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‘Green Bonds: A Study on Expected Returns and Liquidity Effects’

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"Liquidity, like pornography, is easily recognized but not so easily defined"

John Maynard Keynes, 1930

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Abstract

The emerging market of Green bonds has seen a positive growth over the recent years in the presence of the Paris objective of limiting the global warming to 2°C by the year 2100. In addition, fuelled the attention from a broader audience of issuers and investors. Although the demand for Green bonds has strongly increased in popularity over the recent years, the supply only represents a small percentage of the total global bond market. This implies a disequilibrium on the Green bond market and the notions of a narrow market were a liquidity premium most likely exists. However, limited empirical research has been conducted on liquidity and financial returns of Green bonds in the past. The thesis therefore investigated whether the liquidity premium had an effect on Green bond expected returns on the global market. The thesis is based on a dataset of 379 Green Bonds over the time period between 2014 and 2018 with the use of an extended Fama and French pricing model in a fixed effects regressions procedure. As a liquidity measure, the thesis employed the bid-ask spread and found that the measure positively influences expected returns for Green bonds. Even after controlling for characteristics such as *age, currency, public listed equity, credit rating* and *initial issued amount* the positive effect still remains. This can be interpreted that investors want to be compensated from bearing the liquidity exposure, hence a positive effect on the Green bond expected price returns. The findings could potentially reduce the information asymmetry and lower the transaction cost on the market for Green bonds, as both issuers and investors can address the liquidity exposure accordingly. Consequently, achieve a better mean of funding future Green projects that potentially have a positive environmental and climate outcome that aligns with the Paris objective.

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1. Introduction

1.1 Does a Liquidity Premium Exist for Green Bonds?

International climate meeting in Paris set an ambitious objective of limiting the global warming to 2°C by the year 2100 (Meyer zum Felde, Pidun, & Rubel, 2018). Contrarian recent reports have indicated that global warming is likely to reach 1.5°C as early as 2030 if the temperature continues to increase with its current state (IPCC, 2018). Reaching the outset objective will require approximately US$90 trillion by the year of 2030 to both reduce emissions and to develop new infrastructure (Worldbank, 2018). This is confirmed by Meyer zum Felde et al. (2018) who states that $1 trillion per year until 2050 is required to be invested in clean energy and other sustainability projects to limit the global warming to 2°C., the current investment level is still far below the target level (Meyer zum Felde et al., 2018). The Climate Bonds Initiative (2017) argue that Green bond issuances would need to increase significantly until the year 2020 to support the global objectives. As Green bonds aim to fund projects with positive environmental and climate benefits (Climate Bonds Initiative, 2017), they can be perceived as a valuable instruments to encounter these environmental objectives. Green bonds in this thesis are defined in consistent with Bloomberg (2015) as *"... fixed income instruments for which the proceeds will be applied towards projects or activities that promote climate change mitigation or adoption or other environmental sustainability purposes"*. Moody's recently reported that Green bonds continue to increase in popularity on a global basis (Hempstead & Kuchtyak, 2019). This increased popularity has also had a positive effect on investors (Inderst, Kaminker, & Stewart, 2012), as more investors seize the opportunity to integrate Environmental, Social and Governance (ESG) and Social Responsible Investments (SRI) factors within their portfolios (Cochu, Glenting, Hogg, Georgiev, Skolina, Elsinger, Jespersen, Agster, Fawkes, & Chowdury, 2016). The increased interest is also complemented with stakeholders demanding sustainable investments to a more extensive degree (EY, 2016).

Although the demand for Green bonds is increasing globally, a problem still exists with the supply-side as it only represented 2.1% of the total global bond issuance during the three first quarters of 2018 (Hempstead & Kuchtyak, 2019). Wulandari, Schäfer, Stephan and Sun (2018) state that the supply-side of Green bonds lacks incentives for investors to actually invest as well as deficiencies in an official classification system. The deficiency primarily depends on whether the bond is labelled Green or not, which potentially causes a transaction cost for the issuers by not being able to label the bond as "Green" before issuing. Transaction costs in this case mainly relate to the transparency and liquidity of the bonds (Edwards, Harris, & Piwowar, 2007), which is consistent with transaction cost theory from Williamson (1983). Edwards et al. (2007) find that bond financing is of great economic importance and claim that transaction cost for bonds are substantially higher than for equities. The transaction cost affects both investors and issuers and is directly dependent on the level of information transparency of the bond. Explicitly whether the issuer can easily define the project and explain to an investor what the invested funds are intended for. Consequently, the issuer will only choose to issue a bond if the estimated transaction cost is low enough since features that reduce bond liquidity is unattractive for the investor and costly for the issuer (Edwards et al., 2007). As a result, the issuance of Green bonds becomes less attractive and reduces the incentives for investors to actually invest in the bond.

Continuously, green funding projects often consist of less mature technologies compared to conventional bonds that usually consist of more tested technologies on the market (Cochu et al., 2016). The risk and opportunities of these green funding's are thus harder to assess as it may lack historical performance. Since Green bonds are assessed by the credit quality by the balance sheet of the issuers and not the credit profile of the bond (Cochu et al., 2016) it consequently leads to insufficient rating information. This leaves investors with insufficient information to make a correct investment decision, hence diminishes the interest for investors to invest in Green bonds.

The implication of this Green bond shortage in supply and excess in demand leads to a narrow market were a liquidity premium is likely to exist. Where the market lacks credible information about the bond classification and credit rating, which reduces the incentives for both investor's decision-making and the incentives of potentially issuing new Green bonds. This issue is brought up by Wulandari et al. (2018) who state that demand for Green bonds will likely exceed the supply even further if the current pace of Green bond issuing continues. Thereby, confirming a potential narrow market with a liquidity premium for Green bonds. As stated above, the characteristics of Green bonds differentiate from conventional bonds, creating incentives for both investors and issuers to understand how the liquidity will affect the returns of Green bonds.

1.2 History of Green Bonds

In 2007, the European Investment bank first introduced a climate-awareness bond to the market (Banga, 2019). This initial issuance has been complemented over the years by various issuers such as commercial banks, institutional investors and governments (Banga, 2019). In 2013, $10 billion worth of Green Bonds were outstanding and during the time period to 2018, the issuance reached $167.6 billion worth of labelled Green bonds (Climate bonds Initiative, 2018). This indicates an extensive increase in interest of green funding projects, which has exploded over the recent years. The global Green bond issuance is set to grow by around 19.3% to approximate $200 billion during 2019 in accordance to Moody's annual report (Hempstead & Kuchtyak, 2019), and thus far exceeding the previous quotation. In this sense are Green bonds not an entirely new phenomena but the shift in both climate changes and engagements in social responsibility have made the market an attractive opportunity for investors (Inderst et al., 2012).

1.3 Purpose and Contribution

Although Green bonds have gained an increased demand over the recent years, there is still limited empirical information available and studies conducted on environmentally responsible investments. Thereby, further research in this limited area is of high interest.

In the case of Green bonds in conjunction to liquidity, the implication of Green bond shortage in supply and an excess demand leads to a narrow market where a liquidity premium is likely to exist. As the liquidity of an asset is directly dependent on how easily it can be traded on the market (Berk & DeMarzo, 2017) and since liquidity has an impact on the expected return of assets in emerging markets (Bekaert, Harvey, & Lundblad, 2007). It becomes central to understand how liquidity affect Green bonds as an emerging market for fixed income.

The thesis aims to investigate the liquidity effect on Green bond returns by applying common factor models from the asset pricing literature. The final results will be evaluated with the purpose to conclude whether liquidity affects the expected return of Green bonds.

Research questions and hypothesis

The thesis will address the main research question:

What effect does liquidity have on Green bonds expected return?

The thesis creates an empirical relationship between liquidity, from the idea of a liquidity premium derived from a narrow market, and expected returns on Green bonds. Liquidity is defined as how easily an asset can be traded on the market (Berk & DeMarzo, 2017). The most commonly used liquidity measure, bid-ask spread (Amihud & Mendelson, 1986), will be adopted as there is no single theoretical standard that captures bond liquidity in the literature. The expected returns will be conducted by using a common factor model from asset pricing theory. The thesis will not account for behavioural consideration or other non-financial factors for returns and merely focus on expected returns. The thesis acknowledges the existence of proven evidence between stock returns and liquidity established by Pástor and Stambaugh (2003). The intention is however to strengthen the relationship between fixed income returns and liquidity and most promptly the liquidity effect on Green Bonds.

