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The Liquidity Risk Effects on Green Bond Yield Spreads

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Abstract

This paper tests the impact of liquidity effects on green bond yield spreads while controlling for credit risks, bond-specific characteristics and macro economic variables. For the sake of accuracy, the analysis focuses on 94-fixed coupon EUR/USD denominated corporate green bonds. By employing the bid-ask spread, percentage of zero-trading days and Amihud's illiquidity as liquidity proxies, this paper finds evidence consistent with the hypothesis that liquidity indeed does have a significant impact on the green bond yield spreads. Furthermore, to avoid any chance of endogeneity bias, a simultaneous equation model is applied, assuring that the obtained results are robust. This outcome urges issuers of green bonds to improve their liquidity levels in order to tighten their green bond yield spreads which in turn will reduce the risks associated with the issuance of green bonds while simultaneously increasing the confidence among investors.

Keywords:
Green Bonds, Liquidity, Risk, Yield, Corporate

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1.Introduction

Demographic change, increasing natural resource demands and urbanization have had critical roles in the enhancement of climate change at a global scale (Satterthwaite, 2007). The resulting climate change-generated hazards carry uncertainty about the magnitude, timing and distribution of climate impact (Wiltshire, 2014). This presents a challenge for governments and private entities and thus increases the significance of taking environmental aspects into account. A major step towards greener economies was taken in 2015, by establishing the Paris Agreement, which sets out a global action plan to deal with the threat and impacts of climate change (United Nations, 2015). Furthermore, governments, companies and investors are becoming increasingly aware of the future environmental impacts of their actions and have therefore started to adapt their legislation processes, business models and investment strategies accordingly.

However, these measures are likely to be inadequate in order to realize the desired environmental policy objectives in sectors such as agriculture, transport and energy according to official expert bodies (Zuckerman & Varadarajan, 2012). This is predominantly due to the fact that green technologies require investments of considerably large sizes early on in the development stage. Because of this, the average traditional investor might perceive that green projects are riskier ventures as compared to conventional investments, and not always commercially viable (Lam & Law, 2016). This cost gap between conventional and green investments has been justified and filled by the public sector up to a certain extent through policy-support measures. In the long run however, financing green investments via public institutions will not be feasible considering the current economic climate (Murray, Cropper, Chesnaye, & Reilly, 2014). An alternative source of green finance would be to initiate green bonds, a more private initiative, which is regarded as a tool that could help source renewable energy, transit systems and water infrastructure for the public sector, but more importantly incentivizing the private sector to take a more active role in this industry (International Finance Corporation, 2016).

1.1 Motivations and Purpose

From the perspective of the market, which includes both the issuer as well as the investor, there are potential benefits from investing in green bonds. An issuer's motivation can be due to financial and marketing reasons. As will be explained in further sections, issuing green bonds could lead to cheaper financing, but also promote the company as a socially responsible firm, eventually creating a bigger market for the firm's bonds. Traditional investors are mainly concerned with returns. In a world where investors have started to place a significant price on environmental risks however, portfolios that are largely invested in carbon-intensive industries are penalized. Hence, the growing impact of carbon risk exposure on portfolios can be costly. Investors that are keen on including green bonds in their portfolios not only take the return factor of their investments into account, but care for the long term performance of the green projects they fund. Such investors are clearly aware of the fact that they can decarbonize their portfolios by means of diversification through green bonds, which eventually may provide protection versus a bond portfolio that does not take environmental factors into account.

The transition to low carbon development and climate resilient growth has resulted in development banks, governments and private companies to raise capital for green investments, mainly through green bonds (Kidney, Giuliani, & Sonerud, 2017). It is estimated that a total of USD 53tn in green investments are necessary by 2035 to keep global temperature rise this century below 2 degrees Celsius (Boulle, Frandon-Martinez, & Pitt-Watson, 2016). The current rate of investment however is much lower than this, which creates urgency among governments, other policy makers and private institutions to increase such investments. The underinvestment is firstly due to a lack of transparency between the green bond issuer and potential investors, because of which investors are incapable of assessing the risk profile of investment in green bonds. Secondly, as of now, the ratings of green bonds still heavily depend on the balance sheets of the issuing firms rather than the performance of the green investments. Furthermore, investments in green projects are still a relatively new concept. Thus, such projects are still in the experimental phase and issuers associated with these projects are considered less mature. Combining the fact that the performance of green projects are not taken into account while rating the bond and that the projects that are financed with these bonds are less mature, issuers of green bonds are perceived as less mature firms with an unclear risk profile of green bonds and ultimately having a higher credit risk.

Since the investment in green bonds (from both issuer as well as investors perspective) is considered to be risky, the purpose of this thesis is to understand the source of risk in the green bond market. In the case of bonds, the level of risk is translated into the yield spread of the bond, that is, the spread of the bond in question over its government benchmark. Many believe that the default risk determines this yield spread, however the default risk can be seen as an exogenous source of risk as it also hugely depends on operating policies that are heavily influenced by economic circumstances (Utz, Weber, & Wimmer, 2016). The yield spread however, also has a non-default component, namely liquidity. Since liquidity is mainly associated with transaction costs and adverse selection of private information of market participants this can be regarded as a more endogenous source of risk (Bekaert, Harvey, & Lundblad, 2007). There are several researches that have concluded that default risk alone does not explain variation in bond yield spreads. Since, green bonds are still a relatively new concept, and credit ratings are only based on information from the balance sheet rather than the underlying projects itself, it would be fruitful to analyze the non-default component of the yield spread.

1.2 Research Question and Hypothesis

The main question that is proposed to address in this thesis is:

Does liquidity have a significant effect on the variation in the green bond yield spread?

In order to answer this question, this paper tries to establish a more empirical relationship between liquidity and green bond yield spreads. In this thesis, liquidity is defined as the action of trading liquidity with ease. Trading costs, information asymmetry, search friction, inventory risk and adverse selection costs result in illiquidity (Amihud, Mendelson, & Pedersen, 2005). The liquidity measures that are employed in this thesis are the bid-ask spread, percentage of zero- trading days (%ZTD) and Amihud's illiquidity measure (ILLIQ) While the former is a more commonly utilized measure of liquidity, the latter two are being applied more often as liquidity proxies across multiple empirical studies.

The maintained hypothesis is that liquidity does have a significant impact on the green bond yield spreads. According to theory, investors require compensation for bearing risk, thus when this holds, costs of illiquidity should affect bond prices through a positive effect on the yield spreads. If liquidity proves to have a significant effect on green bond yield spreads, issuers have a wider scope of solutions to reduce their risk exposure, besides only looking at decreasing the default risk. Analyzing a comprehensive sample of green bonds, this thesis finds that liquidity measures are significantly positively related to the green bond yields spreads when credit rating data is included in the regressions. A 1 percent increase in the %ZTD or ILLIQ measures lead to an increase in the yield spreads with 95.42 and 287 basis points respectively. Therefore, a company's exposure to risk is not solely determined by external factors, such as default risks. Issuers can take matters into their own hands, change internal factors regarding their operations and improve their liquidity status, by which they will be capable of acquiring larger funds that they can dedicate to green investments.

This thesis contributes to the debate on the sources of risk within the green bond market, which are currently still rather ambiguous. By knowing the risk factors that hamper investment in the green bond market will be able to effectively reduce barriers that exist within this market and issuers can reduce their sources of illiquidity and ultimately achieve cheaper means of financing with green bonds.

1.3 Outline

The remainder of this paper is organized as follows. Section 2 discusses previous literature on green investing and bond theory, section 3 describes the elimination process through which the green bond dataset is constructed and analyzed. Section 4 presents the regression results and cross checks for any potential endogeneity bias. Finally, section 5 concludes.

