A comparative study on the financial performance of Green bonds and their conventional peers

Louis William Wagner Ley*

Master Thesis in Financial Economics
Erasmus University Rotterdam

Erasmus School of Economics

Dr. Jan Lemmen

November, 2017

Keywords: Asset Pricing, Financial Economics, Fixed Income, Green Bonds, Financial Performance, Bond Pricing
JEL Classification: G12, G17, Q54

*Louis William Wagner Ley Germain Joseph Fernand (449910), Ernastrasse 20, CH-8004 Zurich, Switzerland. Phone: +352 621 50 68 91. Email: louis.wagnerley@gmail.com

Acknowledgments

The author wants to thank Annemarie Arens, General Manager of the Luxembourg Finance Labelling Agency, and Maurice Bauer, Secretary General of the Luxembourg Stock Exchange, for their very helpful insights, opinions and the provision of still unpublished data and reports.

Non-plagiarism Statement

By submitting this thesis the author declares to have written this thesis completely by himself/herself, and not to have used sources or resources other than the ones mentioned. All sources used, quotes and citations that were literally taken from publications, or that were in close accordance with the meaning of those publications, are indicated as such.

Copyright Statement

Abstract

The market of Green Bonds has seen exponential growth over the recent years and was fuelled even more by the COP 21 agreement. However, until today and to the best knowledge of the author, no empirical analysis on the financial return of those instruments has been conducted. This investigation conducts the first comparative analysis of the financial performance of Green Bonds and their conventional peers. Based on a dataset of 359 Green Bonds and 1291 conventional bonds, the analysis is conducted over the period between 2011 and 2017 and uses an extended Fama-French model in a Fama-Macbeth regression procedure. Green Bonds do outperform conventional ones over the full sample period but with a low significance. In a subsample period aligned to the "take-off" of the corporate Green Bond issuance, the outperformance can still be confirmed but this time with a high significance. We can observe that the significance is constantly increasing over time. This can be seen as an important supporting argument for the investment in Green Bonds and the fight against climate change. At the same time it implies that institutional investors are not acting against their fiduciary duties due to investment in those sustainable debt capital products.

Contents

1 Introduction

"The gentleman understands moral duty, the petty person knows about profit" (Ebrey, 2010)

After the recent global financial crisis, the restructuring of national and international financial regulations as well as the still increasing complexity and interconnectedness of financial markets, this 2500 year old Confucian saying is more accurate than ever before.

For a long time, the consideration of ethical values and principles has been considered a threat to profits in the corporate world. However, these attitudes changed recently and stakeholders ranging from consumers to investors are not only encouraging but requiring higher levels of transparency and compliance with ethical standards (Glomsrød and Taoyuan, 2016). Environmental, Social and Governance criteria (ESG) are gaining more and more importance when it comes to corporate decision-making and strategy-setting.

The financial sector, heavily criticised for its unethical behaviour in the wake of the last financial crisis, is increasingly introducing ESG and other sustainability criteria in their investment decision processes. Today, ethics "sells" and unethical behaviour is punished by corporate image losses and shareholder activism.
For a long time, climate change has not been a priority on the ethical investors' agenda. Lately though, the corporate world is increasingly willing to act on these matters. Stakeholders around the globe are requiring sustainable and responsible business models(EY, 2016).
Moving towards a low- or even carbon-neutral world requires the adoption of green solutions for financial capital. After the United Nations Framework Convention on Climate Change (UNFCC) and the Kyoto Protocol, the 2015 Paris Agreement is the first treaty that brings together all nations - including the United States of America - for collective action by an international public legal agreement that constitutes at the same time a platform for investors to step up against climate change. The aim is to reorientate all financial flows away from fossil fuels and towards clean forms of development. The COP21 meeting in Paris, with the parties confirming their commitment to keep the

global warming well below 2°C compared to pre-industrial levels and the mobilisation of USD 100 billion per year by 2020 in order to lessen the effects of climate change in developing countries, is generally considered as a turning point. The United Nations are also considering the tackling of climate change as one of their 17 sustainable development goals.

In general, the political support for addressing the issue is gaining momentum and providing clear signals for future investment patterns (Clapp et al., 2016), despite the "change in mind" of the U.S. government, the corporate sector sees the necessity to act on the matter. Therefore, Green Finance in general, is set to play a crucial role in the implementation of these goals.

One can observe a strong rise in the demand of institutional investors for a financial tool that is incorporating both, their need for an adequate short-term portfolio risk and return balance as well as the decrease of risk of long-term climate change (Climate Bonds Initiative, 2017). Since recently, the term of "Green Bonds" is circulating more and more frequently in the news as being the new financial tool that addresses the fight against climate change and does, at the same time, have the afore-mentioned required characteristics.
The World Bank defines Green Bonds as "fixed income, liquid financial instruments that are used to raise funds dedicated to climate-mitigation, adaptation, and other environment-friendly projects" (World Bank, 2015).

Green Bonds are therefore considered to fulfill this premise and key in the implementation and capital raising of the Nationally Determined Contributions (NDCs) to the 2015 Paris Climate agreement. They provide a suitable and simultaneously risk-managed tool for both public and private investors.

The history of Green Bonds can be traced back to the issuance of the first so-called Climate Awareness Bond by the European Investment Bank (EIB) in 2007, which was quickly followed by the first Green Bond set-up by the World Bank in 2008 (EY, 2016). The Climate Bond Initiative, an international Non-Governmental Organisation with the goal to activate debt-capital markets for climate finance saw the day in 2009.
While the first Green Bonds were mostly issued by development banks and municipalities, the proportion of issuance by commercial banks and other corporates is steadily increasing.

In general, any entity that can issue a conventional bond can also set up a

Green Bond, which means that even a "brown" company (a company investing in fossil resources) is able to issue a Green Bond in compliance with the Green Bond Principles. Also, there is an increasing amount of divestment initiatives for projects exposed to coal and other fossile energy or non-renewable resources by large institutions and multinational firms such as the Rockefeller Brother Fund, the Norwegian Government Pension Fund Global, AXA, Bank of America or Citigroup (Glomsrød and Taoyuan, 2016).

The year 2013 is generally seen as the tipping point of the market. By 2014, Green Bonds compromised a third of the total corporate bond issuance, which was equivalent to about USD 15 billion (NEPC Impact Investing Committee, 2016).

In 2016, the market for Green Bonds hit a new record with a total issuance of USD 81 billion and an outstanding volume of USD 180 billion (Climate Bonds Initiative, 2017).

Today, the major part of issuers and purchasers comes from Europe or North America, while most of the projects financed are located in developing countries.

In its outlook, New Climate Economy, a research initiative, notes that, to stay in the limits of the 2 degree target, a USD 93 trillion of investment are required across the global economy which translates into a huge growth market for Green Bonds (Climate Bonds Initiative, 2016).

For a long time, the labelling process was largely unregulated and mainly subject to self-labelling. Even if reputational risks are against it, the absence of a central regulatory authority is a potential incentive for greenwashing in the sector.
This lack led to the development of different projects, associations, as well as regulatory or independent opinion initiatives such as the Green Bond Principles, the Climate Bonds Initiative or different actions taken at national and supranational legislative levels (NEPC Impact Investing Committee, 2016).
While the Green Bond Principles, launched by a group of banks and the International Capital Markets Association (ICMA), are mainly addressing the traceability of proceeds in terms of the issuance, disclosure and reporting processes, the Climate Bonds Initiative is focusing more on the development of clear and science-based criteria to define the term "green".
Similar actions are taken by the People's Bank of China, The National Development & Reform Commission and the Securities and Exchange Board of India or the Luxembourg Stock Exchange with the launch of the world's first

green exchange (Climate Bonds Initiative, 2016). Moreover, audit and consulting firms offering third-party verification services as well as international labelling agencies for financial instruments such as the Luxembourg Finance Labelling Agency (LuxFLAG) are enhancing the credibility of the green bond market (LuxFLAG, 2017).

Despite the in-depth research on the necessity and impacts of green finance and Green Bonds in special, there is little empirical evidence of the financial performance of these investments. Many investors are still considering the instrument as a "charity investment" and businesses still seem anxious about returns of so-called green investments (EY, 2016).
Some of them are said to be willing to pay a "greenium", a premium for being green, that translates into lower returns but less costly funding for the issuer. One cause for this premium could be a lack of supply for Green Bonds relative to their demand.
However, there is little evidence for this greenium in the general market (NEPC Impact Investing Committee, 2016).

Yet, as for any other financial instrument, the aspect that is of key importance to investors is the risk-adjusted financial return. An increasing risk of "carbon bubbles" is challenging the profitability of "brown" investments (Glomsrød and Taoyuan, 2016) but that does not imply that green investments are providing a relatively superior performance. "The credit metrics of green bonds have been on-par with their traditional peers" says Samantha D. Palm of Parnassus Investments (Parnassus Investments, 2015). Nonetheless, until today, little academic evidence exists to support this quote.

The present study conducts the first comparative analysis of the financial performance of global Green and conventional bonds. The results shall thereby contribute to getting a 360 degree view on the financial characteristics as well as drawing stronger statistical insights on the performance of Green Bonds.
The following investigation shall explain if the fact of a bond being green increases its expected financial performance versus its traditional peers. This is the central research question that is to be answered by this analysis.