The central hypothesis of the thesis is that liquidity has a significant impact on the expected returns of Green bonds. The hypothesis, which the thesis aims to address, is formulated as the following:

H_0: Liquidity has not a significant impact on the expected return on Green bonds

As liquidity changes over time in a dynamic setting, investors require a compensation for bearing the risk (Amihud, Mendelson, & Pedersen, 2006). Liquidity should therefore have an effect on the Green bond price, with a positive effect on the expected return. In other words, Green bond expected returns are positively affected by the liquidity measure, bid-ask spread. If liquidity shows to have a significant impact on the expected returns on Green bonds, it will confirm the general notion from Bekaert et al. (2007) that liquidity has an effect on the expected return of assets in emerging markets. This would spread the knowledge about the effect of liquidity and potentially reduce adverse selection costs, as liquidity is perceived as a transaction cost on the Green bond market. This aligns with Lin, You and Huang, (2012) findings that information asymmetry is positively associated with liquidity. Since both issuers and investors can address the liquidity exposure accordingly, this would improve investors' incentives to actually invest and issuers to minimize the information asymmetry by being more transparent about the financial information of the bond. This would consequently achieve a better mean of financing future Green projects that has both positive environmental and climate benefits.

Contribution

The thesis aims to investigate the liquidity effects on Green bonds expected return, thereby contributing to the on-going debate on sources of risk within the research body of Green bonds. As the results enlighten future investors about risk factors that hinder investments in Green bond markets. This holds true for issuers as well, since understanding the impact of liquidity, preventive actions to reduce adverse selection costs could be applied. The knowledge of this would potentially increase issuer's transparency and bring new investment to the market.

The liquidity effect on Green bonds expected return will be investigated through a liquidity proxy *(LIQ)* on buy-sell difference in conjunction with common factor models used in asset pricing theory. Thereby, contributing to research on fixed income within the body of asset pricing. The thesis intends to evaluate the parametric of the common factor models for fixed income returns, and to provide methodological evidence on liquidity effects on Green bonds to the research on fixed income returns. In addition, research on Green bonds is a rather new phenomenon and by so supports the marketing for and interest in this specific security type.

Outline

A reminder for the reader, the thesis is outlined as follows. Section 2 discusses the literature on climate change and financing needed, asset performance associated with liquidity and general asset pricing theory. Section 3 will outline the used asset pricing-, and regression models. Section 4 outlines the data collection process for Green bonds, descriptive statistics and the statistical variables applied in the analysis. Section 5 describes the analysis of the applied regressions and the interpretation of significant variables. Section 6 concludes the final remarks from the analysis and ends with a general discussion. In section 7, the authors' thoughts on further research and limitations of the research are presented.

2. Literature review

2.1 Climate Change and Financing Demand

It exists a common belief in society that the temperature of the planet will continue to rise from activities performed by industries and humans (NASA, 2018). The global warming is likely to reach 1.5°C somewhere between the years 2030 to 2052 if the temperature continues to increase in the same pace as before (IPCC, 2018). Making the already set Paris objectives of limiting the global warming of 2°C by year 2100 (Meyer zum Felde et al., 2018) even more difficult to achieve. The implications of missing the objectives would be enormous, as sustainable development becomes harder to achieve, this would consequently affect the chances of economic prosperity in the future (IPCC, 2018). The World Bank (2018) denotes that investments must reach about $90 trillion by the year of 2030 to retain a sustainable development, hence contributing to a new epoch of economic growth. Meyer zum Felde et al. (2018) address the same issue and imply $1 trillion per year until 2050 is required to be invested to limit the global warming. The negative effect of global warming from historical rapid growth from industries with an increased globalization has now made companies shift focus towards more environmentally responsible investments (Chariri, Bukit, Eklesia, Christi, & Tarigan, 2018). Park (2018) claims that over 70% of all mainstream institutional investors are considering sustainability as a central role in their investment plan, as investors are more aware of the consequences from increased global warming.

2.2 Liquidity and Asset Returns

Kidney, Giuliani and Sonerud (2017) state that expected returns and liquidity are two important factors for attracting new public investors into both equity and fixed income markets. This is brought up in earlier research by Chuhan (1994) who state that limited access of information and the size of the emerging market create inherent issues including adverse selection and illiquidity. A general notion in the research is that variation in liquidity is an important factor, where Bekaert et al. (2007) describe liquidity as a driver for expected return in emerging asset markets. They find support that liquidity is a priced factor that correlates with the expected returns (Bekaert et al., 2007). This was confirmed by the evidence shown in the research from Pástor and Stambaugh (2003) who find stocks that are more sensitive to aggregated liquidity have substantially higher expected returns. Further, Lo, Mamaysky and Wang, (2004) explain that liquidity has a significant impact on asset pricing of fixed income since liquidity creates an interest for the assets. This aligns with Amihud et al. (2006) who confirm that liquidity risk as a factor is priced and affects the return of the asset in equity markets. They find evidence on how liquidity pricing explains returns and that illiquidity creates a premium that consequently requires higher expected returns. Since liquidity changes over time, higher expected return is consequently demanded from investors. This is derived from investors demanding to be compensated for bearing the risk of the investment over a long time-period (Amihud et al., 2006).

2.3 Modelling Fixed Income Returns

The literature on pricing and modelling fixed income expected returns is in general far less extensive compared to the literature on equity, the same holds true for the limited literature on Green bonds compared to conventional bonds. Despite this, both asset classes share similar factors for estimating expected returns. This is confirmed by Fama and French (1989), who show that stocks and fixed income expected returns are correlated and move together.

In equity markets, the most commonly used model to compute for expected returns is the single-factor capital asset pricing model (Fama & French, 2004). Given its limited explanatory power from the single-factor capital asset pricing model for equity and fixed income markets, Fama and French (1992) extended the model to a three-factor capital asset pricing model. Beside the initial factor for market premium, two new factors were developed which proxy for size and value premiums (Fama & French, 1993). This substantially improved the quality of the initial model as it directed the relation to size of companies and respectively to the book-to-market equity ratio (Fama & French, 1993).

The three-factor capital asset pricing model for equity returns was then extended with two fixed income specific risk factors. Thereby, constructed an asset pricing model that considered the common risk and average returns for fixed income market, as for corporate bonds (Fama & French, 1993). The two bond specific factors proxy for the risks of unexpected increases in interest rate and for the default probability from changes in the underlying economic condition. The importance of a default factor was strengthened by Merton (1973) who found that default factor is a major explanatory variable for pricing fixed income assets. Chen, Roll and Ross, (1986) confirm that unexpected changes in interest rates have an essential part in excess returns. The research from Chen et al. (1986) became the basis for Fama and French (1993) research of unexpected changes in interest and expected returns for fixed income.

Carhart (1997) extended the initial Fama and French three-factor model (Fama & French, 1993) with a momentum factor to capture the effect composed by Grinblatt, Titman and Wermers (1995) research. Grinblatt et al. (1995) found that investments based on momentum strategies, by investing in existing market trends, significantly increased the performance in equity mutual funds and thereby increased the explanatory power of the model.

To test how multiple factors explain fixed income returns, cross-sectional fixed effect regressions were adopted. The procedure uses both time-series and cross-sectional regressions and is considered a viable approach to test asset pricing models with panel data (Wulandari et al., 2018; Fernandes, Fonseca & Iquiapaza 2018; Atiligan & Demirtas, 2013).

3. Methodology

3.1 Capital Asset Pricing Model

The Capital Asset Pricing Model (CAPM) was developed by William Sharpe and John Lintner (Fama & French, 2004) and is based on the model of portfolio choice from Harry Markowitz (1952). The models assume that investors are risk averse and only care about the mean variance of a one-period investment return (Markowitz, 1991). Investor's portfolio choice can therefore be considered a probability distribution from the two single parameters: expected value and standard deviation (Sharpe, 1964). To obtain the available mean variance of the efficient portfolios, investors use a combination of risk-free assets and a risky tangency portfolio (Fama & French, 2004). The CAPM formula can be represented from the following form:

$$E(R_i) = R_f + \beta_{iM}[E(R_M) - R_f)],\ i = 1, \ldots, N.\ , \qquad \textit{(Eq 1)}$$

where $E(R_i)$ conditions the expected return for assets *i*. R_f is the risk-free interest rate, R_M denotes the market return and R_M-R_f is the expected excess return on the market portfolio. β_{iM} is the coefficient that measures the correlation of stock returns with the excess return on the market portfolio (Fama & French, 2004).