2. Theoretical Background

In essence, a green bond is a security that, in addition to its characteristics of conventional bonds, is designed to finance projects that offer environmental benefits (The World Bank, 2015). Theoretically speaking, the only way green bonds will be widely accepted as a source of renewable energy project financing is if this debt instrument is modeled on existing ‘vanilla’ bonds as accurately as possible (Mathews & Kidney, 2012). In order words, the structural features of green bonds must be in line with those of conventional bonds. It speaks for itself that in order for green bonds to succeed, the investors of such bonds need to make a return while exposing themselves to a level or risk that does not exceed that of a conventional government and corporate bond market. Therefore the energy projects, which are financed with the proceeds of the green bonds, need to be capable of generating a sustainable and regular income stream by which means its investors will realize their returns. The assets backing the green bond issues, in this case the renewable energy projects, need to be credible and government guaranteed, the same goes for conventional bonds (Bate, Bushweller, & Rutan, 2003). However, there is one striking difference with regard to green bond structures as compared to the ‘vanilla’ bonds they intend to mimic, the former favors a longer maturity whereas the latter associates longer maturity with higher risks. The main reason behind this is that initially, renewable energy projects entail huge amounts of investments and will therefore be at a loss-making stage in its beginning phase, however as time progresses these projects make higher profits as compared to fossil fuel energy projects (Mathews & Kidney, 2012). The trade-off lies between maturity and risk; from an investors point of view the longer the maturity, the more risk the investment entails. However, from a renewable energy project promoter’s perspective, the longer the time to maturity, the greater the chances are for revenues to overrule the initial costs that had to be made.

2.1 Evolution of the Green Bond Market

The green bond market kicked off in 2007 with a EUR 600 million Climate Awareness bond issued by the European Investment Bank (EIB) funding projects related to renewable energy and energy efficiency (IFC, 2016). Since then, the market has grown rapidly in OECD countries and has a current total value of outstanding green bonds of USD 295.23 billion, over half of which is issued by corporations and public entities according to the Green Bond Database. The main players in the green bond market can be classified in to five groups; issuers, underwriters, external reviewers, market intermediaries (such as stock exchanges), and investors. Multi-stakeholder initiatives and policy makers, also have a crucial part in the development of the green bond market as they intend to promote transparency and disclosure (Cochu, et al., 2016).

Corporates gain access to additional capital by issuing green bonds, while simultaneously investing in the green standards or their business. By doing so, many would expect that enhanced environmental performance would lead to higher profits. A much-cited study by Hart and Ahuja (1996) analyses the relationship between emission reductions and firm performance in the S&P 500 and indicates that investing in efforts focused on reducing emissions has a positive effect on the firm's financial performance with respect to cost advantages, higher efficiency and competitiveness. Cost reductions are a result of taking the environmental impact of their production into account. By paying attention to pollution prevention, waste reduction, energy savings, a firm improves its competitive position (Bacallan, 2000). A sample of leading ISO14001 certified companies in South Asia serve as proof that greener supply chains go hand in hand with better economic performance of firms. In addition to cost savings, greener supply chain management leads to a larger market share, more market opportunities and overall higher profit margins (Rao & Holt, 2005). Furthermore, improved environmental performance makes a firm less prone to accidents or legal sanctions, both of which reduce firm specific risk from a stakeholder's perspective (Sharfma & Fernando, 2008). Reducing risks leads to lower insurance costs and lower interest rates on debt. Consequently, this lowers the required return on capital and increases share value. Also, addressing environmental concerns of consumers could motivate them to purchase your products and services, which in turn increases revenues.

In order to determine whether green bonds have the capacity to enhance return value for investors, one needs to examine whether non-financial ESG data lead to better risk and return portfolio characteristics. In today's knowledge-based economy, impact factors are becoming more important in the evaluation of corporations (Volkov & Garanina). Four decades ago the business atmosphere placed a huge emphasis on tangible assets, in 1975 about 83 percent of S&P 500 market value was generated through plant, property and equipment (PP&E). In current times, the opposite holds, intangible assets are the main drivers of firm value through creation of brand awareness, intellectual property and disclosing a company's stance on social and environmental issues (Ocean Tomo, 2011). When intangible assets are the source of most of the value creation of companies, non-financial data are key factors that ought to be considered during the evaluation process of a company's stock. Non-financial data aids in assessing risks that sit outside of the company's balance sheet, but are critical to the financial performance. Therefore ESG ratings could lead to better investment decision-making and augments traditional financial analysis (Snider, 2016).

Issues such as climate change can have a direct financial impact on a company's performance if it fails to consider environmental and social risks. A research conducted by Breckenridge finds that investment managers are more capable of performing credit analysis and evaluate risk management by considering a broader array of risks; as a result the company now incorporates ESG factors into all its investment decisions. By integrating ESG factors into the investment analysis process, managers get a better sense of the quality and character of the corporate borrower (Breckinridge, 2015). Risk associated with management's operational decisions related to the environment could have a huge effect on portfolio performance. For example, companies that are largely dependent on natural resources can use this as a form of environmental protection. In the process, such companies reduce future costs while sustaining their reputation and most importantly avoid ratings downgrades. To illustrate this, take Statoil ASA, a Norwegian multinational oil and gas company. Considered as one of the front-runners in the carbon intensity industry, Statoil ASA manages to maintain their stance on the environmental front by dedicating themselves to spill prevention, emissions and environmental safety. Meanwhile, from a credit perspective, Statoil's financial leverage is one of the lowest in their respective industry with a net debt to total capitalization ratio of 10 percent (Breckinridge, 2015). Additionally, the same report examined the net income volatility of two groups: (1) the top 100 S&P 500 companies with regard to ESG ratings and (2) all S&P 500 companies. Results suggest that companies in group (1) show less volatility in their earnings as compared to the broader group (2). From a risk mitigation perspective, earnings stability and margins are credit fundamentals when managing investment-grade bond portfolios. An MSCI Ratings Analysis Report of October 2012 finds a low positive correlation between its ESG ratings and Moody's credit rating. The study found a calculated correlation of 0.34 between the two respective ratings, pin pointing on the fact that factors that were considered by ESG ratings were not necessarily incorporated by Moody's ratings of comparable corporate issuers. Fixed-income securities generally have maturities lasting from 5 to 10 years and therefore entail longer time horizon risks, which may not be accounted for by Moody's credit ratings. ESG issues might not have an immediate material impact, but will most likely have an effect on a company's ability to repay its debt in the long run (Snider, 2016).

With great growth potential within the green bond market, there sought to be more clarity considering the definitions and processes related to green bonds. Therefore, a set of guidelines framing the issuance of green bonds were introduced in 2014 known as Green Bond Principles, GBP (IFC, 2016). The GBP are framed by four core components (Use of Proceeds, Process for Project Evaluation and Selection, Management of Proceeds and Reporting) and mainly provide issuers with guidance on launching credible green bonds and aid investors by extending additional data for them to assess the environmental and social impact of their green bond investments. According to these guidelines, green bonds and conventional bonds should not be considered fungible as the latter does not align with the four main components of the GBP (ICMA, 2016).

The four main components of the GBP assist in ensuring the required transparency and accuracy of the information disclosed by issuers to the investors (ICMA, 2016). Firstly, the Use of Proceeds is a legal document that describes the utilization of the proceeds generated by the security. The document should provide the environmental benefits of the financed green projects, in quantitative terms where feasible. Furthermore, it is plausible that a share of the proceeds are used for refinancing, in such cases the issuers should estimate the share of the proceeds used for financing versus refinancing for each project portfolio. The GBP recognize several categories of green projects that are supported by the green bond market all addressing key areas of concern regarding climate change (ICMA, 2016). Such categories include, but are surely not limited to the following: renewable energy, energy efficiency (including the production of transmission), sustainable management of living natural resources (such as, sustainable agriculture) and climate change adaption (information support systems consisting of climate observation or early warning systems). The process for project evaluation and selection requires issuers of a green bond to outline how a project portfolio fits within the eligible green projects categories recognized by the GBP. In addition, issuers need to obtain an external review of the selected green projects. Green bond investors may also refer to the issuers profile and performance concerning environmental sustainability to assess the issuers' quality. The management of proceeds addresses handling of funds that await investment. An issuer ought to disclose the intended operations concerning the unallocated proceeds to its investors. The GBP encourage issuers to use external reviews such as auditors or other third party, to verify and track how the green bond proceeds are distributed amongst the existing funds. Lastly, issuers should have readily available up to date information on their proceeds for their reporting. One way to do this could be to provide a brief statement containing the main characteristics of a green bond portfolio and disclosing details regarding the project prospects and their environmental impact. Due to confidentiality agreements and competitive considerations the amount of information that can be disclosed will be limited, however the GBP recommends qualitative performance indicators where feasible.