The study is conducted with an extended Fama-French framework. By this it takes into account different equity and bond factors that are capturing the major part of the underlying fundamentals in the bond market (Fama and French, 1993). These factors are the so-called Fama-French factors being a market risk premium, a size and value premium as well as Carhart's momentum factor and a term structure and default probability proxy. To compare the Green Bond to its conventional peer the $GREEN$-dummy variable, which accounts for the fact of a bond being green in accordance to the Green Bond Principles is introduced. The research is conducted with a set of 1650 bonds and over a six and a half year time horizon. It finds that Green Bonds do actually have superior estimated future returns. The results indicate that the significance of the $GREEN$ factor does increase in recent years and is more or less aligned with the expansion of the Green Bond market. The same holds true for the explanatory power of the used seven-factor asset pricing model. This pattern is also similar to the ones found by other studies focusing on sustainable investments but other asset classes. To the author's knowledge this is the first empirical study to find evidence for a hypothesis that can support the marketing for and interest in Green Bonds even further.

The remainder of the thesis is structured as follows: the following chapter describes the existing literature in terms of fixed income pricing as well as the characteristics of sustainable and responsible investments that this study is based on. Chapter 3 defines the data used to conduct the analysis; Chapter 4 sets out the methodology used; Chapter 5 presents the results of the empirical analysis; and Chapter 6 concludes while Chapter 7 provides insights on the limitations of this investigation and possible future research.

2 Literature

In general, the literature on bond pricing and the modelling of their expected returns is far less extensive that the one focusing on equities. However, both asset classes do have similar key factors that can be used for estimating their expected returns. The most commonly known model for calculating expected future returns in equity markets is the single-factor Capital Asset Pricing Model (CAPM) of William Sharpe (Sharpe, 1964) and John Lintner (Lintner, 1965). Given its poor explanatory power, Fama and French (1992) constructed an extended three-factor model that substantially improved the quality of the model. Fama and French (1993) then extended their own three-factor CAPM model used to determine excess equity returns to a five factor model that incorporates both, stock and bond market risk factors that could be commonly used to model bond returns.

Besides the initially used market premium, size and value factors (Fama and French, 1992), the authors developed a factor to proxy the risk in bond returns arising from unexpected interest rate changes as well as one proxying the default probability of the relative company or institution. The importance of the default factor was confirmed by Merton (1973) stating that it is a major explanatory variable for the pricing of bonds. Gabbi and Sironi (2005) provided more evidence and spoke up against the relevance of primary and secondary market liquidity as a relevant factor. The utility of the Fama-French model in the pricing of bonds was further tested and acknowledged by Johansson and Lundgren (2012). Carhart (1997) and Grinblatt et al. (1995) constructed a momentum factor to further increase the power of the model. Considering this, the present investigation does opt for the inclusion of the momentum factor into the final pricing model.

The Fama-Macbeth procedure (Fama and Macbeth, 1973) using both, time-series and cross-sectional regressions, is considered as the reference approach to testing asset pricing models with panel data and has therefore been adopted in this analysis.

The market of sustainable and responsible investments (SRI), being still in development and gaining attention within the general financial markets only lately, explains the rather poor quantity of research in this area and especially on the financial performance of these SRI instruments.

While Xiao et al. (2012) did not find a significant relationship between sus-

tainability and returns, Gil-Bazo et al. (2010) provided evidence for a better before- and after-fee performance of US SRI fund in comparison to non-SRI funds.
Besides these, one of the only studies comparing the financial performance of green and conventional investments was conducted by Ibikunle and Steffen (2015).
Despite the fact that this study focused only on equity mutual funds, this thesis will adopt a similar approach for evaluating and comparing the performance of green bonds to their conventional peers. The researchers used a four-factor extended Capital Asset Pricing Model following Carhart (1997).
For the comparative analysis, the authors included a dummy variable to their model that is related to the class of the fund (*green*, *conventional* or *black*). They found no significant difference in the performance of conventional and green mutual funds and in their subsample covering only the recent years they can even observe an outperformance of the green funds in comparison to the traditional ones.
This paper is going to adopt the same method in order to distinguish the performance of green and conventinal bonds.
These formerly found results for the equity market are a strong incentive to conduct a similar study on the fixed income side and suggest the hypothesis that green bonds do not differ from their conventional counterparts in terms of their financial performance.
Still unpublished articles and papers on the same topic that were conducted by commercial banks and made available to the author of this investigation do suggest similar results.

The central hypothesis of the paper is that expected returns on green bonds are not statistically different from those of conventional bonds. The investigation focuses the yield-to-maturity as return measure for the reasons specified in the Data Chapter and defines a Green Bond in accordance with the Green Bonds Principles that are explained in detail in the same chapter.
Being the first study conducting a comparative analysis on the financial performance of those two bond categories, the study might potentially make a significant contribution to the literature and provide further insights for investors to the world of sustainable and responsible investing.
The thesis is purely focusing on financial performance and does not take into account behavioural considerations or other non-financial factors potentially driving performance.
In addition to this, the thesis relies on the Green bonds quality check by Natixis

(2017) still unpublished at the current date of writing and kindly made available to the author by the Luxembourg Stock Exchange. Figures 1, 2 and 3 provide a more detailed overview on the existing research on asset and more specifically bond pricing as well as on the financial performance of SRI investments.

Overview of relevant previous research/literature on asset pricing				
Year	**Authors**	**Model/Approach**	**Control Variables**	**Findings**
1964	William Sharpe	CAPM	Market Premium	market equilibrium theory of asset prices under conditions of risk
1965	John Lintner	CAPM	Market Premium	model for the calculation of a minimum acceptable excpected rate of return
1973	Eugene F. Fama and James D. Macbeth	Two-step procedure for panel regressions	Two Parameter portfolios	pricing of stocks reflects the attempts of risk-averse investors to hold portfolios
1973	Robert C. Merton	Extended Black-Scholes Model	Default factor	Default factor is a major explanatory variable for bond pricing
1993	Eugene F. Fama and Kenneth R. French	3-factor-model	Market Premium; Size Premium; Value Premium	CAPM cannot explain cross-section of asset retunrs but FF3F can
1993	Eugene F. Fama and Kenneth R. French	5-factor-model	Term Premium; Default Premium	Finding of common risk factors for stocks and bonds
1995	Grinblatt et al.	Model for measuring momentum strategies	Momentum Factor	On average, fund investing on momentum are performing significantly better than others
1997	Mark M. Carhart	Extended Fama-French Model	Momentum Factor	Individual funds do not earn higher returns from following momentum strategy in stocks
2001	John Cochrane	Factor Pricing Models	CAPM; ICAPM; APT; GMM and other factor models	Approves Fama Macbeth method with minor changes

Figure 1: Literature Overview

Overview of relevant previous research/literature on asset pricing				
Year	**Authors**	**Model/Approach**	**Control Variables**	**Findings**
2005	H. Asbjørn Aaheimand Nathan Rive	Global Responses to Anthropogenic Changes in the Environment	Household Income; Production Factors; International Trade and Development Factors; Greenhouse Gas Emissions	Provide a model for long-term economic analysis of climate change impacts and greenhouse gas abatement policy
2005	Giampaolo Gabbi and Andrea Sironi	Multifactor regression for bond spreads	Default factor; Expected Recovery Rate; Liquidity Rate; Tax treatment; Primary Market Efficiency	Primary and expected secondary market liquidity is not a relevant explanatory factor for bond returns, rating and thereby default probability is
2008	Lewellen et al.	CAPM, Fama-French three factor model	Market Premium; Value Premium; Size Premium	suggestions for improving empirical tests and evidence that several proposed models do not work as well as originally advertised
2009	Andreas C. Gintschel and Christian Wiehenkamp	Regression of fixed income returns to liquidity proxies	Liquidity Factor	Liquidity factor is significantly associated with returns in a broad part of fixed income markets
2010	Javier Gil-Bazo and Pablo Ruiz-Verdú and André A. P. Santos	Carhart 4 factor model	Market Premium; Size Premium; Value Premium; Momentum Factor	US SRI funds had better before- and after-fee performance than conventional ones
2003	Patrick Houweling and Albert Mentink and Ton Vorst	Regression of excess yields to Fama-French and Liquidity Factors	Fama-French Factors, Liquidity Proxy	Use of excess yields for instead as expected return measure, findings of liquidity premia

Figure 2: Literature Overview

Overview of relevant previous research/literature on asset pricing				
Year	**Authors**	**Model/Approach**	**Control Variables**	**Findings**
2012	Xiao et al.	Extended Fama-French Model	Sustainability Factor	no significant relationship between sustainability and returns
2012	David Johansson and Tobias Lundgren	A study of corporate bond returns using CAPM and Fama-French	Market Premium; Size Premium; Value Premium; Term Premium and Default Premium	Large fraction of variability in corporate bond returns can be captured by CAPM but more by Fama-French model
2013	Caroline Flammer	Regression Discontinuity Approach	CSR proxies	Adoption of shareholder proposals related to CSR leads to positive announcement returns and superior accounting performance
2015	Gbenga Ibikunle and Tom Steffen	Comparative Study on Green Equity Mutual Funds	Market Premium; Size Premium; Value Premium; Momentum Factor and Green Factor	Green funds significantly underperform over whole sample period but performance improves over time until it equals the one of conventional funds
2016	Jennie Bai and Turan G. Bali and Quan Wen	Cross-sectional bond pricing	Downside risk; Credit Risk; Liquidity Risk	Downside risk is strongest predictor for bond returns
2016	Solveig Glomsrød and Wie Taoyuan	Multiregional general equilibrium model	Household Income; Production Factors; International Trade and Development Factors; Greenhouse Gas Emissions	Green finance leads to shifts of investments towards industries generating more value
2017	Credit Suisse AG	Comparative Study on Green Bonds	MSCI Global Green Bond Index; Bloomberg Barclays Global Aggregate Index (EUR hedged)	Outperformance of green bond index

Figure 3: Literature Overview

3 Methodology

3.1 The Capital Asset Pricing Model

The Capital Asset Pricing Model was developed by William Sharpe and John Lintner (Fama and French, 2004) and is based on Markowitz's (1991) model of portfolio choice. Markowitz assumes investors to be risk-averse and considering the investment outcome as a probability distribution. Two single parameters are at the basis of the investor's portfolio choice: expected value and standard deviation. The utility function can be thought of in the following form:

$$U = f(E_w, \sigma_w)$$

where E_w stands for the expected future wealth and σ_w is the estimated standard deviation of the possible discrepancy between expected future wealth and the actual future wealth (Sharpe, 1964).