3.2 Fama and French Three-Factor model

By the model introduced from William Sharpe (1964) and John Lintner (1965), where Fama and French (1993) subsequently introduced a three-factor model for expected returns. The model was derived due to the limited explanatory power of the single-factor CAPM for equity and fixed income markets. Importantly, this extended model was set to retain the common risk and average returns for fixed income, such as for corporate bond markets, as well as making the model a tool for measuring bonds expected return (Fama & French, 1993).

The Fama and French three-factor model can be represented from the following form (Fama & French, 2004):

$$R_{it} - R_{ft} = \alpha_i + \beta_{iM}(R_{Mt} - R_{ft}) + \beta_{is}(SMB_t) + \beta_{ih}(HML_t) + \varepsilon_{it},, \qquad \textit{(Eq 2)}$$

where the intercept α_i in the time-series regression is zero for all assets *i* as it capture more variation in average return for portfolios formed on size, book-to-market equity, and other price ratios; β_{iM} being the coefficient for the market exposure with R_{Mt}-R_{ft} as the excess market return by subtracting the risk-free rate from a market portfolio; β_{is} is the coefficient for the small effect on asset return with SMB_t account for the difference between the return on diversified portfolios of small and big stocks, being the size premium; β_{ih} is the coefficient for value effect on asset return with HML_t as the difference between returns on diversified portfolios of high and low book-to-market stocks, being the value premium.

Small minus big (SMB)

The size premium, small minus big (SMB) aims to reflect the risk in return in relation to the size of companies (Fama & French, 1993). The size factor is composed by creating three portfolios with small stocks (S/L, S/M, and S/H) and three portfolios with large stocks (B/L, B/M, and B/H) with the stock's market equity define the size (L, M, and H). The average return on this portfolio is the computed by the average return on three small portfolios minus the average return of three big portfolios (Fama & French, 1993). This means that one assumes the stock development in the long run to be positive and for small companies to be negative. The *SMB* can be represented from the following form (Fama & French, 1993):

$$SMB = \frac{R_{S/L}+R_{S/M}+R_{S/H}}{3} - \frac{R_{B/L}+R_{B/M}+R_{B/H}}{3}.$$

(Eq 3)

High minus low (HML)

The value premium, high minus low (HML) aims to reflect the risk in return in relation to book-to-market equity (Fama & French, 1993). The factor is composed by two value portfolios and two growth portfolios based on a book-to-market equity ratio. The average return in this portfolio is the difference between the average return on two high book-to-market equity portfolios (S/H and B/H) and two low book-to-market equity portfolios (S/L and B/L). The *HML* factor can be represented from the following form (Fama & French, 1993):

$$HML = \frac{R_{S/H}+R_{B/H}}{2} - \frac{R_{S/L}+R_{B/L}}{2}.$$

(Eq 4)

3.3 Carhart's Four-Factor Model

Carhart (1997) extended the initial Fama-French three-factor model (1993) by adding a momentum factor to capture the effect composed by Grinblatt et al. (1995). Grinblatt et al. (1995) found that investments based on momentum strategies increased the performance significantly than those excluding this factor. The so-called Carhart's four-factor model can be represented from the following form (Carhart, 1997):

$$R_{it}-R_{Ft}= \alpha_i+\beta_i(R_{Mt}-R_{Ft})+\beta_{is}SMB_t+\beta_{ih}HML_t+\beta_{iMOM}MOM_t +\varepsilon_{it,} ,$$

(Eq 5)

where MOM_t denotes the difference in returns between a high performing portfolio and a low performing portfolio under a time period at time *t*. Whereas, β_{iMOM} is the coefficient that measures the effect of the momentum strategy.

Momentum Factor

The momentum factor is the average return on two high portfolio returns minus the average on two low portfolio returns (French, 2019), which is consistent with the research from both Carhart (1997) and Grinblatt et al. (1995). The momentum factor is captured from the following form (French, 2019):

$$MOM=\frac{1}{2}(\text{Small High}+\text{Big High})-\frac{1}{2}(\text{Small Low}+\text{Big Low}).$$

(Eq 6)

3.4 Fama and French Extended Three-Factor Model

Fama and French (1993) indicated the relevance of common risk factors incorporated for both equity and fixed income returns in their paper. They showed that stock returns have shared variations since the stock market factors are linked to bond returns through shared variations in bond market factors. Fama and French (1993) therefore extended the three-factor model with two bond specific factors: *DEF* and *TERM*. As a result, this extended three-factor model helps to explain average return on both stocks and bonds. Further, research from Gebhardt, Hvidkjaer and Swaminathan (2005) find that shared market factors have almost no explanatory power for fixed income returns in the presence of bond specific factors. The Fama and French extended three-factor model with bond specific factors, related to fixed income market, can be represented from the following form:

$$R_{it}-R_{Ft}= \alpha_i+\beta_i(R_{Mt}-R_{ft})+\beta_{is}SMB_t+\beta_{ih}HML_t+\beta_i TERM +\beta_i DEF +\varepsilon_{it,}.$$

(Eq 7)

TERM

An important risk associated with bonds is the risk for unexpected increases in the interest rate, which the factor *TERM* takes into consideration (Fama & French, 1993). The factor consists of the difference between monthly return on long-term government bonds with maturity of five years or longer, and one-month Treasury bill rate measured at the end of the previous month. The one-month Treasury bill rate creates a proxy for the general level of expected returns, where *TERM* accounts for the deviation of long-term bond returns from expected returns due to the basis of increased interest rates (Fama & French, 1993). The *TERM* factor builds on the research from Chen et al. (1986) who describe how unanticipated changes in interest rates influence the price and the time value of future cash flow of an asset. As such, influence the expected return on fixed income assets.

DEF

The shift in the underlying economic condition of bonds changes the likelihood of default (Fama & French, 1993), which the *DEF* factor accounts for. The factor consists of the difference between the long-term return of government bonds and the long-term return on a market index of corporate bonds. The importance of incorporating the likelihood of default in bonds is strengthened by previous studies from Merton (1974). In evaluating bond returns the factors *DEF* and *TERM* in relation to other factors are the most important constellation (Fama & French, 1993).

3.5 Liquidity Modelling

The bid-ask spread is a natural measure of liquidity (Amihud & Mendelson, 1986; Conroy, Harris, & Benet, 1990) as it implies there exists a premium in form of the spread between the immediate buy and sell. This consists of the sum of the premium for buying and the concession for selling the assets (Amihud & Mendelson, 1986). In other words, the amount by which the ask price exceeds the bid price for either equity or fixed income assets. The relative bid-ask spread from one asset to another differ mainly due to the liquidity of each asset (Amihud & Mendelson, 1986). Yet, there are still limitations with the bid-ask spread measure. Chen, Lesmond and Wei, (2007) provide an estimation for liquidity by the LOT-measure that captures costs that may not be included in the bid-ask spread. This measure requires a return generating model that has not yet been defined by literature as well as zero return days to fully retain the liquidity effect. The authors has also proven that both the LOT-measure and the bid-ask spreads are positively correlated (Chen et al., 2007), hence the inclusion of applying both estimations are reduced. The thesis therefore assumes that expected returns for fixed income are affected by the liquidity measure, bid-ask spread.

The calculation of the bid-ask spread is computed in comparable approach to earlier research (Amihud & Mendelson, 1986; Conroy et al., 1990). The model can be represented from the following form:

$$LIQ = \text{Bid-ask spread}_i = \frac{\text{Ask price - Bid price}}{\text{Average of ask and bid price}},$$

(Eq 8)

where Ask price is essentially the highest price that a buyer is willing to pay for an asset and Bid price is the lowest price that a seller is willing to accept to sell the asset for. The Average of ask and bid price represents the average of the highest price and the lowest price that the parties are willing to accept.

The last extension, to be considered in the analysis, of the common factor model builds on the notion of Fama and French three-factor model (*SMB* and *HML*) with incorporated bond specific factors (*TERM* and *DEF*), momentum strategies (*MOM*) and the bid-ask spread as a liquidity proxy (*LIQ*). The model will be referred as to the "Liquidity model" and is constructed as following:

$$R_{it}-R_{Ft}= \alpha_i+\beta_i(R_{Mt}-R_{Ft})+\beta_{is}SMB_t+\beta_{ih}HML_t+\beta_i TERM +\beta_i DEF +\beta_{iMOM}MOM_t+\beta_{iLIQ}LIQ_t+\varepsilon_{it,}.$$

(Eq 9)

3.6 Panel Data Regression Model

For the regression procedures, a commonly known approach for identifying how multiple factors explain asset returns is to use fixed or random effects cross-sectional regressions. This approach has been adopted in several researches on expected asset returns (Wulandari et al., 2018; Fernandes, Fonseca & Iquiapaza 2018; Atiligan & Demirtas, 2013)[1]. Fixed and random effects regression models are applied for datasets arranged as panel data, where the basic regression model is captured from the following form:

$$y_{it}=x'_{it}\beta+z'_i\alpha+\varepsilon_{it},$$

(Eq 10)

[1]Fama-Macbeth two-step cross-sectional regressions (Fama & Macbeth, 1973) is perceived as the reference approach in the asset pricing literature. This approach was not adopted as the model leads to omitted variable from misspecification in the linear regression model for several variables.

where $z'_i\alpha$ is the heterogeneity or the individual effect; z_i contains a set of either group or individual specific variables with a constant term, which are used to keep these variables constant over time and to realize information across both time and space (Greene, 2003).