As of June 2016 there were four types of green bonds, additional types may emerge depending on the development of the green bond market in the future: Use of Proceeds green bonds, revenue green bonds, project green bonds and asset backed green bonds (ICMA, 2016). The Climate Awareness Bond, issued by the EIB, is a clear example of a "use of proceeds" bond. This is a standard bond of which the debt re-course is entirely on the issuer (Climate Bond Initiative, 2017). In case the issuer is unable to satisfy the agreed upon debt obligation, investors have the right to the issuer's liquid assets. Revenue green bonds hold the revenue streams from the issuer as debt collateral, though fees, taxes etc. are the collateral for debt (ICMA, 2016). In the case of project green bonds the credit exposure is linked to a single project.

Therefore, the collateral is only in form of the project's assets and the balance sheet (ICMA, 2016). Finally, asset backed green bonds are collateralized bonds for which the collateral is a cohort of projects that have been bundled together. Majority of the green bonds issues are "use of proceeds" or asset backed green bonds (Climate Bond Initiative, 2017).

Despite the recent spike in growth, the green bond market remains just a small fraction of the total bond market. On that premise, development of the green bond market could be further stimulated with more support from the public sector. However, no entity is in complete accord on the extent to which the public sector can provide for support. For instance, take China's example, according to Tracy Cai, the Chief Executive Officer of Syntao Green Finance, a consulting agency that focuses on sustainable investments in alliance with financial institutions, green bonds constitute 2 percent of China's bond market (Hirtenstein, 2017). Furthermore, the People's Bank of China predicts that, on an average, USD 400 billion ought to be invested every year in order to solve issues regarding the environment and climate change (Climate Bond Initiative, 2016). The public sector will only able to cover 15 percent of the total capital needed, therefore private capital is vital.

2.2 Key Challenges

The green bond market faces several barriers to its further evolution and growth. According to the study on the Potential of Green Bond Finance for Resource-Efficient Investments conducted by the European Commission the following are some of the prominent ones (Cochu, et al., 2016).

1. **Lack of green bond supply**

As investors are becoming more aware of the environmental impact of their investments, the demand for green bonds is strong. However, at the present moment, the number of projects that are to be financed through green bonds are lacking. Thus, the supply of green bonds is not able to keep up with its demand. As stated in the study, bonds are primarily refinancing instruments, therefore a decent amount of capital needs to be easily available and ahead of time if necessary. In addition to the financing gap, there is also a lack of commercially well-identified green projects.

Even the issuance of green bonds increases, it is not certain whether the current demand for the securities will be able to be sustained. Majority of the green bond markets are still considered a niche, investors may refrain from investing as they perceive them as being less liquid than other assets. Furthermore, institutional investors require issue amounts exceeding EUR 200mln in order to be able to invest, currently green bonds are incapable of reaching such amounts.

2. **Lack of skills for aggregating small projects**

As previously stated, the sizes of green projects are too small to attract large institutional investors. The number of small green projects is however rising. Assorting several small projects into one big package or grouping cash flows stemming from asset-backed securities could potentially attract large investors. The challenge here is that financing institutions lack the ability to assess risks associated with the underlying projects in an adequate manner.

3. **Lack of green bonds definition and framework**

Currently, the GBP is a reasonably well-developed structure used to label green bonds. Nevertheless, it is a voluntary structure, this implies that there is no monitoring framework to ensure compliance and every nation is free to set its own standards. Since the definition of being "green" is not standardized, companies are prone to entering conflicts that may damage their reputation in case their interpretation of "green" is disputed. In the process, issuers who are very well capable of issuing green bonds may refrain from doing so. Additionally, the focus on Environmental Social and Governance factors could potentially lead to incremental costs to investors, asset managers and corporations. ESG commitment, reporting and analysis take time and resources to implement. This could drive a company's attention away from return maximization. A company also takes on the additional responsibility of reporting and is subject to more criticism (Desclée, Hyman, Dynkin, & Polbennikov, 2016).

4. **Lack of information and market knowledge**

A main hindrance to the green bond market development is the limited knowledge possessed by the green bond market participants, which can be traced back to the fact that there is a lack of a standardized definition and framework regarding green bonds in general. It is a challenging environment in which issuers face difficulties in obtaining favorable credit ratings and are uncertain when assessing green investments and their impacts as the green bond market still finds itself in its developing stages, Good credit ratings are however vital in order to attract large institutional investors, who in particular are bound to strict requirements regarding the qualitative assessment of the financial assets they invest it. Since many (potential) green bond issuers are less mature firms they will be granted lower credit ratings as compared to firms that have a long record of accomplishment in the general bond market. This hinders new market participants with innovational business models to obtain sufficient ratings and enter the bond market for financing.

5. **Unclear risk profile of green investments**

Green investments have their shortcomings in the sense that they are not yet at a stage at which they can disclose enough information regarding performance and are characterized by less mature technologies. Therefore, rating agencies and institutional investors consider the technology risk higher for emerging green investments than for conventional investments in more matured sectors. Many sustainable projects are still in the initial stages, therefore risk assessments is mainly based on the balance sheets of the issuing firms rather than on the projects itself. The lack of clear reporting by bond issuers and poor quality assessment by external reviewers both result in an unclear risk profile of green bonds.

2.3 Bond Theory

In order to increase the green investment rate, investors with a large asset base need to be incentivized to participate in the green bond market. Institutional investors hold the majority position as one of the key participants of the global bond market and own over 80 percent of institutional assets in middle-income countries, they have the resources required to drive and amplify green investments. As an investor, one is likely to invest in bonds that provide the highest return. Understanding the factors drive different bond spreads, gives an insight to why bonds perform differently from one another. In general, returns on the bond market are reflected with the risk involved with a particular bond investment. Investors ought to accept additional risk in order to earn higher returns. There is no clear consensus on which factor is mainly responsible for the credit bond spread, however academics do seem to agree upon the fact that this spread is not solely due to the default risk associated with a particular bond. Other factors that have high explanatory power over the observed credit spread are tax effects, risk premium and liquidity.

In brief terms, a bond, more formally classified as a fixed income security, is a debt instrument issued by public and private institutions in order to raise capital for their activities. In the most generic sense, bonds are issued with three essential components; maturity, which indicates the life of the bond, par value or principal, which is the amount the bondholder will be repaid when the bond reaches maturity and is determined at issuance, and the coupon rate, which is the percentage of par value that will be paid to bondholders usually on annual or semi-annual basis. Thus, bonds are characterized by fixed interest payments and a return of principal at maturity (RBC Wealth Managemen, 2017).

There are various types of bonds, depending on the type of coupons and different redemption features. The interest paid by bonds can be fixed, floating or payable at maturity. In the case of fixed rate bonds, investors receive a fixed interest rate until maturity, whereas holders of floating rate bonds receive coupons that are subject to periodical adjustments offering protection against fluctuations in the market interest rates. In contrast, zero coupon bonds do not have periodic interest payments, but are instead sold at a deep discount and are redeemed at the full face value at maturity. Although the maturity is a good indication for how long a bond will be outstanding, some bonds have structures that enable to issuer to redeem them before maturity. This significantly changes the expected life of the investment (Choudhry, 2004). This thesis only to focuses on plain vanilla fixed coupon bonds that are only callable at maturity.