All mean-variance efficient portfolios are therefore a combination of a risky tangency portfolio and the risk-free asset (Fama and French, 2004).

The formula for the CAPM used in this research is:

$$r_{it} = r_{ft} + ß_{iM} * [r_{Mt} - r_{ft}]$$
$$\forall\ i$$

where r_f is the risk-free rate and $r_{Mt} - r_{ft}$ the weighted excess return of the market portfolio. $ß_{iM}$ measures the correlation of the stock return with the excess market portfolio return, r_f is the return of a risk-free asset that is not correlated with the market and therefore also called “zero-beta asset” (Fama and French, 2004).

3.2 An extended Capital Asset Pricing Model

The econometric methodology used in this paper is based on the Capital Asset Pricing Model by William Sharpe (Sharpe, 1964) and John Lintner (Lintner, 1965).
However, given the poor explanatory power of the single-factor CAPM, for

the equity and fixed income market, this study proceeds with the use of the three-factor model developed by Fama and French (1993).
As the authors showed, the extended version of their model is also able to catch the common risk factors for the bond market and thereby a good approximation of expected returns in the considered market.

The basic Fama-French three-factor model is set up as follows:

$$r_{it} - r_{ft} = \alpha_{i,t} + ß_{iM}[r_{Mt} - r_{ft}] + ß_{i,SMB}SMB_t + ß_{i,HML}HML_t + \epsilon_{i,t}$$

where $r_{M,t} - r_{f,t}$ is the excess market return calculated by subtracting the risk-free rate from a global market portfolio with $\beta_{i,M}$ being the coefficient for the market exposure , SMB_t the size premium with $\beta_{i,SMB}$ measuring the small firm effect on the bond return and HML_t the return difference between a high and low book-to-market portfolio with $\beta_{i,HML}$ accounting for the value premium.

The size and value premium are based on the presumption that, on average, small firms earn higher returns than their larger counterparts as a compensation for illiquidity risk. This difference in the returns between a large corporate and small corporate portfolio is considered as a factor accounting for the size risk which is the equivalent to a premium based on size that investors require. The same intuition goes for the value premium that incorporates the difference in risk between growth and value firms (Petkova, 2011).

For this comparative study, I extend the initial Fama-French three-factor model with a momentum factor following Carhart (1997). Grinblatt et al. (1995) found that investments based on momentum strategies performed significantly better than those omitting this factor. The so-called Carhart four-factor model is constructed as follows:

$$r_{it}-r_{ft} = \alpha_{i,t}+ß_{iM}[r_{Mt}-r_{ft}]+ß_{i,SMB}SMB_t+ß_{i,HML}HML_t+ß_{i,MOM}MOM_t+\epsilon_{i,t}$$

with MOM_t being defined as the return difference between a portfolio of 12-months winner and 12-months looser stocks at time t, while $ß_{i,MOM}$ measures the effect of the momentum strategy on the return.
Fama and French (1993) demonstrated the relevance of their stock risk factors for the bond market. Furthermore, they extended their model with two spe-

cific factors relating to the fixed income market:

$$r_{it} - r_{ft} = \alpha_{i,t} + ß_{iM}[r_{Mt} - r_{ft}] + ß_{i,SMB}SMB_t + ß_{i,HML}HML_t + \\ ß_{i,TERM}TERM_t + ß_{i,DEF}DEF_t + \epsilon_{i,t}$$

Unexpected interest rate changes are captured by the $TERM$ factor. The term spread proxies for a deviation in the return of long term bonds from the expected changes coming from a shift in short-term interest rates (Fama and French, 1993).

The DEF factor captures the default spread. It thereby accounts for the probability of default of a corporate firm. This spread between long-term government bonds and a portfolio of long-term corporate bonds is found to have a high explanatory power for pricing the default premium (Fama and French, 1993).

The six-factor model used for the research of this paper then takes the form of:

$$\begin{gathered} r_{it} - r_{ft} = \\ \alpha_{i,t} + ß_{iM}[r_{Mt} - r_{ft}] \\ +ß_{i,SMB}SMB_t + ß_{i,HML}HML_t \\ +ß_{i,MOM}MOM_t \\ +ß_{i,TERM} + ß_{i,DEF} \\ +\epsilon_{i,t} \end{gathered}$$

where $TERM_{i,t}$ is the term spread of bond i at time t and $DEF_{i,t}$ the default spread of bond i at time t. $ß_{i,TERM}$ is measuring the term-structure impact on the bond return while accounting for the effect of the default probability.

In order to compare the performance of green and conventional bonds with each other, I make use of a dummy variable that is controlling for the effect of the respective bond's classification and determines its relative performance to it's counterpart. With this approach, the analysis follows Ibikunle and Steffen (2015).

The final model that is used in the second-pass of the Fama-Macbeth procedure is then constructed as follows:

$$
\begin{gathered}
r_{it} - r_{ft} = \\
\alpha_{i,t} + ß_{iM}[r_{Mt} - r_{ft}] \\
+ß_{i,SMB}SMB_t + ß_{i,HML}HML_t \\
+ß_{i,MOM}MOM_t \\
+ß_{i,TERM} + ß_{i,DEF} \\
+\delta_{i,GREEN}GREEN_i \\
+\epsilon_{i,t}
\end{gathered}
$$

where $\delta_{i,GREEN}$ is measuring the effect on the returns of a bond being green. $GREEN$ takes the value 1 if the bond is green and 0 otherwise.

3.3 The Fama-Macbeth Procedure

For the regression procedure, I follow Fama and French (1992) in applying the Fama-Macbeth procedure as described in detail in Fama and Macbeth (1973).

The approach is commonly known as "two-pass cross-sectional regression" (CSR) since it consists of a two-step procedure testing the time-series average of estimated risk premia in cross-sectional regressions (Cavenaile et al., 2009).

The procedure firstly conducts a time-series regression to estimate betas (first-pass regression) before making use of a cross-sectional regression (second pass) to test the hypothesis derived from the used model (Cochrane, 2009). The first stage of the Fama-Macbeth approach runs a seperate time-series regression of the excess returns against the different considered risk factors for every bond in the sample. These regressions are performed using the Ordinary Least Squares (OLS) regression:

$$
\begin{gathered}
r_t^{ei} - r_t^f = a^i + ß^i f_t + \epsilon_t^i \\
\text{t = 1, ..., T} \\
\forall \text{ i}
\end{gathered}
$$

where r_t^{ei} is the return of asset i at time t, r_t^f the risk-free rate at time t, f_t the value of the explanatory variable at time t and $ß^i$ the coefficient of f_t over time.

The outcome of the time-series regression are 1880 coefficients, for every bond i and every factor included in the extended Fama-French model. Those coefficients are estimated over the considered time period of the analysis. Since the affiliation of the bonds to the green or conventional class does not vary over time, I only integrate the $GREEN$ dummy for the second, cross-sectional, pass of the procedure.

In the second step of their procedure, Fama and Macbeth run cross-sectional regressions. Following this, I regress the excess returns of the 1880 considered bonds against the estimates which are the outcomes of the previously conducted time-series regression. The intuition is that the estimates are now treated as explanatory variables (Cavenaile et al., 2009). Following Cochrane (2009), I do not use an intercept in the second pass.
For the cross-sectional regression, we observe "multiple entities" at a single point in time t (Stock and Watson, 2012).
In this case 359 green and 1521 conventional bonds. The intention is to test the multiple factor model across the different bonds (Cochrane, 2014).

To estimate the risk premia, I run cross-sectional regressions of:

$$r_t^{ei} - r_t^f = ß^i \hat{\lambda}_t + \alpha_i$$
$$\text{i= 1,2, ..., N}$$
$$\forall \text{ t}$$

In accordance with this approach, I estimate 1570 cross-sectional regressions to receive 1570 lambda estimates for every observed risk factor and every point in time t. As required by the applied procedure, I then conclude with averaging $\hat{\lambda}_t$ by:

$$\bar{\lambda} = \frac{1}{T} \sum_{t=1}^{T} \hat{\lambda}_t$$

with T being the number of time periods observed.

In an all explaining model, the cross-sectional disparities in expected returns should be explained by the risk loadings with the cross-sectional R^2 being close to 1.

The cross-sectional R^2 is calculated by:

$$R^2 = 1 - \frac{\sum_{i=1}^{N} \bar{\bar{\eta}}_i^2}{\sum_{i=1}^{N} (\bar{y}_i - \bar{\bar{y}})^2}$$

with η_i being the regression error of the cross-sectional regression.
The adjusted R^2 adjusts for the number of independent variables in the model and therefore only increases if an additional predictor increases the predictive power of the model by calculating:

$$R^2_{adj.} = 1 - \frac{(1-R^2)*(N-1)}{N-p-1},$$

with N being the total sample size and p being the number of predictors used in the model.

4 Data

This section outlines the data collection process for the two bond categories (conventional and Green) as well as the market benchmarks and the Fama-French factors used for the empirical analysis. Furthermore, the data section documents the detailed construction of the TERM and DEF factors and provides in-depth information on the procedures for data quality assurance.