Fixed effects

The fixed effects model assumes that differences in the constant term of the model can capture differences across the units of the model (Greene, 2003). Each α_i is treated as an unknown parameter that will be observed (Greene, 2003). If z_i is unobserved but correlated with x_{it} for fixed effects, then the least squares estimator of the β will be biased, mainly due to an omitted variable (Greene, 2003). Although, if this condition holds, the fixed effect regression procedure can be represented in this following form:

$$y_{it}=x'_{it}\beta+\alpha_i+\varepsilon_{it}, \qquad \textit{(Eq 11)}$$

where $\alpha_i=z'_i\alpha$ embodies all observable effects and specify an estimated conditional mean for the model. The model for fixed effects uses the α_i as a constant group-specific term for the regression, thus the fixed effects refers to the correlation of x'_{it} and α_i. The term "fixed" explains that variables do not vary over time, not that is nonstochastic, which is a condition for the fixed effect regression model (Greene, 2003).

The approach of fixed effects regression for analysis of expected returns in connection to risk factors has been applied to several different researches in the asset pricing field. As with Fernandes et al. (2018) who examined the relationship between risk factors and fund performance. The approach has also been proven valuable for emerging asset markets as in the research from Atilgan and Demirtas (2013) that examined the downside risk and expected returns with different capital asset pricing models. The researchers Wulandari et al. (2018) applied the regressions procedure to the Green bond market when examined how the yield spreads are affected by a liquidity premium. In this sense the applicability of fixed effect regressions in order to investigate the expected return for Green bonds in conjunction to a liquidity risk factor could be perceived rational.

4. Data

4.1 Data Analysis

Investors of Green bonds are mostly considered as institutional investors such as pensions funds with a long-term investment approach. Hence, a common measure for fixed income returns are the use of yield-to-maturity in the bond liquidity literature (Houweling, Mentink, & Vorst, 2005). As this proxy accounts for current coupon income, realised capital returns until maturity, future cash flows and by so are forward looking. At the same time, research has already established a significant relation between liquidity and yield-spread for Green bonds (Wulandari et al., 2018). The thesis therefore compute returns as the realized price returns[2] since this is the reference approach in the general asset pricing literature. From here on, the thesis refer expected returns to price returns.

The thesis is not section to any specific geographical bond market, thereby intends to include the global Green bond market. For this reason, were inconsistencies in the dataset from differences in specific geographical market with non-trading days over-bridged by algorithms. The Green bond dataset was provided by Bloomberg Terminal and converted into U.S currency since roughly half of the bonds were listed in U.S dollars. The conversion ensures comparability and avoids negative influences by changes in exchange and inflation rates. Further, the initial sample is filtered for bias drivers in order to derive higher quality and robustness of the data, which is introduced in the next section.

Filtering process

The initial dataset of Green Bonds subsists of a total of 1022 bonds issued between 2010 and 2018, approximately an eight-year time period. As there is no agreed upon classification nor standard for Green bonds, the thesis adopted the "Green bond" tag in the Bloomberg database for the selection process. Bloomberg's definition of Green Bonds is introduced in the introduction section and consistent with the thesis overall expression of Green Bonds. The time period was revised due to the real growth in Green bonds started out in 2014 with the market only contributed with two Green bonds prior to 2014. This is clear when considering the historical overview of the issuance of Green bonds in Figure 1[3]. The revised time period was thus between the years 2014 to 2018. In

[2] Realized price returns were computed by logarithmic returns.

[3] Number of Green bond issues was retrieved with the adopted "Green bond" tag and active status for the stated time period from Bloomberg Terminal.

order to retain increased robustness in the dataset for Green bonds, the selection processes include removal of bonds with less than one year of data and duplicates[4]. The final dataset of 379 Green bonds had an average of 693 trading days.

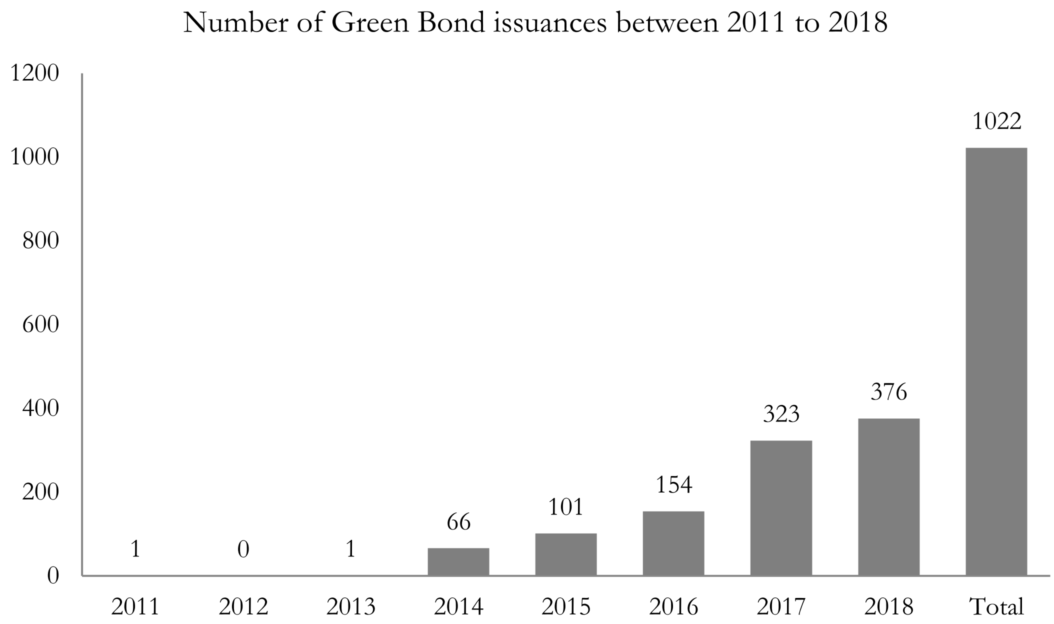

Figure 1: Number of Green bond issuance

Descriptive statistics

Table 1 provides the descriptive statistics of the Green bond dataset. After applying the selection processes the Green bond sample consists of 379 bonds over the time period from 2014-01-01 to 2018-12-31. The variable *RETURN* is the dependent variable, *MF, SMB, HML, MOM, DEF, TERM* and *LIQ* are the independent variables whereas*, AGE, CURRENCY, LISTED, RATING* and *ISSUED* are the controlling characteristics in the regressions. The descriptive statistics suggest that the dataset sample has an average price return of -0.004 and a standard deviation of 0.121 for Green bonds.

[4]The exact selection process was as the following: Step (1) opted Green bonds as defined by the Bloomberg Terminal tag, Step (2) choose security status as active for Green bonds. Step (3) and (4) adopted the global region and the revised time period 2014-01-01 to 2018-12-31. Step (5) and (6) considered the removal of Green bonds with less than one year of data and elimination of duplicates.

Table 1: Descriptive statistic for the dataset

Variable	Obs.	Mean.	Std. Dev.	Min.	Max.
DATE	262.980	21003.99	373.8149	19733	21549
SMB	262.980	-.0294	.504879	-1.66	2.5
HML	262.980	-.0217552	.5381852	-1.69	2.38
MOM	262.980	.0234155	.6816704	-3.13	3.64
RETURN	262.980	-.0040342	.0121043	-1.475594	1.186205
LIQ	262.980	.007219	.0400013	-.069704	1.997087
DEF	262.980	-2.38e-06	.0042193	-.0232235	.0265372
TERM	262.980	-.0038996	.0055196	-.0307213	.0245577
MF	262.980	-.0037687	.0074821	-.0512762	.0256744
BOND	262.980	196.6186	107.4551	1	379
RATING	262.980	1.31621	.464997	1	2
AGE	262.980	1.120834	.3259352	1	2
CURRENCY	262.980	1.495209	.499978	1	2
ISSUE	262.980	1.640657	.4798088	1	2
LISTED	262.980	1.536014	.4987022	1	2

In table 2, the correlation matrix for the variables in the dataset is provided and confirms the validity of the applied statistical variables in the regression. The statistical variables correlates with each other in different ways, hence the risk of regressions produce misleading and multicollinearity results are reduced.