2.4 Yield Spread and the Non-Default Component

Based on the bond price and the predetermined coupon, the yield is the actual return an investor earns on a bond. The (current) yield measures the current income an investor receives in relation to the current price of the bond. It is calculated by dividing the bond's yearly coupon payments by the market value of the bond. Although this measure is appropriate for investors aiming to maximize their current income, it does not take indicate whether investors make a loss or gain when the bond matures or is sold. Therefore the yield is not to be confused with the yield to maturity. The yield to maturity equals all interest payments an investor receives from holding the bond since purchase until maturity plus any gain or loss (depending on whether the bond was purchased above or below par respectively). For this reason, the yield to maturity is considered more meaningful.

The risk free interest rate compensates for the time value of money. Moreover, investors expect to earn some additional return for risk-bearing investments, which is the risk premium. This thesis defines the yield spread as the yield of a corporate green bond minus the yield of a benchmark government bond of exactly the same maturity and currency. It is highly unlikely to find a government benchmark with the exact same maturity as the respective corporate green bond. Therefore, most studies interpolate the benchmark yield using a government with a lower and another government bond with a higher maturity. The difference between the government benchmark yield and the corporate green bond is defined as the risk premium, since government bonds are considered to be risk free (Utz, Weber, & Wimmer, 2016).

As stated previously, majority of the corporate bond spread is due to default risk. However, a several recent studies find that default risk cannot fully account for the size or changes in corporate yield spreads. By deducing measures of the size and the default and non-default components in corporate yield spreads through information obtained from credit swap premiums, Longstaff (2005) finds a significant non-default component for 75% of the firms in their sample ranging from 20 to 100 basis points. Tax effects are a weak determinant of the non-default component, whereas measures of individual corporate bond illiquidity are strongly related to the non-default component (Longstaff, Mithal, & Neis, 2005). Another study examines a dataset consisting of investment-grade corporate and government bonds, which are withdrawn from the Lehman Brothers Fixed Income Database. In this case, of 10-year corporates, 46.17 percent of the difference between spot rates on corporate and government bonds remain unexplained by expected default or taxes (Elton, Gruber, Agrawal, & Mann, 2001).

This thesis will not account for tax factors and solely focus on how liquidity influences variation of the yield spread.

2.5 Yield Spread and Liquidity Risk

Liquidity is as of yet not defined as a single metric, but rather reflects 3 main characteristics of a security marketplace. Firstly, it mirrors how urgent the trade is. Secondly, it depicts the ability of an asset to trade in large volumes. Thirdly, it considerers how responsive the asset's price movement is to the size of the trade (Keller, Rodrigues, & Stevenson, 2008). This thesis adapts the following definition of liquidity, which is the ease of trading a security. In a frictionless market, any security can be traded at no cost at any moment in time. Illiquidity in markets is generated by trading costs, search problems, information asymmetry and adverse private information and inventory risk. Trading costs and search problems reduce the number of noise traders on the market and affect liquidity. When private information exists amongst traders, all players will be skeptic regarding the information that might be withheld on trading a security by their respective counterparty. Then, trading with an informed counterparty will result in a loss. To compensate for this loss, market makers try to gain from trades with uninformed traders by charging a certain bid-ask spread (Amihud, Mendelson, & Pedersen, 2005). Finally, market makers should be capable of providing immediate trades to any trader, and therefore need to build up inventory. Such inventory carries a price risk for which market makers need to be compensated for by higher bid-ask spreads (Utz, Weber, & Wimmer, 2016). Finally, a study covering over 4000 corporate bonds from investment grade and speculative categories, concludes that more illiquid bonds earn higher yield spreads and improvement in liquidity cause a significant reduction in yield spreads (Chen, Lesmond, & Wei, 2007). This suggests that liquidity is indeed priced in corporate yield spreads.

3. Data and Methodology

3.1 Data

A list of green bond ISINs were retrieved from Bloomberg on 16 November 2017. There were then 887 active corporate bonds that were labeled as green on the total market. According to the Climate Bonds Initiative, there are a number of exchanges that have established specialized green bond listings or dedicated segments enabling institutional investors to easily discover and invest in assets addressing climate change. Current exchanges that are considered as one of the top Green Bond Listing leaders are the Luxembourg Stock Exchange, London Stock Exchange and the

Euronext Exchange (Whiley, 2017). Since the United States is also a major issuer of green bonds, this thesis will also include bonds listed under the Trade Reporting and Compliance Engine (TRACE). Floating rate bonds, zero-coupon bonds and other bonds that have irregular or complex coupons (171 bonds) are excluded from the data set since they have a different yield measure than fixed coupon bonds. Next, all bonds with special features that would result in their being priced differently are eliminated, these are bonds with call options (119 bonds). Determinants of the green bond yield spread variation may vary considerably with the currency of issuance (Zerbib, 2016). The data set only includes bonds denominated in Euro (EUR) or the United States Dollar (USD), which are 166 bonds.

Daily data on the clean prices and yield spreads are obtained from Datastream based on the ISIN of the green bonds. The clean price is the price of the security less any accrued interests. The yield spread is obtained by comparing the maturity and yield of the respective green bond with an equivalent government benchmark. The maturities of most bonds in this sample will not be parallel to that of the available government bonds, therefore the spread is calculated as the difference between the green bond yield and the interpolated benchmark yield. The data span nearly a five-year period, the earliest information dates back to 1 January 2013 and the latest information is dated 17 November 2017. For the yield spreads, the yearly average is computed of the daily spreads, therefore any bond that does not have at least 1 daily spread quote since the year of issuance will be disregarded. In sum, there are 94 green bonds in the final sample.

Finally, bond-specific and macroeconomics factors largely affect the yield spread and the bond liquidity, therefore data on these factors for each bond is obtained from Datatream and Bloomberg respectively (Elton, Gruber, Agrawal, & Mann, 2001). Bond specific data includes the coupon rate, time to maturity, bond volatility, the 1-year yield on the government bond and the term slope (difference in yields of 10-year and 2-year government bonds). Since the dataset consists of bonds denominated in EUR and USD, yield data on the 1-, 2- and 10-year Eurozone bonds and US Treasury Notes are downloaded. To account for default risk, credit ratings for each bond come from Standard & Poor's rating on Datastream. In this sample there are 32 bonds with available rating data ranging from AAA to BB+. From these credit ratings a new variable Rating Scale is constructed which codes a numeric value to each rating class ranging from 1 for AAA to 11 for BB+ (Standard & Poor's Financial Services LLC, 2016). Since not all bonds have available credit ratings, accounting ratios are included to account for the effect of default risk for all bonds. Firm level data is collected on a yearly basis in the year prior to the yield spread measurement. These ratios include; Income-to-Sales ratio (Operating Income divided by Revenue), Debt-to-Sales ratio (Long Term Debt divided by Total Assets), the Interest Coverage ratio (Operating Income after Depreciation divided by Interest Expense) and the Debt-to-Capital ratio (Long Term Debt plus Debt on Current Liabilities divided by Total Liabilities and Shareholders Equity). When the accounting data is unavailable in Bloomberg, it is hand-collected from the firms' financial statement.

3.2 Liquidity Measures

3.2.1 Bid-Ask spread

Most literature on liquidity focuses on the transaction costs. Since there is no single theoretically correct and globally recognized standard that captures a bond's degree of liquidity, this paper opts to use the most widely accepted measure, namely the bid-ask spread. The bid-ask spread is a widely used measure of transaction costs, it mirrors the cost borne by investors in cases of buying a security and then selling it immediately (Zhao & Wang, 2015). Decreased spreads reflect a larger trading volume that in turn may result to a more steady price movement with small fluctuation, and eventually signal a more liquid market and vice versa (Febrian & Herwany, 2008). The intuition behind this mechanism is as follows, say a bond inhibits high transaction costs, the demand for trades regarding this bond will decrease and so will the number of potential traders in the market interested in this bond. Additionally, since higher bid-ask spreads cause transactions to revolve around the market makers' spread rather than the fundamental value of the security, traders are encouraged to engage in transactions outside the market makers' market; as such trades will be worth the search costs (Sarr & Lybek, 2002). Conversely, when bid-ask spreads are lower, traders will prefer to engage in transactions within the market makers' market instead of incurring the direct search costs themselves. This results in transaction prices being closer to an asset's true value and eventually leads to a more unified and deep market.