Since most of the Green bond buyers are institutional investors such as pension funds with a long-term investment approach, this research is based on a hold-to-maturity approach. It therefore focuses on yield-to-maturity to proxy the return of conventional and Green bonds in the extended Fama-French framework. By doing so, the paper takes into account the current coupon income, any gains or losses in capital realised by holding the bond until its maturity as well as the timing of the cash-flows. As such, this investigation follows Houweling et al. (2005) that pronounced a "distinct advantage" over the use of realised returns: While the latter is looking at the outcome of a stochastic process, the former is a market expectation of the bond's return to maturity. The paper thereby also follows the literature on bond liquidity. This measure assumes however, that all coupon payments can be reinvested at the computed Yield-to-Maturity.

4.1 Bond Dataset

The initial bond dataset consists of a total of 2480 bonds issued between June 2007 and July 2017, a ten-year period. All data was provided by Bloomberg and converted to U.S. Dollar to ensure comparability that could otherwise be negatively influenced by changes in exchange and inflation rates. In order to assure the quality and robustness of the data, the initial sample is further cleaned and filtered for possible bias drivers as described later in this section.

4.2 Green Bonds

The analysis starts with an initial set of 1062 Green bonds. Since there is still no universally agreed on definition of a Green bond, the sample of this paper is compiled using the "Green Bond" tag in the Bloomberg database. This excludes all so-called Green bonds which are not clearly classified as such by the issuer or have not been provided with the needed supporting information. In general, Bloomberg's working definition is adopted from the afore-mentioned Green Bonds Principles and reads as follows: "Labelled green bonds are fixed income instruments for which the proceeds will be applied towards projects or activities that promote climate change mitigation or adaptation or other environmental sustainability purposes"(Bloomberg New Energy Finance, 2016).

While the first Green bond was issued as a "climate awareness bond" by the European Investment Bank in 2007, the real growth in the market started only in 2011 when supranationals, governments and especially corporates started issuing a multitude of green bonds. Table I provides an overview of the amount of green bonds issued categorised into years and industry sectors.

Considering this, and in order to present a significant study, the present sample is revised to the period between January 4th, 2011 and June 30th, 2017. Moreover, all data is converted to USD data by the provider in order to eliminate potential currency bias. After applying the different filters and manipulations, the final sample consists of 359 Green bonds. The exact filters are showed in the Figure 4 below:

Green Bond Selection and Filtering Process	
1	Green Bond Issuance as defined by Bloomberg tag
2	Time Period 01/07/2007 - 30/06/2017
3	Eliminate duplicates
4	Remove Bonds with less than 1 year of data (206 BD)

Figure 4. Green Bond Selection

Table I. Green Bond Issuance

Green Bond Issucance by Industry Sector and Year											
Industry Group	Year										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Consumer Discretionary	0	0	0	0	0	0	0	4	4	6	6
Energy	0	0	0	0	0	0	0	8	154	16	12
Financials	0	0	0	0	0	0	12	41	40	81	83
Government	1	1	4	55	30	19	25	61	99	90	54
Health Care	0	0	0	0	0	0	0	0	0	0	1
Industrials	0	0	0	0	0	1	0	5	9	9	18
Materials	0	0	0	0	0	0	0	0	0	5	4
Technology	0	0	0	0	0	0	0	1	0	2	1
Utilities	0	0	0	0	0	0	1	13	15	32	39
Total	1	1	4	55	30	20	38	133	321	241	218

4.3 Conventional Bonds

The conventional bonds sample is selected from the global bond universe provided by the Bloomberg database. The sample is then filtered for the time period between 1st July, 2007 to 30th June, 2017. To be coherent with the Green bonds sample, the paper only includes bonds whose use of proceeds are labelled with the "investment" or "project finance" tag by the data provider. Also, all non-investment-grade bonds are excluded since for a bond to be compliant with the Green Bond Principles and included in this investigation's sample it needs to have an investment-grade ranking. This investigation further excludes all bonds issued in a currency other than EUR or USD since these two currencies represent the major part of the global green bond issuance. With a mean maturity of 4.16 and 4.12 years respectively and a mean duration of 4.12 and 3.55 years the Green and conventional bonds sets are well-suited for a comparative study as can also be seen in Table II. Following this selection process, the conventional bonds sample consists of 1521 bonds. By revising the time period coherently with the procedure adopted for the Green bonds sample, for the period between January 4th, 2011 and June 30th, 1291 conventionals stay in our final sample that is used for the further research in this study. The exact filters are showed in the Figure 5 below:

Conventional Bond Selection and Filtering Process	
1	Bloomberg Fixed Income Bonds Research
2	Time Period 01/07/2007 - 30/06/2017
3	Use of Proceeds: Project Finance, Investment
4	Rating: S&P Investment Grade (AAA - BBB-)
5	Currency: USD, EUR
9	Eliminate duplicates
10	Remove Bonds with less than 1 year of data (206 BD)

Figure 5. Conventional Bond Selection

4.4 Risk-free Rate

This paper follows the the approach of Fama and French (1993) and considers the one-month T-Bill rate of the United States as risk-free. This is also coherent with the USD data for the bonds sample. The rates are downloaded on a daily basis from the CRSP data server.

4.5 Fama-French Factors

The market, size and value premium, generally considered as the Fama-French factors are gathered from the CRSP database.
In their research on the cross-section of expected stock returns, Fama and French (Fama and French, 1993) find that the ratio of book equity to market equity (BE/ME) captures most of the cross-section of average stock returns. Therefore, when rationally priced stocks are presumed, systematic differences in average returns can be traced back to differences in risk (Fama and French, 1992).

Moreover, the authors find evidence that the book-to-market equity ratio can substantially improve the model for the prediction of stock returns. They also find a similar pattern when considering firm size as a further explanatory variable in the model (Fama and French, 1993). The size and value premia are constructed from the 6 value-weighted portfolios formed on size and book-to-market ratio which are available on Kenneth French's personal website (French, 2015). The authors find that those factors do not only have an explanatory power for the stock market but are common risk factors for stocks and bonds (Fama and French, 1993).

The market premium is the difference between the market return of the and the risk-free rate.

The size premium, SMB (Small Minus Big), is the average return on the three small portfolios minus the average return on the three big portfolios,

$$SMB = 1/3(SmallValue + SmallNeutral + SmallGrowth) - 1/3(BigValue + BigNeutral + BigGrowth)$$

The value premium, HML (High Minus Low), is the average return on the two value portfolios minus the average return on the two growth portfolios,

$$HML = 1/2(SmallValue + BigValue) - 1/2(SmallGrowth + BigGrowth)$$

(French, 2015)

In Fama and French (1993) "Common Risk Factors in the Returns on Stocks and Bonds", a complete description of the factor returns is provided (Fama and French, 1993) (French, 2015).

4.6 Momentum Factor

The momentum factor is provided by the CRSP database in accordance with Grinblatt et al. (1995) on a daily basis.

4.7 Bond Factors

The bond factors are constructed according to Fama and French (1993).
The $TERM$ factor is defined as "the difference between the monthly long-term government bond return and the one-month Treasury bill rate" (Fama and French, 1993).
For the long-term government bond return this paper uses the ten-year constant maturity rate provided by the FRED database of the Federal Reserve Bank of St. Louis on a daily basis.
The risk-free rate is again the one-month T-Bill rate provided by the CRSP.

Eugene Fama and Kenneth French define the DEF factor as "the difference between the return on a market portfolio of long-term corporate bonds and

the long-term government bond return" (Fama and French, 1993).
This paper uses the Bloomberg Barclays Long US Corporate Total Return Index from the Bloomberg database as proxy for the long-term corporate bond returns. The long-term government bond return is constructed in the same way as for the $TERM$ factor.
Both factors are constructed with daily data.

5 Empirical Research

5.1 Summary

Table II provides the summary statistics of the Green and conventional bond samples. After the previously mentioned data cleansing and filtering, the Green bond sample consists of 359 bonds while the set of conventional bonds is made of 1291 fixed income contracts. The overall sample then consists of 1650 different bonds.
Over the considered time period between January 4th, 2011 and June 30th, 2017, the average yield-to-maturity of the conventional bonds amounts to 4.12%. The descriptive statistics suggest that the Green bonds sample, with an average yield-to-maturity of 4.16% seems to outperform the conventional sample by about 0.04% on average. Conventionals do show a standard deviation of 4.81% while the one of green bonds amounts to 10.52%. Figure 6 summarises the average amount of Green and conventional bond issuances per year while Table III provides basic descriptive statistics for the factor loadings.

Table II.
Summary Statistics of Green and conventional bond samples

Bond Class	*Mean YtM*	*Mean Mod. Duration*	*Std. Dev.*	*# of Bonds*
Green	4.162198	4.12427	10.52012	359
Conventional	4.11899	3.55318	4.808956	1291
Total				1650

The table provides summary statistics on both Green and conventional bond samples used in this paper after applying the different data cleansing and filtering operations mentioned earlier in the study. The considered time period is January 4th, 2011 until June 29th, 2017. The average yield-to-maturity is calculated using daily data and constructing the equally wheighted mean of all 1650 bonds over the sample period. The same procedure is applied for the calculation of the standard deviation. All figures are in U.S. Dollars.

Average Amount Issued (in m.USD)		
	Green Bonds	Conventional Bonds
2011	7	375
2012	118	343
2013	322	221
2014	293	210
2015	161	254
2016	379	317
2017	321	580
Total Average	**229**	**329**

Figure 6.

Table III.
Descriptive statistics for independent variables used in seven-factor model

	$Market$	SMB	HML	MOM	$TERM$	DEF
Mean	0.00055	-0.00006	0.00002	0.00005	0.02251	0.05610

The table provides basic descriptive statistics for the market risk premium ($Market$), the size and value premia (SMB, HML), the momentum (MOM) factor as well as term and default premia ($TERM$, DEF) used in the different models of this research in order to estimate bond returns. The are calculated by averaging the data provided by the CRSP and the $TERM$ and DEF factors constructed as explained in detail in Section 4.7.