Table 2: Correlation matrix for the dataset

	SMB	HML	MOM	RETURN	LIQ	DEF	TERM	MF	RATING	AGE	CURR	ISSUE	LISTED
SMB	1.0000												
HML	-0.1241*	1.0000											
MOM	-0.0846*	-0.3945*	1.0000										
RETURN	0.0008	-0.0157*	-0.0107*	1.0000									
LIQ	0.0015	0.0011	-0.0010	-0.0858*	1.0000								
DEF	-0.0120*	0.0948*	0.0179*	-0.1053*	0.0015	1.0000							
TERM	-0.0087*	-0.1474*	-0.0199*	0.2184*	-0.0081*	-0.7902*	1.0000						
MF	0.0060*	-0.0463*	0.0035	0.1402*	-0.0054*	-0.0341*	0.1848*	1.0000					
RATING	-0.0002	-0.0004	0.0008	-0.0050*	0.0047	0.0002	-0.0105*	-0.0082*	1.0000				
AGE	-0.0007	-0.0009	0.0029	-0.0112*	0.0282*	-0.0006	-0.0219*	-0.0188*	0.0960*	1.0000			
CURR	-0.0044	-0.0002	0.0015	0.0008	0.0548*	0.0019	0.0072*	0.0064*	-0.0716*	-0.0486*	1.0000		
ISSUE	-0.0003	-0.0006	0.0001	-0.0036	-0.0197*	0.0000	-0.0061*	-0.0042	0.3795*	0.0391*	-0.0433*	1.0000	
LISTED	0.0011	0.0026	-0.0029	0.0030	-0.0139*	-0.0001	0.0047	0.0046	-0.1119*	0.0969*	0.0014	0.1553*	1.0000

*Table 2 presents the correlation matrix for the full sample of 379 Green bonds observations. The correlations are shown as numbers whereas * is corresponding to a statistic significance level at the 0.1%.*

4.2 Statistical Variables

The statistical variables adopted were provided from Kenneth French's database-website (French, 2019) with exceptions for the bond specific factors, market factor and the bid-ask spread that were provided from Bloomberg Terminal. All of the variables were retrieved or converted into U.S dollars on daily basis in order to retain comparability with the Green bond dataset.

Fama and French factors

In the thesis, the market, size and value premium are considered the Fama and French factors and are computed in consistent with the research from Fama and French (1993). The size and value factors were constructed by six value-weight portfolios formed on size and book-to-market (French, 2019). The value premium, (*HML*) is the average return on the two value portfolios minus the average return on the two growth portfolios (French, 2019) and consistent with the paper from Fama and French (1993). The size premium, (*SMB*) is the average return on the three small portfolios minus the average return on the three big portfolios (French, 2019), which is also consistent with Fama and French (1993).

In the asset pricing literature, the excess market returns for equity and fixed income have been extensively discussed. Fama and French (1993) state that if integrated markets exist, one single market factor should be able to explain expected returns for both equity and fixed income assets. This is confirmed by the efficient market hypothesis (EMH) theory that claims that if the market is integrated all information should be reflected in the asset price (Malkiel, Burton, & Fama, 1970). The above argument contradicts the research establish by Elton, Gruber and Blake (1995) who state that an index of aggregated bond returns serves as the optimal market factor for a single factor model for fixed income returns. The thesis therefore adopted the latter and used the MSCI World Bond Index as the proxy for bond market portfolio to capture the variation in fixed income returns. The MSCI World Bond Index was collected from Bloomberg Terminal with daily prices. The market premium is computed as the difference between the market return and the risk-free rate on a daily basis.

Bond specific factors

In the thesis, the DEF and TERM factors are considered the bond specific factors in accordance to Fama and French (1993). The DEF is defined as the difference between the long-term return on a market index of corporate bonds and the long-term return of government bonds (Fama &

French, 1993). The thesis uses the Bloomberg Barclays US Corporate Total Return Value Index in order to proxy for the long-term return of corporate bonds, whereas the long-term return of government bonds is proxied by the 10-year Citi World Government Bond Index. The TERM factor consists of the difference between monthly return on long-term government bonds with maturity of five years or longer, and the one-month Treasury bill rate measured at the end of the previous month (Fama & French, 1993). The thesis uses the 10-year Citi World Government Bond Index to proxy for the long-term government bond return provided by Bloomberg Terminal, whereas the one-month Treasury bill rate, the risk-free rate, is provided from CRSP[5].

Risk-free rate

In accordance to Fama and French (1993), the thesis establishes the risk-free rate as the U.S one-month Treasury bill rate. This utilization makes sense as the Green bonds are globally distributed and roughly half of the bonds were listed in U.S dollars in the dataset. The risk-free rate is provided by CRSP database on a daily basis.

Momentum

The momentum factor is provided by Kenneth French's database-website (French, 2019) on a daily basis in U.S dollars. This is consistent with the research papers from both Carhart (1997) and Grinblatt et al. (1995).

Bid-ask spread

The bid-ask spread is calculated as the ask price minus the bid price divided by the average of both ask and bid price. The quotes on the bid- and ask prices for each bond were provided from Bloomberg Terminal on a daily basis.

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5 CRSP is an acronym for Center for Research in Security Prices.

4.3 Robustness

Econometric validation of the bond modelling

The dataset was revised with consideration to outliers that required a few adjustments. This task was executed with a conservative approach in order to not alter the regression outcome. In order to strengthen the robustness of the results, the model was tested for correlation between the errors and the regressors, by so compared fixed and random effects in accordance with Hausman (1978). The applied model was also tested for heteroscedasticity (Breusch & Pagan, 1979; Cook & Weisberg, 1983) and panel-level autocorrelation (Drukker, 2003; Wooldridge, 2002). As a result, all the applied parametric tests showed significant impacts, hence the model for Green Bond returns was constructed by fixed effect regressions with clustering standard errors on time which minimize the chances of unbiased results from heteroscedasticity and auto-correlations in the panel data[6]. As the thesis emphasize to observe changes in time for Green bonds expected return, no consideration was given on clustering on bond nor combined as this approach is perceived outside the framework of the thesis.

Portfolios based on credit ratings

A portfolio approach based on credit ratings was adopted in order to strengthen the estimated results, this is consistent with earlier asset pricing research of Fama and French (1993) that groups securities into different portfolios. The argument is that the market betas and expected returns interact equally in portfolios as in non-portfolios. Fixed income should therefore be priced with all available information on the market, hence no arbitrage profits can be made by structuring securities into portfolios or not. This is in line with the efficient market hypothesis theory, that a market is efficient when the security prices reflect all available information (Malkiel et al., 1970). The effect of grouping bonds into portfolios also reduces the problem of critical errors in variables (Fama & French, 2004).

The Green bonds were structured into three different credit rating-based portfolios with no consideration of plus or minus signs for the credit rating, which is consistent with the research paper from Fama and French (1993). The first portfolio consists of high graded (HG) Green bonds and was constructed with AAA and AA credit rated bonds, the second portfolio was based on low graded (LG) Green bonds which contains BBB and BB credit rated bonds and lastly a portfolio of

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[6] The regressions was executed in different step as follows: (1) Initial regressions with fixed effects and random effects regression models (2) Test whether fixed effects or random effects is preferable by the Hausman test (3) Test for autocorrelation by the Durbin-Watson test (4) Test for heteroskedasticity by the Breusch-Pagan test (5) Conditional treatment of heteroskedasticity and/or autocorrelation.

Green bonds with no credit rating (NA)[7]. The thesis does not account for the skewed distribution of credit ratings in each portfolio, nor the large amount of Green bonds that lack credit rating information, although there may exist internal ratings for these bonds. As this approach of constructing portfolios based on credit ratings are solely applied to strengthen the estimated results, hence the distribution and amount of available credit rating information did not affect the actual outcome. Table 3 display a summary of the different constructed portfolios.

Table 3: Summary of applied portfolios

Portfolio	Number of Green bonds	Credit rating
High graded (HG)	145	AAA+AA+A
Low graded (LG)	30	BBB+BB
No grading (NA)	204	NA
Total	379	

Control variables

To retain robust results on how liquidity impact fixed income returns, the thesis controls for characteristics such as *age, listed equity, currency, credit rating* and *initial issued amount*. The characteristics are defined as indirect liquidity measures and have been used in previous research on fixed income performance and liquidity by Houweling et al. (2005). A summary of the controlling variables with the expected relation to expected return of each control is presented in table 4 at the end of this section.