Data on daily bid and ask quotes are downloaded from Datastream. The daily bid-ask spread is calculated as the ask price minus the bid price divided by the average of the ask and bid price. Next, in order to estimate the average yearly bid-ask spread, the mean of all daily bid-ask spreads is calculated per year for each bond if at least one bid-ask spread is available in that respective bond year.

3.2.2 Zero-trading Days

Since there is no clear consensus on which liquidity measure is the most appropriate, this paper considers including another liquidity proxy that is regarded as a trading activity measure, namely the zero-trading days measure. Zero-trading days are days during which the price of a bond does not change, and thus results in a zero return. In an information-efficient market, prices of bonds should incorporate new information instantaneously. However, the presence of transaction costs causes some deviations from this mechanism. Transaction costs have an effect on both the sell as well as the buy side of the market. When these costs of trading exceed the value of new information available to traders, the marginal investor will not react to the information signal, but will instead refrain from participating in the transaction (Corwin & Schultz, 2012). Therefore, previous literature relates zero returns to illiquidity by arguing that zero returns occur when informed traders are not willing to trade (Dick-Nielsen, Feldhutter, & Lando, 2012).

The measure depicts the percentage of days during a trading year where a bond does not trade and is calculated as follows:

$$ZTD_{i,t} = \frac{\#\ of\ zero\ trading\ days_t}{\#\ of\ trading\ days_t}$$

where the subscript *i,t* denotes bond *i* in year *t*. This measure is calculated based on the difference in clean prices on a day-to-day basis. Then, the summation of the number of zero-return days is divided by the number of trading days in that respective year.

3.2.3 Amihud's ILLIQ measure

Similar to the quoted bid-ask spread, Amihud's illiquidity measure (ILLIQ), also serves as a measure of illiquidity due to the negative relationship between the price movements and the degree of bond liquidity (Amihud Y. , 2002). Amihud (2002) defines ILLIQ as the ratio of the daily absolute return to the daily dollar/euro trading volume and is consistent with the definition of liquidity as it measures how capable an asset is of trading at large volumes on short notice without experiencing noticeable fluctuations in its price. This measure has one main advantage over other liquidity measures. According to previous literature, the measure has a strong positive relation to the expected return and is therefore considered to represent the liquidity premium that compensates for price impact of transaction costs (Lou & Shu, 2017). ILLIQ is calculated as follows:

$$ILLIQ_{i,t} = \frac{1}{D_{i,t}} \sum_{t=1}^{D_{i,t}} \frac{|R_i|}{VOL_i}$$

where the subscript denotes bond *i* in year *t*. *D* is the number of trading days, *R* is the daily absolute excess return and *VOL* is the daily trading volume denoted in either USD or EUR. Since it is possible that there are non-trading days present in the dataset and this ratio is not defined for both zero-trading days and zero-volume days, the ILLIQ estimate is calculated as the average of individual day fractions. This ratio reflects the absolute percentage change per dollar/euro of daily trading volume, which is the daily price impact of the bond and suggests that illiquid bonds will have greater changes in price than liquid bonds.

3.3 Yield Spread Determinants

This thesis analyses panel data in a way that is closely related to that used by Chen et al. (2007) to assess the liquidity effects on bond yield spreads. While, the latter study examines U.S. corporate bonds in general, this thesis focuses on the impact of liquidity on a specific subset of green bonds. It is worthy to note that in this analysis, the impact of time-invariant variables (such as the Rating Scale and Coupon) are essential, therefore it is necessary to examine the dataset with a model that does not omit any variables that do not vary over time when performing the regression analyses. The Breusch-Pagan Lagrange multiplier (LM test) indicates that the random effects regressions model is more a more suitable model to examine this dataset as compared to an OLS regression model when we incorporate the Bid-Ask spread and Zero-trading Days as our liquidity proxies, but not when including the ILLIQ measure. Therefore this paper will include two panel estimation models (random effects model and an OLS regression model). The following regression contains the yield spread as the dependent variable, which is regressed on the liquidity estimates, bond-specific, macroeconomic and firm-specific variables:

$$
\begin{aligned}
&Yield\ Spread_{i,t} \\
&\quad = \beta_0 + \beta_1\ Liquidity_{i,t} + \beta\ {}_2 Maturity_{i,t} + \beta_3\ Coupon_{i,t} \\
&\quad + \beta_4 Volatility_{i,t} + \beta_5\ RatingScale_{i,t} + \beta_6\ GovernmentBond_{i,t} \\
&\quad + \beta_7\ TermSlope_{i,t} + \beta_8 \frac{Income}{Sales}_{i,t-1} + \beta_9 \frac{Debt}{Assets}_{i,t-1} \\
&\quad + \ \beta_{10} \frac{Debt}{Capital}_{i,t-1} + \varepsilon_{i,t}
\end{aligned}
$$

where the subscript *i,t* denotes bond *i* in year *t* and *Liquidity* refers to either the bid ask spread, the percentage of ZTD or ILLIQ measure. This regression includes two macroeconomic variables, namely, 1-year government bonds and term slopes, both these variables signal the status of general economic growth. Previous literature finds that interest rates are negatively related to yield spreads, the same holds for the relationship between the term slopes and yield spreads. Higher spot rates mean that the default risk of the firm decreases and so the yield spread decreases too (Chakravarty & Sarkar, 1999). Decreasing term slopes forecast a weak economy, and therefore lower recovery rates, which again translate into higher yield spreads (Collin-Dufresne, Goldstein, & Martin, 2001). Since not all bonds have available data on credit rating, the firm-specific accounting ratios play an important role in explaining the green bond yield spreads. Long-term debt to assets and debt to capital indicate the level of leverage of a company. Highly levered firms are more prone to financial distress and have higher chances of default. On the contrary, the higher the income to sales ratio ratio is, the more operating income is generated relative to sales, indicating more financially successful companies which are less likely to default. So, while the latter ratio is negatively associated with the green bond yield spread, the former two are not (Campbell & Taksler, 2003).

Due to the lack of rating scale availability, the yield spread determinants will be regressed using 2 separate models. Model 1 accounts for only accounting data and Model 2 includes both accounting data and credit rating.

3.4 Robustness

In order to avoid any chance of endogeneity bias and obtain robust results, a simultaneous equation model is applied. Possible sources of endogeneity are the liquidity measures since credit ratings can have an effect on them. In the case of green bonds, it is assumed that the credit ratings signal the level of private information costs associated with a particular green bond. Thus, bonds with a higher credit rating lead to higher bond liquidity and vice versa. Additionally, the credit quality may also be a potential source of endogeneity. Besides considering the financial accounting information of the issuing firm, credit rating agencies may also take a green bond's yield spreads into account during their assessment. Hence, higher yield spreads could lead to lower credit ratings.

To control for potential biases caused by each liquidity measure and the credit rating, the following simultaneous equations are specified:

$$\begin{aligned} Yield\ Spread_{i,t} &= \beta_0 + \beta_1\ Liquidity + \beta\ {}_2 Maturity + \beta_3\ GovernmentBond_{i,t} \\ &+ \beta_4\ TermSlope_{i,t} + \beta_5\ RatingScale_{i,t} + \varepsilon_{i,t} \end{aligned}$$

$$\begin{aligned} Liquidity_{i,t} &= \beta_0 + \beta_1\ BondVolatility + \beta\ {}_2 RatingScale_{i,t} + \beta_3\ YieldSpread_{i,t} \\ &+ \varepsilon_{i,t} \end{aligned}$$

$$\begin{aligned} Rating\ Scale_{i,t} &= \beta_0 + \beta_1 \frac{Income}{Sales}_{i,t-1} + \beta_2 \frac{Debt}{Assets}_{i,t-1} + \beta_3 \frac{Debt}{Capital}_{i,t-1} \\ &+ \beta_4\ YieldSpreads_{i,t} + \varepsilon_{i,t} \end{aligned}$$

where the subscript *i,t* denotes bond *i* in year *t*. The bond volatility is calculated based on daily returns in clean prices using a historical volatility period of 252 days, which roughly corresponds to 1 trading year. The returns are calculated based on the log returns of the previous day. Then, taking the standard deviation of the daily returns per year annualizes the bond volatility. By incorporating the abovementioned equations, a three-stage leas squares model estimation technique analyses to what extend the liquidity proxies and credit ratings affect the green bond yield spreads. The results are presented in the following section.