5.2 CAPM Regression Results

Table IV shows the CAPM results for the study using the Kenneth R. French factor provided by the Center for Research in Security Prices as market benchmark. The overall international investment orientation of the considered bonds supports the choice of this factor which follows Ibikunle and Steffen (2015). The results show an outperformance of Green bonds over the market benchmark in comparison to conventional ones over the full sample period from 2011-2017. However, we can observe a rather low adjusted R^2 of 0.1475 that is consistent with the literature of Fama and French (1993) and Lettau and Ludvigson (2001). This would support the hypothesis, that the $GREEN$ coefficient is so high because it incorporates other effects not taken into account by the model. We are probably facing an unobserved variable bias and extend the initial CAPM with further predictor values to increase its power as demonstrated in the literature (Fama and French, 1993).

Table IV.
Fama-Macbeth Regressions: $\bar{\lambda}_j$ Coefficient
Average estimates on betas in cross-sectional regression following Fama Macbeth Two-Step Procedure

Asset Pricing Model:	$\bar{\lambda}_{RM}$	$\bar{\lambda}_{GREEN}$	R^2	$R^2_{adj.}$
CAPM	0.8828	4.3821*	0.1549	0.1475
	(10.52)	(6.49)		
Observations				1570

The table presents $\bar{\lambda}_j$ estimates for the CAPM-based regressions. The Fama-Macbeth Approach is used with excess yield-to-maturities of 359 Green and 1291 conventional bonds. The $\bar{\lambda}_j$ estimates result from averaging the results of the cross-sectional regressions (second pass) of the Fama-Macbeth procedure and are estimates for the betas of the factor in the column heading. *RM* is the market proxy collected from the Center for Research in Security Prices that is used to approximate the equity market performance and measure the risk-adjusted returns of the two bond classes. $\bar{\lambda}_{RM}$ measures the effect of *RM*.
The standard errors are shown in parentheses. *, ** and *** are corresponding to a statistic significance at the 10 %, 5 % and 1 % level respectively.
The R^2 and $R^2_{adj.}$ are calculated by averaging the R^2 and $R^2_{adj.}$ of all cross-sectional regressions run in the Fama-Macbeth procedure. The adjusted R^2 adjusts for the number of independent variables in the model and therefore only increases if an additional predictor increases the predictive power of the model.

5.3 Fama-French Three-Factor Model Regression Results

Fama and French (1993) prove the inferior explanatory power of the Capital Asset Pricing Model and suggest an extension that should enhance the capability of predicting equity returns. For the bond sample that this paper is analysing, adding the size and value premia as explanatory variable does add to the quality of the model but only very little with an $R^2_{adj.}$ of 0.1811 compared to an $R^2_{adj.}$ of 0.1475 for the CAPM as it is shown in Table V. In their research Fama and French (1993) find a high $R^2_{adj.}$. The difference can still be consistent with their findings since their three-factor model is focusing on stocks and not bonds. This research is going to test their five-factor model including the bond factor later on.

Table V.
Fama-Macbeth Regressions: $\bar{\lambda}_j$ Coefficient
Average estimates on betas in cross-sectional regression following Fama Macbeth Two-Step Procedure

Asset Pricing Model:	$\bar{\lambda}_{RM}$	$\bar{\lambda}_{SMB}$	$\bar{\lambda}_{HML}$	$\bar{\lambda}_{GREEN}$	R^2	$R^2_{adj.}$
FF3F	0.5993	0.2283	0.0105	4.3768*	0.1958	0.1811
	(4.22)	(5.11)	(2.98)	(7.00)		
Observations						1570

The table presents $\bar{\lambda}_j$ estimates for the Fama-French three-factor Model-based regressions. The Fama-Macbeth Approach is used with excess yield-to-maturities of 359 Green and 1291 conventional bonds. The $\bar{\lambda}_j$ estimates result from averaging the results of the cross-sectional regressions (second pass) of the Fama-Macbeth procedure and are estimates for the betas of the factor in the column heading. RM is the market proxy collected from the Center for Research in Security Prices that is used to approximate the equity market performance and measure the risk-adjusted returns of the two bond classes. $\bar{\lambda}_{RM}$ measures the effect of RM. SMB is the size premium accounting for the size anomaly while HML is the value premium that proxies for the value anomaly. Both factors are retrieved from the CRSP database. $\bar{\lambda}_{SMB}$ and $\bar{\lambda}_{HML}$ measure the effect of SMB and HML respectively.
The standard errors are shown in parentheses. *, ** and *** are corresponding to a statistic significance at the 10 %, 5 % and 1 % level respectively.
The R^2 and $R^2_{adj.}$ are calculated by averaging the R^2 and $R^2_{adj.}$ of all cross-sectional regressions run in the Fama-Macbeth procedure. The adjusted R^2 adjusts for the number of independent variables in the model and therefore only increases if an additional predictor increases the predictive power of the model.

5.4 Carhart Four-Factor Model Regression Results

Grinblatt et al. (1995) find a superior performance for equity investments based on momentum strategies. A similar reasoning could be made for including the momentum factor to the bond pricing model of this paper. Table VI shows that the results of the Fama-Macbeth procedure for this model do provide an superior adjusted R^2 of 0.2486 that leads to support the afore-mentioned argument. The $GREEN$ coefficient is contiously decreasing with the addition of new factors to the initial model which supports the hypothesis of the omitted variable bias. All four-factors of this model do however relate to the equity market which could be is another explanation of the, still, rather poor performance of the model. The following seven-factor model is going take into account two bond factors and provides support for this argument.

Table VI.
Fama-Macbeth Regressions: $\bar{\lambda}_j$ Coefficient
Average estimates on betas in cross-sectional regression following Fama Macbeth Two-Step Procedure

Asset Pricing Model:	$\bar{\lambda}_{RM}$	$\bar{\lambda}_{SMB}$	$\bar{\lambda}_{HML}$	$\bar{\lambda}_{MOM}$	$\bar{\lambda}_{GREEN}$
Carhart four-factor Model	0.7440	0.0133	−0.1543	−0.3649	3.6451*
	(5.49)	(−2.76)	(−2.32)	(−12.16)	(5.18)
R^2					0.2666
$R^2_{adj.}$					0.2486
Observations					1570

The table presents $\bar{\lambda}_j$ estimates for the Fama-French three-factor Model-based regressions. The Fama-Macbeth Approach is used with excess yield-to-maturities of 359 Green and 1291 conventional bonds. The $\bar{\lambda}_j$ estimates result from averaging the results of the cross-sectional regressions (second pass) of the Fama-Macbeth procedure and are estimates for the betas of the factor in the column heading. RM is the market proxy collected from the Center for Research in Security Prices that is used to approximate the equity market performance and measure the risk-adjusted returns of the two bond classes. $\bar{\lambda}_{RM}$ measures the effect of RM. SMB is the size premium accounting for the size anomaly while HML is the value premium that proxies for the value anomaly and MOM proxies momentum in the market to take account of the momentum anomaly. The three factors are retrieved from the CRSP database. $\bar{\lambda}_{SMB}$, $\bar{\lambda}_{HML}$ and $\bar{\lambda}_{MOM}$ measure the effect of SMB, HML and MOM respectively.

The standard errors are shown in parentheses. *, ** and *** are corresponding to a statistic significance at the 10 %, 5 % and 1 % level respectively.

The R^2 and $R^2_{adj.}$ are calculated by averaging the R^2 and $R^2_{adj.}$ of all cross-sectional regressions run in the Fama-Macbeth procedure. The adjusted R^2 adjusts for the number of independent variables in the model and therefore only increases if an additional predictor increases the predictive power of the model.

5.5 Seven-Factor Model Regression Results

Table VII shows the results for the Fama-Macbeth estimation of the seven-factor model as specified in Section 3.2. With a coefficient of 1.6047 the $GREEN$ dummy still remains positive and suggests that Green bonds are outperforming conventional ones over the sample period. Thereby the initial hypothesis, stating that the performance of Green bonds is inferior to the one of their conventional peers can be rejected. The adjusted R^2 of the seven-factor model does increase in comparison to the Carhart four-factor model but is however not comparable to the one found in Fama and French (1993). By referring to the Green bond issuance stated in Table I we observe a very low number of Green bond issuances over the first years of the research. Furthermore the first Green bonds are mostly issued by supranational and governmental institutions whereas the real growth of the market only starts with corporate Green bond issuances. Considering this and as a further robustness check, a subperiod coinciding with the "take-off" of the corporate green bond issuances in 2015 is constructed. The results from this test can be seen in Table VIII.
One can observe that the constructed seven-factor model is able to explain much of the underlyings for the movements in bond yield-to-maturities in the subperiod. The substantial increase of the adjusted R^2 in the subperiod compared to the whole sample period supports the argument that the explanatory power of the model increases with the "take-off" of the green bond market.
At the same time, the adjusted R^2 of 0.6319 in the subperiod leads to the conclusion that there are still other, unobserved factors such as inflation or issuer-specific risk factors that are influencing the outcome and that have to be identified and observed in order to further improve the model although the results obtained here are consistent with those of Fama and French (1993).

Again, the substantial factor loading of the $GREEN$ dummy provides empirical evidence of the outperformance of Green bonds versus their conventional peers.
The pattern of the findings of this research is very similar to the one Ibikunle and Steffen (2015) find for the green equity mutual fund market: They find that the performance of green funds progressively improves over time and suggest that this could be driven by "the transition from a fossil fuel age into an emission-constrained one". The same reasoning could be adopted for the findings of this paper on behalf of the Green bond market even if this analysis does not provide a definite proof for this pattern.
If one analyses the single regression results of the cross-sectional regressions,

one notifies the consistent increase of the adjusted R^2 as well as the fact that after April 2017, the $R^2_{adj.}$ is consistently above 0.79 as it can be seen in Figure 8 and in the appendix. From this point, it would be interesting to conduct the same research again at a later point in time and analyse if this pattern is continuing.