Age

Age has indicated to be a determined factor for liquidity as research has shown when bond gets older, a larger part of the amount issued are absorbed by investors with the interest of holding the investment for a longer time period (Houweling et al., 2005). As a result, when the trading volume decreases the liquidity of the bond will consequently decrease and stay illiquid until maturity. McGinty (2001), further state that newly issued bonds experience higher trading volume than older issued bonds. This is confirmed by Edwards et al. (2007) who state that recently issued bonds experience lower transaction costs and thus higher liquidity. Aligned with the research from Houweling et al. (2005), the thesis expects a positive relation between age and expected returns.

7 Credit rating information was collected directly from Bloomberg Terminal.

The highest premium was shown to be between four months and two years (Houweling et al., 2005), arbitrarily the thesis uses a threshold of fourteen months as the benchmark between young and old bonds. The expectation for this control variable is that newly issued bonds will experience higher liquidity and lower expected returns, older bonds will be more illiquid and experience higher expected returns.

Currency

Houweling et al. (2005) construct a proxy for currency with the prediction that bonds issued in large currencies, as EUR, are more liquid and hold lower yields. The main reason of this argument is that other bonds that are denominated in legacy currencies are relatively old, less known for investors and therefore harder to trade (Houweling et al., 2005). The paper by Houweling et al. (2005) accordingly state that currencies, which can be perceived as more prone to be traded with, are also more liquid. The thesis divides bonds into two groups with regard to this argument. Green bonds that are denominated either in USD, EUR or CNY, which amounts for 54% of the total sample, are comprehended as more liquid and the other currencies as more illiquid. This means that Green bonds denominated in USD, EUR or CNY are expected to experience low expected return, due to high liquidity and the other currencies to experience high expected return due to low liquidity.

Publicly listed equity

The research from Alexander, Edwards and Ferri (2000) state that firms whose equity is listed on the public market must disclose more private information than privately held firms. Hence, the cost of making a transaction in bonds of listed firms should thus be smaller. The thesis expects a firm whose equity is publicly listed is associated with bonds of high liquidity and low expected return, which is in line with Houweling et al. (2005) research.

Credit rating

Alexander et al. (2000) applied credit rating as a control variable in their research in order to measure for liquidity for a sample of bonds. They categorized the credit rating in a binary approach, where a high credit rating took the value of zero and low rating a value of one. Namin (2017) furthermore analysed the liquidity for bonds by applying credit rating. Bonds with lower credit rating and bonds that experienced a downgrading in credit rating traded with a higher bid-ask spread, meaning that these bonds were more illiquid. Bonds with higher credit rating traded more easily and are therefore more liquid (Namin, 2017). Aligned with Namin (2017) research, the thesis expectation is that Green bonds with high credit rating to be more liquid and therefore a negative relation to expected return, whereas Green bonds with low credit rating to be illiquid and experience a positive relation to expected return.

Initial Issued amount

The initial issued amount of a bond conveys an indication of its liquidity (Houweling et al. 2005). The initial issued amount functions as a trading proxy, where a large initial issue should trade in higher volumes and thus work as a proxy for liquidity. Large initial issues should hold lower transaction costs since more investors own the bond and subsequently made several analyses of the investment (Crabbe & Turner, 1995). This holds true for small initial issues as well as these bonds are subject to less analysis. Thereby, should small initial issues have higher returns since there may exist a liquidity premium (Houweling et al., 2005). Amihud and Mendelson (1991) further on claim that smaller initial issued amounts may be hold for longer time periods in investors' portfolios, thereby reducing the liquidity of the bond. Aligned with the research from Houweling et al. (2005) the thesis expects a negative relation between the initial issued amount on the fixed income returns, meaning that large initial issues should experience lower expected return due to high liquidity and small initial issues should experience high expected return since low liquidity. The thesis arbitrarily uses the average initial issued amount of $408.444.257 as the threshold between "large initial issues" and "small initial issues" for Green bonds.

Table 4: Summary of variables and expectations

Control variables	Expected relation to expected return
Age	Positive (+)
Currency	Negative (-)
Public listed equity	Negative (-)
Credit rating	Negative (-)
Initial issued amount	Negative (-)

5. Results and Analysis

This section opts to firstly analyse the comparison between applied capital asset pricing models and liquidity, to understand how liquidity effect Green bonds expected return from multiple models and to support the Liquidity model. Secondly, the Liquidity model is analysed in the aspect of liquidity and expected returns for Green bonds and followed by a controlling section. Lastly, the Liquidity model is applied and analysed in the aspect of credit rating-based portfolios in order to strengthen the estimated results from the Liquidity model.

5.1 Comparison Between Applied Models

Table 5 indicates that the initial CAPM model, CAPM three-factor model and Carhart's four-factor model generates approximately the same R-square (R^2) values, 0.079, 0.080, and 0.082, with only the market factor and liquidity as statistically significant. This provides an indication that adding new factors from the initial CAPM model does not increase the explanatory power for fixed income returns. In addition, the extended three-factor model with bond specific factors, *DEF* and *TERM*, shows to be statistically significant factors that drastically contribute to explain expected returns for fixed income. Since the R^2 value drastically increases from 0.080 to 0.277 when including the bond specific factors, as shown in table 5. This is consistent with the research from Gebhardt et al. (2005) who state that the market factor has almost no explanatory power for fixed income returns in the presence of *DEF* and *TERM*, hence the market factor only adds noise to the regression. This is clear when considering the estimated R^2 values by excluding both the Fama and French and Carhart's momentum factors from the Liquidity model as shown in table 6.

Table 5: Applied capital asset pricing models with liquidity proxy

	CAPM	CAPM THREE FACTOR	CARHART'S FOUR FACTOR	CAPM BOND SPECIFIC	LIQUIDITY MODEL	CONTROLLING
MF	0.208***	0.208***	0.209***	0.121***	0.120***	0.122*
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
HML		-0.000	-0.000*	-0.000*	-0.000*	0.000*
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
SMB		-0.000	-0.000	0.000	0.000	0.000
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
MOM			-0.000		0.000	0.000
			(0.00)		(0.00)	(0.00)
DEF				0.446***	0.447***	0.463***
				(0.03)	(0.03)	(0.03)
TERM				0.685***	0.687***	0.703***
				(0.03)	(0.03)	(0.03)
LIQ	0.231***	0.233***	0.231***	0.053***	0.053***	0.012***
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.00)
AGE						-0.000*
						(0.00)
CURR						-0.000
						(0.00)
LISTED						0.000
						(0.00)
ISSUED						-0.000
						(0.00)
RATING						-0.000
						(0.00)
Constant	-0.004***	-0.004***	-0.004***	-0.001***	-0.001***	-0.001***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
R-sqr	0.079	0.080	0.082	0.277	0.277	

Table 5 presents the coefficient estimations and significant levels for the different capital asset pricing models, CAPM, CAPM Three Factor, Carhart's Four Factor, CAPM Bond specific and Liquidity model based on fixed effect regressions. Cross-sectional regressions of the fixed effect approach are used with price returns of 379 Green bonds. MF is the market proxy collected from the MSCI World Bond Index in security prices that is used to approximate the market performance for fixed income and measure the risk-adjusted market excess. SMB is the size premium accounting for the size deviation while HML is the value premium that proxies for the value deviation. MOM proxies for the momentum in the market that takes into account the momentum deviation. The three factors are retrieved from the Kenneth

*French database. TERM accounts for the long-term bond deviation from expected returns caused by shifts in interest rates. It is calculated from the difference between of a long-term government bond return and the one-month Treasury bill. DEF proxies for the change in default probability due to changes in the underlying economic condition and is calculated as the difference between a portfolio of long-term corporate bonds and the long-term government bond return in consistent to Fama and French (1993). Lastly, the controlling regressions is introduced. The coefficients are shown as numbers whereas the robust standard errors are shown in the parentheses. *, ** and *** are corresponding to a statistic significance level at the 0.1%, 1% and 5%.*[8]

Table 6: Comparison between including and excluding market factors

	Liquidity model with all dependent variables	Liquidity model with bond factors
MF	0.120*** (0.01)	
HML	0.000* (0.00)	
SMB	0.000 (0.00)	
MOM	0.000 (0.00)	
DEF	0.447*** (0.03)	0.496*** (0.03)
TERM	0.687*** (0.03)	0.739*** (0.03)
LIQ	0.053*** (0.01)	0.079*** (0.01)
Constant	-0.001*** (0.00)	-0.001*** (0.00)
R-sqr	0.277	0.254

*Table 6 presents the coefficient estimations and significant levels for the Liquidity model with two different approaches. The first approach takes into consideration the Liquidity model included with all variables whereas the second Liquidity model does only account for the bond specific factors and the LIQ variable. The coefficients are shown as numbers whereas the robust standard errors are shown in the parentheses. *, ** and *** are corresponding to a statistic significance level at the 0.1%, 1% and 5%.*

In terms of explanatory power, it is clear that the initial CAPM from Fama and French (1993) increases in explanatory power by extending the model with the bond specific factors. Hence, it can be concluded that the Liquidity model is feasible to adopt as for modelling bond returns. The Liquidity model was used both on the rating-based portfolios and the non-portfolio approach in a way to reduce potential biases and strengthen the reliability of the estimated results.

