-value of 0.923. The pattern of low magnitude of the Green Dummy coefficient is consistent within the different regressions of the rating-based portfolios as well. The low magnitude comes as no surprise and is in fact perfectly in line with the expectations and the hypothesis, that the yield should be unaffected by whether the bonds are labeled as Green or not. Such difference would violate no-arbitrage-assumptions and indicate mispricing in the market.

Looking at the point estimates for the Green dummies in the most basic models they are slightly negative while they are slightly positive when the five- and six-factor models are used. These point estimates could however be assigned by randomness since they are not statistically significant. Furthermore, the point estimates of the rating-based portfolios, turned out to be insignificantly low, clearly in line with the consistency of low magnitude. According to the evidence in line with the hypothesis, there is no reason to believe that investments in Green Bonds should yield worse than conventional bonds and thus investments in Green Bonds should therefore be superior compared to investments in conventional bonds due to the opportunity to gain intangible assets at no cost. Discussions regarding the magnitude of this free asset gain is forwarded to researchers in the field of Green Bond and sustainability, however, there is no reason to believe that Green image is negligible when it comes to rational company management. As stated by the theory of Edmans (2011), employees who are satisfied with the sustainability service in the business model seem to outperform firms whose employees are not satisfied. Hence, this could potentially serve as one way of justifying that attaining a Green image adds value to the firm.

The choice of using stock specific factors as HML and SMB with the intention to explain bond returns may at first glance seem inconvenient, however studies by Fama et al. (1993) show that such factors contribute to the explanatory power of return for bonds to some extent. Furthermore, the factors are used by Elton et al. (2001), as motivated for in the literature section. It is also shown in this thesis results that the three-factor model indicates statistically significance for both the SMB and the HML factor and that the three-factor model is able to explain at least a part of the bond returns with an adjusted R^2-value of 27%. These factors seem to drop in t-value when the models are extended to incorporate both stock and bond specific returns, however the HML factor shows significance even in the five-factor model and contributes with explanatory power.

As always, there are certain noises that may affect the results to stretch somewhat. One of these noises could be a geographically bias derived from the fact that Green Bonds are very popular in certain regions of the world, while conventional bonds are more evenly distributed around the globe. For instance, Sweden is a country that early took an interest in Green funding of project. This has led to a situation where 31 (8%) of the Green bonds available in Bloomberg are listed in Sweden, compared number to zero randomly draw bonds from Sweden. Such skewness could explain parts of the outperformance Since Sweden has had a great economic development during the time period compared to the rest of the world, however, this skewness is relatively small and larger countries as USA makes up for 270 (55%) of the Green Bonds and 250 (52%) of the conventional bonds which should decrease the significance of the geographically bias that mainly comes from smaller countries.

7. Conclusion

This thesis is written in order to investigate whether investors should expect lower yield from Green bonds compared to conventional bonds. The hypothesis going into the study was that the excess return of Green Bonds compared to conventional bonds is zero since the bonds issued should be priced with all available information on the market and hence be correctly priced so that no arbitrage profits can be made. For instance, this would mean that a bank is able to put funds into Green project and expect the same return, while spreading the word of being a sustainable company, which in turn should attract customers and entail a differential advantage compared to competitors.

In order to find reliable results and determine which of the most common factors model that are most suitable to determine bond returns, different common models are tested using different factors, showing which of one actually help explain the variability of bond returns. The results are found using the Fama-MacBeth two-step approach. As illustrated in the summarized results in table 12, the explanatory power of the models increases as the models are extended towards the most extensive Six-factor model. The simplest CAPM-model is able to explain 31% of the variability in the model which is a considerable high value for such a simple model. Looking at the exclusively bond specific model Def-Term, it gives similar coefficients and the model is able to explain 26% of the variability. The Carhart model is conducted to test whether momentum in stock returns help explain bond returns trough adding the Momentum factor, the explanatory power turns out to be almost unaffected with a three percentage point increase in adjusted R^2.

Moving to the five-factor model where stock- and bond specific factors are incorporated in the same model, the explanatory power increases significantly from 56% to 68%. As the case with the Carhart model, the momentum factor is not contributing enough to improve the model significantly as shown in the Six-factor model, where the R^2 adjusted value is 70%. The model preferred to use is hence the five-factor model, where the combination of stock specific and bond specific factors together show a high explanatory power with reliable coefficients.

Table 12. Summarized Results, showing only pricing error and Green dummy coefficients, in basis points

	α coefficient	α t-stat	δ GREEN coefficient	δ GREEN t-value	R^2	R^2 Adjusted
CAPM Model	3.90	3.96 (***)	-0.47	-0.26	0.33	0.31
DefTerm Model	5.50	4.95 (***)	-0.58	-0.36	0.27	0.26
Three Factor Model	3.10	3.91 (***)	-0.55	-0.29	0.55	0.53
Carhart Model	3.20	4.12 (***)	-0.32	-0.32	0.57	0.56
Five Factor Model	2.20	3.00 (***)	0.23	0.23	0.69	0.68
Six Factor Model	2.30	3.09 (***)	0.43	0.43	0.71	0.70

As it turns out, throughout our seven different models, the pricing error is statistically significant, and remains very small in the interval of 2-6 basis points. Looking at the variable of interest in our Fama-MacBeth regression, the Green dummy, it is clear that the coefficients remain statistically insignificant different from zero for all six models, indicating that no matter if the bond is Green or not, the investors view on expected return should not be different. These results are in line with the expectations that there are no differences in returns comparing Green Bonds to conventional ones, and it confirms the hypothesis that investors are able to gain intangible assets by investing in Green Bonds, without losing anything when it comes to expected return of the investments. This pattern is also consistent after grouping the bond returns into portfolios based on ratings.

Since the Green Bond existence is as short as a decade yet, it would most certainly be interesting to see similar studies conducted for the upcoming years, with even more data available to reach even more reliable results. When more data are available in the future, investigations could be conducted using data exclusive from a specific geographic region, for instance the U.S, in order to eliminate potential geographical bias. Furthermore, extensions could be done through incorporating additional factors and taking other portfolio formations into account such as industry. Further investigations regarding the implications of the benefits of getting intangible assets from increased sustainable image could be made to further contribute to the area of value creating effects of sustainability.

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