Table VII.
Fama-Macbeth Regressions: $\bar{\lambda}_j$ Coefficient
Average estimates on betas in cross-sectional regression following Fama Macbeth Two-Step Procedure

Model:							
	$\bar{\lambda}_{RM}$	$\bar{\lambda}_{SMB}$	$\bar{\lambda}_{HML}$	$\bar{\lambda}_{MOM}$	$\bar{\lambda}_{TERM}$	$\bar{\lambda}_{DEF}$	$\bar{\lambda}_{GREEN}$
7-Factor Model	0.5906	0.2450	0.3187	−0.6559	0.0241*	−0.5780	1.6047
	(3.95)	(0.85)	(3.48)	(−10.02)	(4.28)	(−7.75)	(3.22)
R^2							0.3164
$R^2_{adj.}$							0.2917
Observations							1570

The table presents $\bar{\lambda}_j$ estimates for the Fama-French three-factor Model-based regressions. The Fama-Macbeth Approach is used with excess yield-to-maturities of 359 Green and 1291 conventional bonds. The $\bar{\lambda}_j$ estimates result from averaging the results of the cross-sectional regressions (second pass) of the Fama-Macbeth procedure and are estimates for the betas of the factor in the column heading. RM is the market proxy collected from the Center for Research in Security Prices that is used to approximate the equity market performance and measure the risk-adjusted returns of the two bond classes. $\bar{\lambda}_{RM}$ measures the effect of RM. SMB is the size premium accounting for the size anomaly while HML is the value premium that proxies for the value anomaly and MOM proxies momentum in the market to take account of the momentum anomaly. The three factors are retrieved from the CRSP database. $\bar{\lambda}_{SMB}$, $\bar{\lambda}_{HML}$ and $\bar{\lambda}_{MOM}$ measure the effect of SMB, HML and MOM respectively. $TERM$ accounts for the long-term bonds deviation from expected returns caused by interest rate shifts. It is calculated from the difference of a long-term government bond return and the one-month T-Bill. DEF proxies the default probability change due to economic condition changes and is calculated as the difference between a portfolio of long-term corporate bonds and the long-term government bond return as in Fama and French (1993). Again, $\bar{\lambda}_{TERM}$ and $\bar{\lambda}_{DEF}$ account for the effect of both factors respectively.
The standard errors are shown in parentheses. *, ** and *** are corresponding to a statistic significance at the 10 %, 5 % and 1 % level respectively.
The R^2 and $R^2_{adj.}$ are calculated by averaging the R^2 and $R^2_{adj.}$ of all cross-sectional regressions run in the Fama-Macbeth procedure. The adjusted R^2 adjusts for the number of independent variables in the model and therefore only increases if an additional predictor increases the predictive power of the model by calculating:
$R^2_{adj.} = 1 - \frac{(1-R^2)*(N-1)}{N-p-1}$, with N being the total sample size and p being the number of predictors used in the model.

Table VIII.
Fama-Macbeth Regressions: $\bar{\lambda}_j$ Coefficient
Average estimates on betas in cross-sectional regression following Fama Macbeth Two-Step Procedure from 25/11/2015 - 29/06/2017

Model:	$\bar{\lambda}_{RM}$	$\bar{\lambda}_{SMB}$	$\bar{\lambda}_{HML}$	$\bar{\lambda}_{MOM}$	$\bar{\lambda}_{TERM}$	$\bar{\lambda}_{DEF}$	$\bar{\lambda}_{GREEN}$
7-Factor Model	0.7510^{***}	0.2958^{***}	0.0936^{**}	-0.4123^{***}	0.0003	$-0.0.0257$	3.7113^{***}
	(21.10)	(9.06)	(2.63)	(-8.48)	(0.26)	(1.15)	(13.80)
R^2							0.64319
$R^2_{adj.}$							0.6336
Observations							1570

The table presents $\bar{\lambda}_j$ estimates for the Fama-French three-factor Model-based regressions. The Fama-Macbeth Approach is used with excess yield-to-maturities of 359 Green and 1291 conventional bonds. The $\bar{\lambda}_j$ estimates result from averaging the results of the cross-sectional regressions (second pass) of the Fama-Macbeth procedure and are estimates for the betas of the factor in the column heading. RM is the market proxy collected from the Center for Research in Security Prices (CRSP) that is used to approximate the equity market performance and measure the risk-adjusted returns of the two bond classes.$\bar{\lambda}_{RM}$ measures the effect of RM. SMB is the size premium accounting for the size anomaly while HML is the value premium that proxies for the value anomaly and MOM proxies momentum in the market to take account of the momentum anomaly. The three factors are retrieved from the CRSP database. $\bar{\lambda}_{SMB}$, $\bar{\lambda}_{HML}$ and $\bar{\lambda}_{MOM}$ measure the effect of SMB, HML and MOM respectively. $TERM$ accounts for the long-term bonds deviation from expected returns caused by interest rate shifts. It is calculated from the difference of a long-term government bond return and the one-month T-Bill. DEF proxies the default probability change due to economic condition changes and is calculated as the difference between a portfolio of long-term corporate bonds and the long-term government bond return as in Fama and French (1993). Again, $\bar{\lambda}_{TERM}$ and $\bar{\lambda}_{DEF}$ account for the effect of both factors respectively.
The standard errors are shown in parentheses. *, ** and *** are corresponding to a statistic significance at the 10 %, 5 % and 1 % level respectively.
The R^2 and $R^2_{adj.}$ are calculated by averaging the R^2 and $R^2_{adj.}$ of all cross-sectional regressions run in the Fama-Macbeth procedure. The adjusted R^2 adjusts for the number of independent variables in the model and therefore only increases if an additional predictor increases the predictive power of the model by calculating:
$R^2_{adj.} = 1 - \frac{(1-R^2)*(N-1)}{N-p-1}$, with N being the total sample size and p being the number of predictors used in the model.

6 Summary and Conclusions

Especially in the follow-up to the COP 21 agenda and the UN 17 sustainable development goals, the sustainable and responsible investment market sees increasing inflows and gets more and more attention even from investors without a specific SRI focus. Green bonds channeling funds to environmentally friendly projects are one instrument to implement those investments. Evidence for this increase can be found in the huge increase of Green bond issuances in the recent year and months as can be seen in Figure 7 below. However, even though the market of Green bonds doubled in terms of amounts issued from 2016 to 2017, the global Green bond market still consists of less than one percent of the overall bond market. Despite more and more investors being obliged to invest sustainably by either the regulator or the client demand, the ultimate criteria for the invest in a certain asset still remains its financial return.

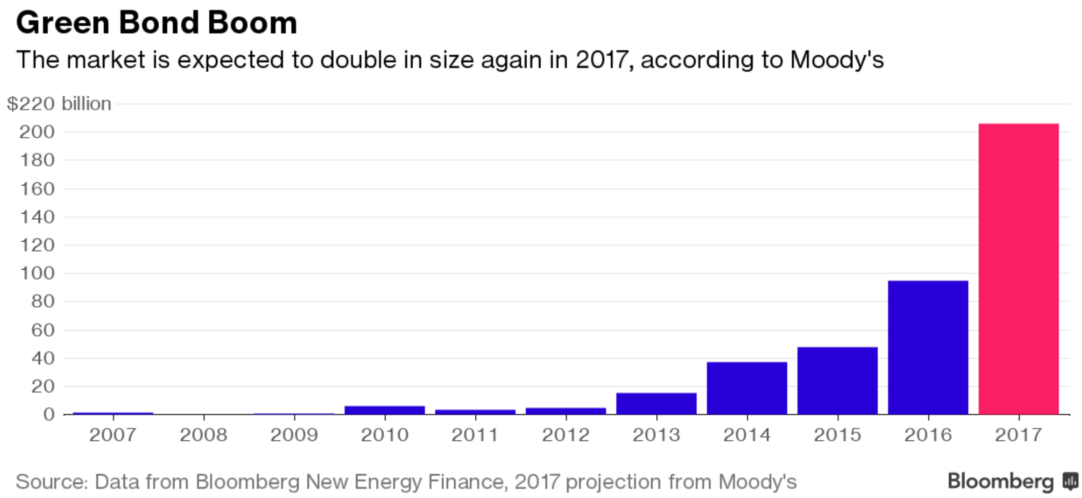

Figure 7.

With the financial performance of Green bonds being a rather unchartered territory in terms of empirical research, this study aims to make a substantial contribution to the field. To the knowledge of the author, this study is the first to analyse the financial performance of green bonds in comparison to their conventional peers based on a forward-looking asset pricing model. Indeed the study tests the performance with various models and creates a $GREEN$ factor in order to account for a potential effect on the financial return due to the fact that the considered bond is green.

The key contributions of the analysis are as follows: (1) it is, to the best knowledge of the author, the first empirical studies to analyse the financial performance of Green bonds compared to their traditional counterparts, (2) it is testing an extended Fama-French model in a fixed income environment and (3) finds that the fact of a bond being green does positively influence its expected financial performance.

As Figure 8 shows, the explanatory power of the constructed model does significantly increase towards the end of the financial year of 2015 which overlaps with the "take-off" of corporate Green bond issuances as Table I demonstrates. The bi-annual cross-sectional regression results that can be found in the Appendix do provide further evidence for this as well as for the increasing significance of the $GREEN$ coefficient over time.