[8] Regressions with control variables were estimated by random effect regressions as the regressions for fixed effects drops time-invariant variables. At the same time the findings are consistent with all applied regression models, hence the validity of the results should not be perceived as compromised.

The R^2 of the Liquidity model is estimated to 0.277, which is not comparable to the R^2 value derived from Fama and French (1993) research. The Liquidity model can explain a decent amount of the underlying movement in the daily price returns for Green bonds. The R^2 of 0.277 for the whole sample period leads to the outcome that there are still unobserved factors which the applied model did not account for. This is most likely related to specific risk factors associated with either the issuers and investors, or changes in the economy. As unobserved factors may influence the outcome of the results, these unobserved factors need to be identified and observed in order to improve the applied model. However, the results obtained are consistent with Fama and French (1993) in terms of statistically significant values for market and bond specific factors.

5.2 Liquidity Model

Table 5 shows the results after tuning the cross-sectional fixed effect regression estimation for the Liquidity model as previously specified in the literature review. The main variable of interest, *LIQ,* appear to be significant at the 1 percent level of significance with a corresponding positive coefficient of 0.053 and robust standard errors of 0.01. This suggests that liquidity does in fact effect the expected returns for Green bonds over the whole sample period. This is strengthened as the *LIQ* variable is shown to be statistically significant at 1 percent level with consistent positive coefficient estimations from 0.231 to 0.233 for all applied capital asset pricing models as well. This suggests that liquidity, in terms of bid-ask spread, shows consistent results over multiple capital asset pricing models and robustness in the overall estimations. In addition, the positive magnitude of the *LIQ* coefficient in the Liquidity model is considered rather small and drops from 0.231 to 0.053 in comparison to the other capital asset pricing models. This change in the *LIQ* coefficient is inevitable when including additional statistical variables and promptly explanatory variables as *DEF* and *TERM* into the regression model. As these variables have been shown in earlier research to have substantial explanatory power on fixed income returns (Gebhardt et al., 2005). The change in the *LIQ* coefficient also strengthens the assumption that bond specific factors explain most of the underlying returns for fixed income. This assumption appears clearer from the positive coefficients of 0.447 for *DEF* and respectively 0.687 for *TERM* in the Liquidity model. The large coefficients for bond specific factors were explained in earlier research of Fama and French (1993) who found that these variables dominated the explanation on the variation of fixed income returns. Hence, the bond specific variables should have a higher explanatory power for Green bonds expected returns as well, which is consistent with the argumentation in the previous section. The factors *HML, SMB,* and *MOM* provide zero coefficients with only *HML* as statistically significant at a 0.1 percent level of significance. This result is reasonable as these variables are all constructed upon equity data. The option of constructing these variables from fixed income data could potentially improve the estimated results since it would retain greater consistencies in the dataset. The thesis leaves out this alternative approach to the research field to be answered.

It could be noted that the *LIQ* coefficients from 0.231 to 0.233 are substantially higher in the models CAPM, CAPM three-factor model and Carhart's four-factor model in comparison to the Liquidity model. This potentially suggests a greater importance for this liquidity measure, bid-ask spread, in less advanced expected return models for fixed income. This indicate that potentially other liquidity measures than the bid-ask spread might be considered more suitable in terms of explaining liquidity and expected returns for Green bonds. This is due to the relatively small estimated *LIQ* coefficient of 0.053 in the Liquidity model and the change in coefficient by the inclusion of bond specific factors.

The overall results indicate a potential trend of liquidity, in terms of bid-ask spread, having a positive effect on Green bond expected returns. The initial hypothesis that liquidity has a significant impact on the expected return on Green bonds can thereby not be rejected. The finding of a suggested pattern of liquidity has a significant effect on Green bond returns is consistent with Bekaert et al. (2007), who found that liquidity has a significant effect on asset returns in emerging market. The pattern shows that the *LIQ* coefficient is consistently positive over all the applied pricing models which aligns with the research by Amihud et al. (2006) who state that investors require a compensation for bearing the risk of holding the investment over a long period of time. The pattern is also consistent with the finding from Wulandari et al. (2018), who find that bid-ask spread as a measure for liquidity has a significant impact for the yield spread of Green bonds. The same interpretation that bid-ask spread has a significant effect can be applied on price returns for Green bonds accordingly. Although the results do not provide any definitive evidence for this last interpretation holds true.

Controlling characteristics

After controlling for*, age, currency, public listed equity, credit rating* and *initial issued amount* variables, the estimated results indicate that liquidity, in terms of bid-ask spread measure, still continues to have a positive effect on expected returns for Green bonds. Although the positive coefficient for the main variable of interest, *LIQ,* appears to drop from 0.053 to 0.011 when including all control variables in the regression. This is shown in table 5 in the previous section. This result is inevitable as the control variables are based on alternative liquidity properties which aim to mimic liquidity effects on the Green bond market, hence reduces the actual effect of the liquidity variable, *LIQ*. The overall estimated results with positive *LIQ* coefficients align with the results from the previous sections and in this sense can be assumed to be robust. It is further shown that only the control variable *Age* had a statistically significant value at a 0.1 percent level of significance with a corresponding negative coefficient. The negative coefficient that indicates negative impact on the expected returns for Green Bonds is not consistent with Houweling et al. (2005) finding. This can be explained as the highest premium for *Age* was shown to be between four months and two years in Houweling et al. (2005) research. As the issued amount during the time period 2017 to 2018 includes 699 Green bonds, which is more than half of the total sample 1022. The extensive amount of newly issued bonds over the last two years potentially explains the negative coefficient from higher liquidity in Green Bonds. It could be noted that three (*Currency, Initial issued amount* and *Credit rating)* of the remaining four control variables follow the thesis expectations regarding relation to expected returns. This could therefore be perceived as further robustness of the estimated results. The thesis leaves out the interpretation of these remaining control variables, with no statistical significance, for the research field to observe and answer.

5.3 Liquidity Model with Rating-Based Portfolios

In terms of applying the Liquidity model to different credit rating-based portfolios, generates consistent results for the effect of liquidity on Green bonds expected return. The *LIQ* variable is shown to be statistically significant at a 1 percent level of significance for the portfolios HG and LG, and with a statistical significance at a 5 percent level of significance for the NA portfolio. All three portfolios show consistent results with a corresponding positive *LIQ* coefficient of 0.047 (HG), 0.075 (LG) and 0.051 (NA). The estimated differences in results between the portfolios HG and NA could be interpreted as higher risk, from no credit rating, and should be compensated with higher expected returns. As shown from a higher estimated *LIQ* coefficient for the NA portfolio compared to HG portfolio. The increased *LIQ* coefficient of the LG portfolio in comparison to the NA portfolio convey inconsistency with the compensated expected returns, since the *LIQ* coefficient is higher for portfolio LG than portfolio NA. This indicate that the portfolio LG is risker than NA, even though credit rating exists and should not be compensated for additionally. This inconsistency could potentially be explained by the Green Bond market being emerging and investors have not effectively incorporated all available information as credit rating, hence information asymmetry on the market.

The found pattern of a positive *LIQ* coefficient of 0.053 in the Liquidity model, from the previous section, is consistent with the rating-based portfolios *LIQ* coefficients from 0.047 to 0.051 and with the estimated *LIQ* coefficients from 0.231 to 0.233 for the different capital asset pricing models. Although the estimated *LIQ* coefficients are directly different in size of effect, the positive effect on Green Bonds expected price return consequently remains and should be perceived as comprehensible evidence. In addition, the *MF*, *TERM* and *DEF* factors all remain statistically significant throughout the rating-based portfolios, the Liquidity model and in the capital asset pricing models. This suggests robustness in the overall modelling for Green bonds expected price return.