4. Empirical Results and Analysis

4.1 Summary statistics

This paper examines the liquidity effects on yield spreads of 94 bonds within a span of almost 5 years. Table 1 reports descriptive statistics for the time-invariant green bond characteristics in this sample. The total sample consists of 19 green bonds denominated in EUR and 75 green bonds issued in USD with an average issued amount equaling to 672 million and 203 million respectively. This shows that the European market issues over 50% more as compared to the US green bond market. Additionally, the average coupon rate for this sample is about 3.16% with a standard deviation of 1.68%, while the mean maturity in this dataset is 7.43 years along with a standard deviation of 4.88 years. This indicates that the age of the green bonds in this sample is a rather heterogeneous variable.

Table 1: Descriptive statistics on the time-invariant green bond sample characteristics

	Coupon (%)	Maturity (years)	Issued Volume (EUR)	Issued Volume (USD)
Mean	3.16498	7.434947	6.72e+08	2.03e+08
Median	2.9375	5.715865	5.57e+07	1.00e+17
Maximum	5.875	30.87535	2.22e+09	1.25e+09
Minimum	0.125	1.273703	3.41e+07	12000
Standard Deviation	1.68164	4.883729	5.54e+08	3.16e+08
Variance	0.0002828	23.65081	3.07e+12	1.00e+17
Skewness	-0.547736	1,736763	1.560557	1.549032
Kurtosis	1.804319	7,91611	4.823025	4.626759
# Bonds	94	94	19	75
# Observations	470	249	95	375

Table 2 provides information by year on the time-variant measures. It is clear that the average yield spread tends to increase every year. Similar trends are observed regarding the liquidity proxies, except for a small decrease in the liquidity measures from 2016 to 2017. Another reason for observing a wider yield spreads can be attributed to the increase in the samples with lower credit rating, which goes from an average Rating Scale of 3 to 5.47 between 2013 and 2017. However, the data availability in the initial sample period is relatively scarce, as there are only 3 bonds with available data in 2013.

Table 2: Descriptive statistics on the time-variant green bond sample characteristics

Year	2013	2014	2015	2016	2017
Yield spread					
Mean	54.87085	66.98458	219.3109	293.6959	367.9517
# Bonds	4	4	62	82	94
Bid-ask spread					
Mean	0.0014793	0.0015456	0.0037961	0.0040465	0.0035867
# Bonds	3	4	62	82	94
%ZTD					
Mean	28.11774	5.55556	5.60999	2.3291	1.84837
# Bonds	4	4	62	82	94
ILLIQ					
Mean	2.90e-06	1.51e-06	3.42e-01	2.57e-01	7.70e-02
# Bonds	1	1	9	21	29
Volatility					
Mean	0.002845	0.0034497	0.0043082	0.0034198	0.002113
# Bonds	4	4	62	81	94
Rating Scale					
Mean	3	3	4,615385	5,347826	5,46875
# Bonds	3	3	13	23	32

4.2 Correlation between Liquidity Proxies

The main aim of this paper is to analyze the effects of liquidity on the yield spreads by employing three liquidity proxies. Table 3 depicts the values of the pairwise correlation between these liquidity measures and indicates a strong positive relationship between the bid-ask spread and the percentage of zero-trading days of 0.7672. The strong correlation indicates that these measures of liquidity could potentially be substitutes of one and other. This is a favorable outcome in this case, as both these measures aim to provide information regarding the transaction costs of trading a bond. Since there is a high correlation between the two liquidity proxies, it is safe to assume that both measures indeed reflected the information they were intended to. On the contrary, the correlation matrix displays a weak relationship between the ILLIQ measure and the other two liquidity proxies, exhibiting a relatively poor correlation of only 0.1900 and 0.0458 with the bid-ask spread and zero-trading days respectively. A possible explanation for this result is that the bid-ask spread and the zero-trading days measures capture the transaction cost quantity of liquidity, while the ILLIQ measure deals with the price impact. Since the former two contain information on a different dimension of liquidity than the latter, the correlation between these measures may be low.

As an extra precaution, a correlation matrix is run between all the independent variables in the regression. Overall, the correlation between these variables are pretty low. The only relatively higher correlation was that between Total Debt/Capital ratio and Income/Sales ratio and Total Debt/Capital and Long Term Debt/total assets. However, after removing this variable, the coefficient estimates hardly changed. A detailed table can be found in Appendix table 3.

Table 3: Correlation values between liquidity proxies

	Bid-ask spread	Zero-trading days	ILLIQ
Bid-ask spread	1		
Zero-trading days	0.7672	1	
ILLIQ	0.1900	0.0458	1

4.3 Yield Spread Determinants Result

To gain insight regarding the relationship between the yield spread and the liquidity proxies, this thesis employs two different panel estimation models (a random effects regression and an OLS regression) for both Model 1 and Model 2. Considering the availability of rating and accounting data in the overall sample, Model 1 has a larger sample size consisting of a maximum of 94 bonds and 245 panel observations during the entire sample period as compared to Model 2, which analyses 32 bonds along with 74 observations over the same period. Each model is run for the three liquidity measure specifications, bid-ask spread, percentage of zero-trading days and the ILLIQ measure. In both Model 1 as well as Model 2, the bid-ask spread and percentage of zero-trading days measures maintain a larger sample size compared to the ILLIQ measure due to the lack of data availability regarding the daily trading volumes of the green bonds. That being said, the ILLIQ measure does exhibit a more significant affect on the variation in yield spreads as compared to the other two liquidity proxies in both models 1 and 2. The regression outcomes are presented in Table 4 and 5.

4.3.1 Model 1 Analysis

In Model 1, which only includes firm level accounting data as a proxy for default risk, the results indicate that none of the liquidity measures, except for the ILLIQ measure, have a significant effect on the variation across yield spreads for this green bond sample. Random Effects (ILLIQ) presents a positive coefficient significant at the 10% level, indicating that an increase in the ILLIQ measure will result in an increase of yield spreads by 644 basis points on average. However, as mentioned before, the LM test indicates that in case of the ILLIQ measure, an OLS model is preferred and thus this estimate potentially should be interpreted with caution.

The bond specific characteristics, *Maturity* and *Coupon*, both have a significant impact on the yield spreads across all liquidity proxies. There exists a negative relationship between the time to maturity and the yield spread for green bonds significant at the 1% level for all proxies over all panel estimations except for in Model 1 Random Effects (Bid-ask spread), where this negative relationship is significant at the 10%. Although these results cannot support the theory regarding a bond's age and its effect on the yield spread, it is in line with outcomes presented in previous literature (Utz, Weber, & Wimmer, 2016). However, consistent with theory, the sign of the coupon rate is positively significant at the 1% level. The bond volatility does not seem to have any significant effect on the dependent variable in any of the panel estimations, apart from in Model 1 OLS (% ZTD) illustrating a negative relationship between the two variables.

As for the macroeconomic level data, the 1 year government bond rate only seems to have a significant (1%) impact for Model 1 (ILLIQ), both for the random effects as for the OLS regression models indicating a decrease of 117.52 and 113.36 basis points respectively in yield spreads. The term slope also has a significant negative effect at the 1% level for Model 1 random effects (Bid-ask spread and %ZTD) and OLS across all liquidity proxies. This negative impact of the macro-level data on the variation of yield spread is as expected from previous literature.