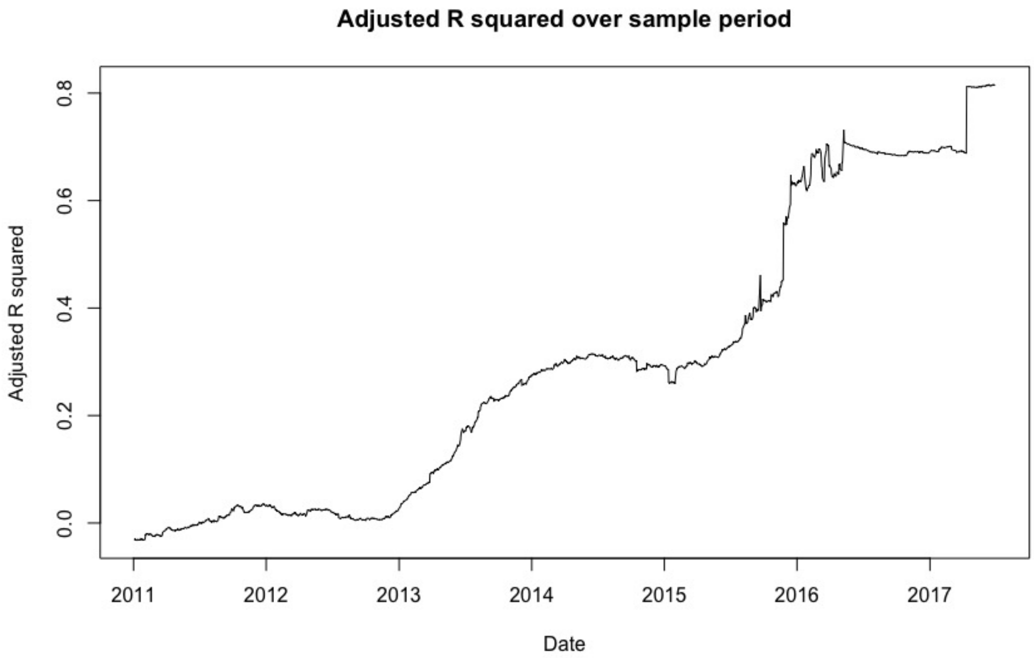

Figure 8. Adjusted R squared over time

As Figure 9 shows, the $GREEN$ coefficient is negative in the beginning of the sample period but increases continually until it gets positive towards the end of 2011. During the first half of the sample period, the factor loading of $GREEN$ is quite volatile but this volatility seems to evade when the amount of corporate green bond issuances starts its "take-off" in 2015. The overall average ($\bar{\lambda}_{GREEN}$) throughout the whole sample period of 1.6047 is clearly speaking for an outperformance of the Green bonds in comparison to the traditional one. In our subsample, the effect of the bond being green seems to have an even bigger effect.

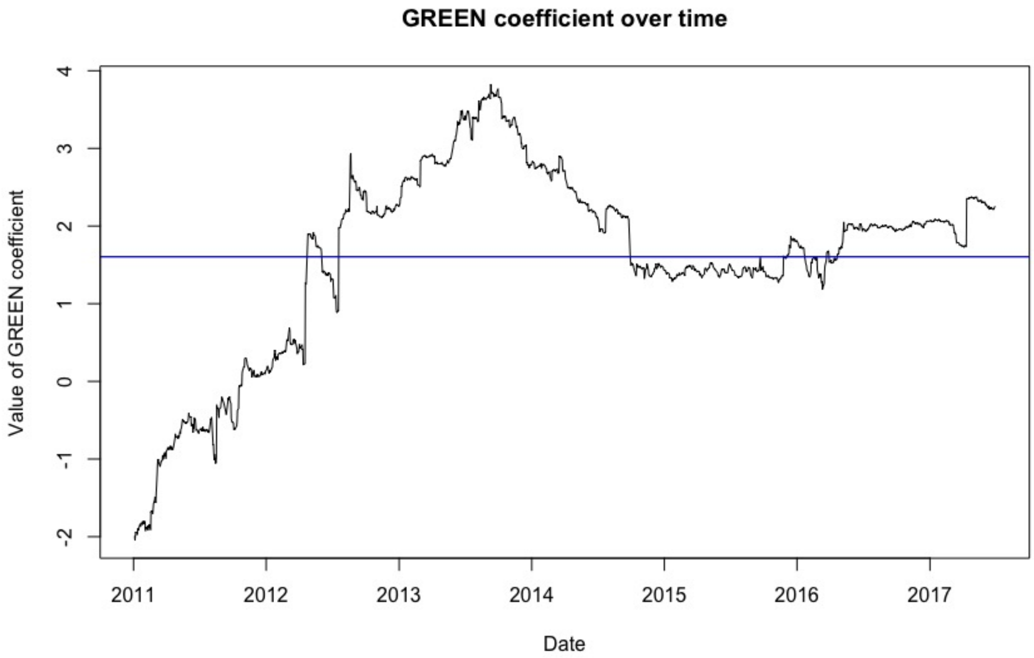

Figure 9. Seven-factor model estimations for $\hat{\lambda}_{GREEN}$ over time

All in all, the findings of this research do not only provide a new insight on the fundamentals of the Green bond market but they are at the same time providing a key element for the development and marketing of the Green bond market. With the argument of Green bonds being more of a charity investment than a financially interesting instrument wiped out, the financing of the fight against climate change should get further attention and support.

7 Limitations and further research

Even if the author has put substantial effort into the representativeness of the data, the findings are limited by the data and only applicable for the considered time period. It is still possible that the estimated positive effect of a bond being green is at least partly due to variables unobserved in this study such as the state of the technology, the innovativeness and general positioning of the issuer. This asks for the inclusion of further factors enhancing the explanatory power of the model and providing further insights into the underlying fundamentals of the Green bond market.

Also, considering the fact the Green bond market was born only ten years ago and the real "take-off" only started in 2015 with a substantial amount of issuances coming from the corporate market, one should conduct the same analysis again at a later point in time with a more mature market that will enable the researcher to make statements based on a longer sample period and a bigger sample of Green bonds that can make up for the unbalanced sample that this research had to rely on.

Furthermore, he thesis is purely focusing on financial performance and does not take behavioural considerations or other non-financial factors potentially driving performance into account.

A further approach to analyse the performance while accounting for issuer specific risks would be to adopt a two-by-two approach comparing Green and conventional bonds coming from the same issuer. Those are considered having the same inherent risk characteristics and the difference in performance should purely came from the "greeness". Also, the inclusion of a *black* bonds class accounting for bonds whose proceeds are specifically targeted to fossil and non-renewable energy projects could be of further interest to the industry. Inflation and liquidity would be two further factors that could be integrated into the pricing model to potentially further increase its explanatory power.
In general, future research and time is due in order to avoid premature statements and tell wether the hypothesis holds true.

References

Bloomberg New Energy Finance (2016). Guide to green bonds on the bloomberg terminal.

Carhart, M. M. (1997). On persistence in mutual fund performance. *Journal of Finance*, 52(1), 57–82.

Cavenaile, L., Dubois, D., and Hlávka, J. (2009). Cross-Sectional Tests of Fama and French Three-Factor Model and Fama-MacBeth Method. Working Paper Ecole de gestion de l'Université de Liège.

Clapp, C., Alfsen, K. H., Lund, H. F., and Pillay, K. (2016). Green bonds and environmental integrity: Insights from cicero second opinions. Technical report, CICERO - Center for International Climate and Environmental Research.

Climate Bonds Initiative (2016). Bonds and climate change - the state of the market in 2016. Technical report, Climate Bonds Initiative.

Climate Bonds Initiative (2017). Green bonds policy: Highlights from 2016. Technical report, Climate Bonds Initiative.

Cochrane, J. H. (2009). *Asset Pricing*. Princeton University Press, Princeton.

Cochrane, J. H. (2014). Empirical Methods notes. http://faculty.chicagobooth.edu/john.cochrane/teaching/35150_advanced_investments/week5a_notes.pdf. Last accessed on 04.07.2017.

Ebrey, P. B. (2010). The cambridge illustrated history of china. Technical report, Princeton University Press, Cambridge.

EY (2016). Green bonds - a fresh look at financing green projects. Technical report, EY.

Fama, E. F. and French, K. R. (1992). The Cross-Section of Expected Stock Returns. *Journal of Finance*, XLVII(2), 427–465.

Fama, E. F. and French, K. R. (1993). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics*, 33(1), 3–56.

Fama, E. F. and French, K. R. (2004). The capital asset pricing model: Theory and evidence. *Journal of Economic Perspectives*, 18(3), 25–46.

Fama, E. F. and Macbeth, J. D. (1973). Risk, return and equilibrium: Empirical tests. *Journal of Political Economy*, 81(3).

French, K. R. (2015). Kenneth French's Website. http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html. Last accessed on 07.05.2017.

Gabbi, G. and Sironi, A. (2005). Which factors affect corporate bonds pricing? empirical evidence from eurobonds primary market spreads. *The European Journal of Finance*, 11(1), 59–74.

Gil-Bazo, J., Ruiz-Verdú, P., and Santos, A. A. P. (2010). The performance of socially responsible mutual funds: The role of fees and management companies. *Journal of Business Ethics*, 94(2), 243–263.

Glomsrød, S. and Taoyuan, W. (2016). Working paper 2016:01 business as unusual - the implications of fossil divestment and green bonds for financial flows, economic growth and engery market. Technical report, CICERO - Center for International Climate and Environmental Research.

Grinblatt, M., Titman, S., and Wermers, R. (1995). Momentum investment strategies, portfolio performance, and herding: A study of mutual fund behavior. *The American Economic Review*, 85(5), 1088–1105.