By composing Green bonds into rating-based portfolios seems to strengthen the explanatory power in comparison to the $R^2$of 0.277 for the Liquidity model. The portfolios HG and LG extensively improved the R^2 to 0.314 and 0.372 respectively. This can be compared to the NA portfolio that possess a lower R^2 of 0.241, which suggests a potential information deficiency between rated and unrated Green bonds on the market. This is in line with Cochu et al. (2016) finding, that investors with sufficient credit information for bonds will easier be able to make a correct investment decision. Investors' perspective of assessing Green bonds credit quality could potentially be perceived rather binary than categorical between e.g. AAA to C credit ratings for Green bonds expected return. As the portfolios HG and LG that possess credit rating information holds higher explanatory power than the portfolios with no credit rating information, NA. Consistently, the portfolio LG holds a higher explanatory power than the HG portfolio that has higher credit ratings, which indicates the rather binary effect of credit rating for Green bonds.

Table 7: Rating-Based Portfolios with Liquidity Model

	Rating-Based Portfolios			Non-Portfolio
	HG	LG	NA	LIQUIDITY MODEL
MF	0.100***	0.078***	0.144***	0.120***
	(0.01)	(0.01)	(0.02)	(0.01)
HML	0.000	0.000*	0.001*	0.000*
	(0.00)	(0.00)	(0.00)	(0.00)
SMB	0.000	0.000	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
MOM	0.000	0.000	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
DEF	0.481***	0.530***	0.403***	0.447***
	(0.03)	(0.03)	(0.03)	(0.03)
TERM	0.734***	0.767***	0.634***	0.687***
	(0.03)	(0.03)	(0.03)	(0.03)
LIQ	0.047**	0.075**	0.051***	0.053***
	(0.02)	(0.03)	(0.01)	(0.01)
Constant	-0.001***	-0.001***	-0.001***	-0.001***
	(0.00)	(0.00)	(0.00)	(0.00)
R-sqr	0.314	0.372	0.241	0.277

*Table 7 presents the coefficient estimations and significant levels for the Liquidity model based on rating-based portfolios with fixed effect regressions. The first section of portfolio HG represents high-rated bonds, portfolio LG of low-rated bonds, portfolio NA that represents bonds with no rating and lastly the Liquidity model is included as a reference approach. Further on, cross-sectional regressions of the fixed effect approach are used with price returns on the 379 Green bonds. MF is the market proxy collected from the MSCI World Bond Index in security prices. This index is used to approximate the market performance for fixed income and measure the risk-adjusted market excess. SMB is the size premium accounting for the size deviation while HML is the value premium that proxies for the value deviation. MOM proxies for the momentum in the market that takes into account the momentum deviation. The three factors are retrieved from the Kenneth French database. TERM accounts for the long-term bond deviation from expected returns caused by shifts in interest rates. It is calculated from the difference between of a long-term government bond return and the one-month Treasury bill. DEF proxies for the change in default probability due to changes in the underlying economic condition and is calculated as the difference between a portfolio of long-term corporate bonds and the long-term government bond return in consistent to Fama and French (1993). The coefficients are shown as numbers whereas the robust standard errors are shown in the parentheses. *, ** and *** are corresponding to a statistic significance level at the 0.1%, 1% and 5%.*

6. Conclusion

In the presence of the Paris objective and the extensive amounts of funds actually needed to limit the global warming to 2°C by the year 2100 (Meyer zum Felde et al., 2018). The Green bond market seems to positively increase and receive more attention from a broader audience. Despite this market growth and that more capital is allocated towards sustainable investments by either regulatory (Inderst et al., 2012; Cochu et al., 2016) or from a sustainable demand from stakeholders (Chariri et al., 2018; Park, 2018; EY, 2016) the inevitable criterion for investments in securities still remain financial returns.

The potential of Green bonds as a way to fund new Green projects, should be considered commonly adopted in the field, however the performance of this security type still remains limited in terms of empirical evidence. The thesis therefore investigated whether liquidity had an effect on Green bonds expected return. The hypothesis going into the study was that liquidity has a significant effect on the expected returns for Green bonds. Since investors require a compensation for bearing the risk (Amihud et al., 2006) that would confirm the research from Bekaert et al. (2007) that liquidity has an effect on fixed income in emerging markets. This knowledge about the liquidity effect could therefore reduce adverse selection costs on the Green bond market, as the level of information asymmetry has shown to be positively associated with liquidity (Lin et al., 2012). The thesis employed the bid-ask spread as a measure of liquidity and found a pattern that the measure is significant to price return on Green bonds. Even after controlling for characteristics such as *age, currency, public listed equity, credit rating* and *initial issued amount* the trend indicated a positive effect. Thereby, suggest that liquidity has a positive effect on expected price returns for Green bonds. The findings could potentially reduce the information asymmetry and lower the transaction cost on the Green bond market, since both issuers and investors can address the liquidity exposure accordingly. Hence, achieve a better mean of funding for future Green projects that have positive environmental and climate benefits that aligns with the Paris objective.

The key contributions of the thesis are as follows: firstly, the analysis suggest that liquidity, in the terms of bid-ask spread, does in fact have a positive effect on expected price returns for Green bonds. Secondly, extending the asset pricing literature for modelling in a fixed income environment with the inclusion of a bid-ask spread. Lastly, confirms the general notion in the research field that the market factor has almost no explanatory power for fixed income return modelling in the presence of the bond specific factors, *DEF* and *TERM*.

7. Discussion and Further Research

All in all, the findings of this research do provide new insight on the fundamentals of the Green bond market that needs to be addressed accordingly. It implies that an increased awareness of different parties in the market is necessary to enhance the transparency. It could be noted a presumably high correlation of 0.379 between the variables credit rating and initial issued amount for Green Bonds. The argument of high correlation is in comparison to the other control variables impact. This suggests that firms are ought to find ways to achieve higher credit ratings, which could potentially increase the size of the initial amount issued. This is supposedly most critical when firms are new entrants on to the Green bond market. As liquidity and credit risks impedes the actual growth of the Green Bond market, as indicated with the size of the initial amount issued, which consequently will affect the actual funding size for future Green projects.

Additionally, regulatory bodies have a crucial role in this process by retaining a more active and proactive stance regarding the on-going debate of Green bonds and establish a global recognized classification for Green bond investments. This could potentially reduce information asymmetry and lower transaction costs from an increased transparency of the risk profile of green investments among parties active on the Green Bond market. This clarifies the importance and therefore opts for a clearer definition of Green bonds classification with an increased reporting quality of green project risk profile in order to enhance the supply of Green bonds on the market.

Lastly, since liquidity has a positive effect on price returns for Green Bonds, it could theoretically give rise to practical implications as well. As the liquidity effect emphasizes that issuers should reveal more sensitive information about their Green projects to increase liquidity and lower transaction costs on the market. Investors could with new available information adjust their risk profile accordingly and control for these risks when calculating future price returns and duration, hence increase the liquidity on the market. As a result, this could potentially lower the coupon rate for the Green bonds, from increased liquidity and compensate investors with a smaller amount of interest. Thereby, have an effect on the actual funding size when issuers have more funds to allocate towards Green projects.

Even if substantial efforts have been considered to create representativeness of the data and robustness in the methodology, the findings are subjected to limitations. Limited in the sense of data availability and the applicability for only the considered time sample. This occurs inevitably for empirical research on emerging markets.

It is still possible that the estimated positive effect of liquidity for Green bonds is due to other variables unobserved in this study. The relatively small coefficient for liquidity is found to be consistent for all capital asset pricing models and suggest that other measures than bid-ask spread could be considered more suitable. This asks for the inclusions of further observing other measures for liquidity, for example LOT-measure, in order to create additional insight into the underlying fundamentals of Green bonds.

An optional approach to observe the expected returns for fixed income, while accounting for liquidity, is the use of Fama-Macbeth two-step cross-sectional regression procedure (Fama & MacBeth, 1973). As this approach is perceived as the reference approach in the asset pricing literature, it is therefore of interest to confirm the estimated results from this study. Thereby, strengthening the robustness of the finding in this thesis by the inclusion of an additional regression procedure.

Fixed income returns are found to be related to the risk of default, which is both shown in this thesis and previous research (Merton, 1974; Fama & French, 1993). As this study did not account for any defaulted bonds in the dataset makes the inclusion of defaulted bonds interesting to observe. Since these defaulted bonds could potentially uncover other inherent risk characteristics for liquidity of Green bonds. This would increase the total sample for Green bonds, strengthen the findings, and contribute to the research area of fixed income returns.

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