The operating income to sales ratio is negatively related to the yield spreads with a statistical significance of 1% in Model 1. This is in accordance with theory, suggesting that higher profit margins denote lower default risk and thus decrease the yield spread of the green bonds in this sample The total debt to capital ratio has a negative effect significant at 1% level across all panel estimations presenting a decrease in yield spreads by 875.74, 784.21 and 581.22 basis points for the bid-as spread, percentage of ZTD and ILLIQ estimates respectively. The aforementioned results are unexpected since higher leverage ratios tend to be associated with higher yield spreads.

Table 4: Model 1

	Bid-ask spread		%ZTD		ILLIQ	
	RE	OLS	RE	OLS	RE	OLS
Yield spread						
	848.33***	541.09***	780.2629***	515.8504***	776.3196***	754.833***
Intercept	(13.15)	(10.89)	(11.95)	(10.10)	(5.03)	(-0.72)
	-474.56	60.65				
BAS	(-0.78)	(0.11)				
			-28.19	-164.12		
%ZTD			(-0.32)	(-1.64)		
					644*	228
ILLIQ					(-1.92)	(-0.71)
	-4.71*	-6.79***	-4.94***	-6.93***	-30.43***	-27.97***
Maturity	(-1.76)	(-3.45)	(-1.99)	(-3.58)	(-3.14)	(-3.24)
	56.90***	73.30***	54.70***	77.74***	102.41***	99.99***
Coupon	(4.96)	(7.46)	(6.61)	(11.65)	(5.45)	(6.27)
	-25.31	-60.49	-34.58	-70.68*	-217.86	-162.91
Volatility	(-0.78)	(-1.53)	(-1.03)	(-5.13)	(-1.00)	()
	0.18	-15.75	3.17	-17.39	-117.52***	-131.36***
Government Bond	(0.01)	(-1.10)	(0.19)	(-1.35)	(-3.19)	(-4.33)
	-68.43***	-126.73***	-72.21	-120.78***	-65.27	-121.21***
Term slope	(-2.84)	(-5.09)	(-3.02)	(-5.13)	(-1.53)	(-2.93)
	-346.82***	-411.03***	-359.59***	-399.70***	-369.36***	-399.38***
I/S	(-8.45)	(-11.02)	(-8.33)	(-10.73)	(-4.00)	(-5.10)
	35.82	63.28	39.76	*74.22	286.44***	268.37 ***
D/A	(0.54)	(1.49)	(0.64)	(1.76)	(3.19)	(4.20)
	-875.78***	-405.26***	-784.21***	-384.29***	-680.33***	-581.22***
D/C	(-11.12)	(-6.54)	(-10.00)	(-6.20)	(-4.15)	(-4.48)
R-squared	0.7447	0.8001	0.7646	0.8037	0.8037	0.8085
Adj R-squared		0.7924		0.7961		0.7747
N	244		245		61	
# Bonds	94		94		31	

*Notes: This table reports upon the RE and OLS regression analysis. The absolute values of t-statistics are shown in parenthesis, *, **, *** denote significance at the 10%, 5% and 1% respectively.*

Table 5: Model 2

	Bid-ask spread		%ZTD		ILLIQ	
	RE	OLS	RE	OLS	RE	OLS
Yield spread						
Intercept	-45.32 (-1.29)	-33,56 (10.89)	-46,77 (-1.37)	-40.59 (-1.30)	-49,52 (-0.80)	1,18 (0.02)
BAS	313.50 (0.97)	485.43* (1.67)				
%ZTD			95.42** (2.44)	122.53*** (2.83)		
ILLIQ					428*** (4.07)	287*** (3.36)
Maturity	-7.97*** (-3.09)	-11.19*** (-4.72)	-7.52*** (-3.08)	-9.99*** (-4.56)	-13.40*** (-3.93)	-11.78*** (-4.32)
Coupon	36.93*** (4.96)	35.14*** (4.07)	39.63*** (4.97)	37.88*** (4.99)	28.81** (2.34)	43.66*** (4.19)
Volatility	254.79*** (-0.78)	311.79*** (6.81)	252.76*** (5.23)	309.21*** (6.80)	335.11*** (4.98)	241.97*** (3.35)
Rating Scale	10.57*** (4.00)	9.71*** (3.93)	11.00*** (4.24)	10.65*** (4.38)	8.64** (2.47)	6.97*** (2.87)
Government Bond	-25.13*** (0.01)	-26.20*** (-3.13)	-29.62*** (-3.70)	-30.72*** (-4.07)	-21.75* (-1.89)	-37.68*** (-3.65)
Term slope	-19.07 (-2.84)	-23.25* (-1.70)	-26.18** (-2.04)	-32.07** (-4.07)	-19.74* (-1.65)	-30.97** (-2.52)
I/S	66.74** (2.09)	63.09** (2.11)	75.12** (2.46)	76.70*** (2.73)	67.36* (1.92)	28.71 (0.93)
D/A	-2.01 (-0.07)	4.77 (0.18)	-5.60 (-0.20)	-1.23 (-0.05)	9.66 (0.25)	21.39 (0.77)
D/C	28.60 (0.84)	28.97 (1.01)	35.28 (1.08)	40.07 (1.46)	69.16 (0.98)	27.36 (0.55)
R-squared	0.9063	0.9102	0.9066	0.9099	0.9673	0.9734
Adj R-squared		0.8957		0.8955		0.9632
N	73		74		37	
# Bonds	32		32		19	

*Notes: This table reports upon the RE and OLS regression analysis. The absolute values of t-statistics are shown in parenthesis, *, **, *** denote significance at the 10%, 5% and 1% respectively.*

4.3.2 Model 2 Analysis

Model 2 includes both firm-level accounting data as well as credit ratings as a measure for default risk. Although this does shrink the sample size remarkably, it provides with more significant coefficient estimates for the liquidity proxies. Similar to Model 1, the bid-ask spread remains to have an insignificant, yet positive, effect on the green bond yield spread. The other two liquidity proxies do exhibit evidence that liquidity measures of higher values carry higher liquidity costs. Hence, the results do indeed support the main hypothesis that lower bond liquidity is associated with a wider yield spread for green bonds. The significance does vary between the two liquidity proxies. While an increase of 1% in the percentage of ZTD is related to an incremental increase in the green bond yield spread by 95.42 basis points, for the ILLIQ estimate this effect is 287 basis points, both are significant at the 5% and 1% level respectively.

The addition of credit rating as a default proxy is what distinguishes Model 2 from Model 1. From table 5, it is evident that credit rating is highly significant. The positive coefficients signify that higher rating scale, and thus a higher default risk, is associated with wider yield spreads. When the green bonds are downgraded by one 1 scale, the yield spread increases by 10.57, 11.00 and 6.97 basis points all significant at the 1% level for the bid-ask spread, %ZTD and ILLIQ respectively.

The 1-year government bond rate remains to be negatively associated with the average variation of yield spreads resulting in coefficients of -25.13, -29.62 and -37.68 all significant at the 1% level for the bid-ask spread, %ZTD and ILLIQ liquidity proxies respectively.

As apposed to Model 1, the operating income to sales ratio is positively related to the yield spreads at a 5% statistical significance level with regard to the bid-ask spread and the percentage of ZTD measure in Model 2. A 1 percent increase in these measures results in an increase in the green bond yield spread by 66.74 and 75.12 basis points respectively. Although there is no theoretical explanation for this result, this negative coefficient can be due to the fact that a large number of bonds represented in this sample are issued by SolarCity Corporation, which is a subsidiary of Tesla, Inc. Despite the company's low operating profit margins, it has tremendous growth potential and so presently issues one of the best performing securities (Kharpal, 2017). This argumentation is however strictly an assumption based on this green bond sample and by no means provides any theoretical base for this relationship. The remaining two accounting rations do not exhibit any significant effects over the yield spreads in Model 2.