Houweling, P., Mentink, A., and Vorst, T. (2005). Comparing possible proxies of corporate bond liquidity. *Journal of Banking and Finance*, 29(6), 1331–1358.

Ibikunle, G. and Steffen, T. (2015). European mutual fund performance: A comparative analysis with their conventional and black peers. *Journal of Business Ethics*, 145(2), 337–355.

Johansson, D. and Lundgren, T. (2012). A study of corporate bond returns - using Sharpe-Lintner CAPM and Fama-French. Master's thesis, Stockholm School of Economics.

Lettau, M. and Ludvigson, S. (2001). Resurrecting the (C)CAPM: A Cross-Sectional Test When Risk Premia Are Time-Varying. *Journal of Political Economy*, 109(6), 1238–1287.

Lintner, J. (1965). The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets. *The Review of Economics and Statistics*, 47(1), 13–37.

LuxFLAG (2017). About us. http://www.luxflag.org/about/who-we-are.html&sid=894bcca948bf0a18e0eb87c4ce53d6ca. Last accessed on 22.09.2017.

Merton, R. C. (1973). An intertemporal capital asset pricing model. *Econometrica*, 41(5), 867–887.

Natixis (2017). Green bonds 3.0: Quality check. Technical report, Natixis Corporate and Investment Banking.

NEPC Impact Investing Committee (2016). What a caia member should know - an introduction to green bonds. Technical report, NEPC Impact Investing Committee.

Parnassus Investments (2015). Parnassus digest - march 2015 - green bonds. https://www.parnassus.com/our-firm/highlight/153. Last accessed on 15.05.2017.

Petkova, R. (2011). *Financial Economics, The Cross-Section of Stock Returns and the Fama-French Three Factor Model*, pages 361–374. Springer New York, http://dx.doi.org/10.1007/978-1-4419-7701-4_21.

Sharpe, W. F. (1964). Capital asset prices: A theory of market equilibrium under conditions of risk. *Journal of Finance*, 19(3), 425–442.

Stock, J. H. and Watson, M. M. (2012). *Introduction to Econometrics*. Pearson Education Limited, 3rd edition.

World Bank (2015). Green bonds attract private sector climate finance. http://www.worldbank.org/en/topic/climatechange/brief/green-bonds-climate-finance. Last accessed on 22.09.2017.

Xiao, Y., Faff, R., Gharghori, P., and Lee, D. (2012). An empirical study of the world price of sustainability. *Journal of Business Ethics*, 114(2), 297–310.

Appendix A: Appendix

1.1 Seven-factor cross-sectional regression results over time (bi-annual)

Table IX. 04.01.2011

	Estimate	Std. Error	t value	Pr(>|t|)
RM	0.3003	2.1924	0.14	0.8914
SMB	0.5517	1.5290	0.36	0.7194
HML	1.1330	2.0342	0.56	0.5794
MOM	-0.3918	1.9567	-0.20	0.8419
TERM	0.0560	0.0499	1.12	0.2656
DEF	-0.6869	0.9761	-0.70	0.4840
GREEN	-1.9926	6.6623	-0.30	0.7658

Table X. 01.07.2011

	Estimate	Std. Error	t value	Pr(>|t|)
RM	0.8730	1.4099	0.62	0.5374
SMB	0.7344	1.1456	0.64	0.5231
HML	0.7147	0.7084	1.01	0.3157
MOM	-0.4897	1.1514	-0.43	0.6716
TERM	0.0514	0.0359	1.43	0.1556
DEF	-0.6818	0.7750	-0.88	0.3814
GREEN	-0.6310	5.6007	-0.11	0.9106

Table XI. 03.01.2012

	Estimate	Std. Error	t value	Pr(>|t|)
RM	1.0283	1.1294	0.91	0.3647
SMB	0.7667	1.0338	0.74	0.4600
HML	0.6195	0.5987	1.03	0.3033
MOM	-0.8903	0.9395	-0.95	0.3455
TERM	0.0354	0.0298	1.19	0.2366
DEF	-0.3843	0.6430	-0.60	0.5513
GREEN	0.1296	4.3821	0.03	0.9765

Table XII. 02.07.2012

	Estimate	Std. Error	t value	Pr(>|t|)
RM	0.6432	0.8524	0.75	0.4518
SMB	0.2781	0.8269	0.34	0.7372
HML	0.6222	0.5038	1.24	0.2190
MOM	-0.8875	0.6540	-1.36	0.1771
TERM	0.0427*	0.0231	1.85	0.0663
DEF	-0.5826	0.4888	-1.19	0.2354
GREEN	1.3167	3.2441	0.41	0.6855

Table XIII. 02.01.2013

	Estimate	Std. Error	t value	Pr(>|t|)
RM	0.4330	0.4866	0.89	0.3747
SMB	0.5679	0.5335	1.06	0.2886
HML	0.2337	0.3358	0.70	0.4874
MOM	-0.7719*	0.4173	-1.85	0.0660
TERM	0.0237*	0.0141	1.68	0.0955
DEF	-0.4955*	0.2888	-1.72	0.0880
GREEN	2.2718*	2.2616	1.00	0.3165

Table XIV. 01.07.2013

	Estimate	Std. Error	t value	Pr(>|t|)
RM	0.6026*	0.3087	1.95	0.0520
SMB	0.3470	0.2999	1.16	0.2482
HML	0.1097	0.2204	0.50	0.6192
MOM	-0.8488***	0.2133	-3.98	0.0001
TERM	0.0267***	0.0101	2.64	0.0088
DEF	-0.5953***	0.1763	-3.38	0.0008
GREEN	3.4154**	1.6120	2.12	0.0351

Table XV. 02.01.2014

	Estimate	Std. Error	t value	Pr($>\lvert t\rvert$)
RM	0.6041***	0.1983	3.05	0.0025
SMB	-0.0106	0.1863	-0.06	0.9545
HML	0.2175	0.1470	1.48	0.1397
MOM	-0.9205***	0.1388	-6.63	0.0000
TERM	0.0256***	0.0059	4.32	0.0000
DEF	-0.6377***	0.1070	-5.96	0.0000
GREEN	2.7866 ***	0.9616	2.90	0.0039

Table XVI. 01.07.2014

	Estimate	Std. Error	t value	Pr($>\lvert t\rvert$)
RM	0.5807***	0.1426	4.07	0.0001
SMB	-0.1417	0.0902	-1.57	0.1164
HML	0.1907**	0.0867	2.20	0.0283
MOM	-0.7661***	0.1054	-7.27	0.0000
TERM	0.0224***	0.0041	5.51	0.0000
DEF	-0.6706***	0.0796	-8.42	0.0000
GREEN	2.1212***	0.6321	3.36	0.0008

Table XVII. 02.01.2015

	Estimate	Std. Error	t value	Pr($>\lvert t\rvert$)
RM	0.6127***	0.1006	6.09	0.0000
SMB	-0.0969**	0.0458	-2.12	0.0346
HML	0.2905***	0.0446	6.51	0.0000
MOM	-0.4710***	0.0431	-10.93	0.0000
TERM	0.0267***	0.0026	10.34	0.0000
DEF	-0.8002***	0.0581	-13.76	0.0000
GREEN	1.4294***	0.4527	3.16	0.0016

Table XVIII. 01.07.2015

	Estimate	Std. Error	t value	Pr(>|t|)
RM	0.5770***	0.0883	6.54	0.0000
SMB	-0.1580***	0.0393	-4.02	0.0001
HML	0.2078***	0.0361	5.76	0.0000
MOM	-0.3960***	0.0333	-11.91	0.0000
TERM	0.0200***	0.0019	10.34	0.0000
DEF	-0.7003***	0.0454	-15.42	0.0000
GREEN	1.5016***	0.3616	4.15	0.0000

Table XIX. 04.01.2016

	Estimate	Std. Error	t value	Pr(>|t|)
RM	0.4275***	0.0715	5.98	0.0000
SMB	-0.0082***	0.0347	-0.24	0.8134
HML	0.1999***	0.0307	6.51	0.0000
MOM	-0.6212***	0.0293	-21.22	0.0000
TERM	0.0091***	0.0015	6.00	0.0000
GREEN	1.8151***	0.3030	5.99	0.0000

Table XX. 01.07.2016

	Estimate	Std. Error	t value	Pr(>|t|)
RM	0.5041***	0.0639	7.89	0.0000
SMB	0.1056***	0.0316	3.34	0.0009
HML	0.2159***	0.0267	8.07	0.0000
MOM	-0.6543***	0.0274	-23.84	0.0000
TERM	0.0021	0.0013	1.56	0.1195
DEF	-0.4156***	0.0333	-12.49	0.0000
GREEN	1.9645***	0.2537	7.74	0.0000

Table XXI. 03.01.2017

	Estimate	Std. Error	t value	Pr(>|t|)
RM	0.5331***	0.0637	8.37	0.0000
SMB	0.1514***	0.0317	4.77	0.0000
HML	0.2801***	0.0267	10.50	0.0000
MOM	-0.7511***	0.0277	-27.13	0.0000
TERM	0.0094***	0.0013	7.03	0.0000
DEF	-0.4680***	0.0334	-13.99	0.0000
GREEN	2.0552***	0.2521	8.15	0.0000

Table XXII. 29.06.2017

	Estimate	Std. Error	t value	Pr(>|t|)
RM	0.5114***	0.0664	7.71	0.0000
SMB	0.5998***	0.0331	18.14	0.0000
HML	0.0943***	0.0278	3.39	0.0007
MOM	-0.8242***	0.0288	-28.57	0.0000
TERM	0.0018	0.0014	1.32	0.1866
DEF	-0.3307***	0.0349	-9.49	0.0000
GREEN	2.2564***	0.2626	8.59	0.0000