Finally, as mentioned before, the striking difference between Model 1 and 2 is the sample size. Model 1 consists of more bonds compared to the latter, however none of the liquidity measures have a significant effect on the variation in the green bond yield spread in this sample. Based on the regression results, the R-squared has values between 74.47% and 80.85% for Model 1. When controlling for both accounting data and credit rating in Model 2, it is evident that the independent variables are a better fit to estimate the variability of the regression model since the R-squared values range from 90.63% to 97.37%. Additionally, in general, all the independent variables in Model 2 have a higher statistical significance relative to Model 1. The ILLIQ measure has the highest explanatory power in Model 2 OLS estimation, attaining an R-squared measure of 97.34% and an adjusted R-squared of 96.32%, followed by Model 2 Random Effects (percentage ZTD) which on average widens the yield spread significant at the 1%, but has a lower explanatory power of 90.66%.

4.4 Three-Stage Least Squares Regression Result

This section presents the results of the three-stage least squares analysis technique that controls the endogeneity of the liquidity measures and the credit ratings present this paper's framework. The results are displayed in Table 6. A separate model is estimated for each liquidity measure. For each model, the last two columns represent the regression estimates for the credit rating and respective liquidity measure as endogenous variables. The results indicate that the credit rating seems to have significantly increases the bid-ask spread and the percentage of ZTD at 10% and 5% respectively. Reasoning behind this could be that credit ratings contain private information that influences the liquidity level of bonds. Section 2 states that bonds with lower credit ratings, and thus higher rating scales, are prone to higher private information costs.

Table 6: 3SLS

	Bid-ask spread			% ZTD			ILLIQ		
	Yield spread	Bid-ask Spread	Rating Scale	Yield spread	% ZTD	Rating Scale	Yield spread	ILLIQ	Rating Scale
Bid-ask spread	755.86								
	(1.23)								
% ZTD				79.46***					
				(-4.35)					
ILLIQ							957*		
							(1.79)		
Maturity	-19.66			12.75***			-0,29		
	(-0.78)			(3.10)			(-0.03)		
GovernmentBond	15.68			16.27*			-2.50		
	(1.11)			(1.80)			(-0.15)		
Term slope	-0.95			46.83*			1.60		
	(-0.02)			(1.66)			(0.12)		
Volatility		1.55**			52,13			3,86	
		(2.30)			(1.45)			(0.18)	
Rating scale	-2.16	0.35e-03*		15.96***	0.02**		10.51***	-8,00e-03	
	(-0.12)	(1.85)		(4.67)	(2.28)		(2.62)	(-1.41)	
Yield Spread		-0.19e-04	0.02***		-0.19e-02 **	0.03***		0.90e-03**	0.03***
		(-1.23)	(8.40)		(-2.28)	(9.65)		(2.07)	(-1.20)
I/S			-2.05*			-2.47**			-2,03
			(-1.73)			(-2.16)			(-3.90)
D/A			-4.92***			-4.40***			-4.90***
			(-6.48)			(-6.24)			(0.85)
D/C			-2.06*			-1,32			1.84
			(-1.70)			(-1.21)			(9.82)
Constant	32.72	-0.68e-03	6.51***	-74.38*	0.98e-02	5.60***	14.74	-2.10e-08	3.09
	(0.34)	(-0.81)	(5.59)	(-1.94)	(0.24)	(5.24)	(0.24)	(-0.86)	(1.60)
N			73			74		37	

*Notes: This table reports upon the simultaneous equation models. The absolute values of t-statistics are shown in parenthesis, *, **, *** denote significance at the 10%, 5% and 1% respectively.*

Since the mean rating scale in this paper's subset of bonds is 5.47 (which roughly equates to a credit rating of A+/A) and the lowest rating according to S&P Standards credit scale is a BB+, majority of the bonds in this sample are considered to be investment grade bonds. Therefore, problems regarding private information in the case of green bonds might arise due to the lack of credit risk profile of green bonds. This suggests that credit rating agencies are inclined to assess green bond risk profiles by enquiring the issuer's balance sheet rather than tracking the financial performance of the green bonds. The rating scale of the green bonds is also highly affected by the yield spread, causing an increase in scale as the green bond yield spreads widen. Moreover, the yield spreads influence both the ILLIQ measure and the percentage of ZTD but with conflicting results. While wider yield spreads have a positive effect on the ILLIQ measure, the opposite holds for the latter. Although the coefficients are very low in both cases (0.0009 and -0.0019 respectively), and thus the liquidity estimates are not affected very much by the yields spreads.

Nonetheless, after controlling for possible endogeneity bias in the coefficient estimates presented in Tables 4 and 5, the outcomes of the simultaneous equation models indicate that all three liquidity measures still continue to have a positive effect on the green bond yield spread. Although the bid-ask spread measure has a positive yet insignificant effect, both the percentage of ZTD and the ILLIQ measure are significant at the 1% and 10%. Therefore, the results presented in the previous section can be assumed to be robust.

5 Conclusions

In the midst of a transition towards a more climate resilient economy, green bonds are highly attractive financial instruments, which stimulate this development as it enables low-carbon project holders to expand their funding capacity. In order to encourage issuance and trading of green bonds, both issuers and investors need to understand the risk component of green bonds. This paper analyses the liquidity risk effects on the green bond yield spreads using EUR and USD denominated fixed rate corporate bonds dating from 2013 till end 2017 by constructing two models and employing two different panel data techniques on a sample of 94 individual green bonds.

In accordance with the purpose of this thesis, the following research question is investigated:

"Does liquidity have a significant effect on the variation in the green bond yield spread?"

The empirical results reflect that the effects of liquidity risk in the green bond yield spread are positive and robust after controlling for potential endogeneity bias. The occurrence of zero-trading days as well as Amihud's illiquidity measure represent the transaction costs and price impact related to trading green bonds respectively. Although the price impact has a larger effect on the yield spread levels as compared to the occurrence of zero-trading days, higher values of both these measures result in wider yield spreads. Based on these findings, this paper maintains the hypothesis that liquidity does have a significant impact on the green bond yield spreads.

5.1 Final Remarks

Having found evidence to back the main hypothesis of this thesis, the three-stage least squares analysis does reveal that credit ratings influence the liquidity estimates and thus contain private information that impact the liquidity of green bonds. The coefficients of simultaneous equation models exhibit unexpected results for the long-term debt to assets and total debt to capital ratios. The income to sales ratios however do depict that if an issuer has a profitable income stream, their bonds achieve a lower rating scale and thus achieve higher credit ratings when considering the liquidity measures dealing with transaction costs. For the most part, these balance sheet ratios do have a significant effect on the credit ratings. This observation proves that credit rating agencies rely heavily on (past) accounting data and are biased towards issuers that have higher financial returns. New comers and younger firms lack the sufficient amount of accounting data and capital to generate sufficient cash flows, both of which are necessary in order to obtain a favorable rating from credit rating agencies. Without this, they are hindered from successfully issuing green bonds that would have otherwise generated capital for green investments. The high correlation between credit ratings and liquidity estimates, together with the pronounced effect of liquidity on green bond yield spreads suggest that firms ought to find a way to achieve higher credit ratings, especially when they are new entrants to the market. Since liquidity risk and credit risk impede the growth of the green bond market to some extent, this research recommends a clearer mandate regarding the definitions regarding ESG integration and higher quality reporting of green projects and their performance or potential.

Issuers of green bonds can improve their liquidity levels by providing counter parties with clear and concise information regarding their green investments, and thereby tightening the green bond yield spread to a certain extent. Additionally, policy makers can play a crucial role in this process by taking a more proactive stance regarding the debate on green financing and establishing internationally recognized standards for green investments. This will facilitate information transfer among the different parties active in the green bond market and bring more clarity to the risk profile of green investments on a global scale.

5.2 Further Recommendations

Nevertheless, this paper has some lacking in the sense that sample size is considerably small. The green bond market is still relatively immature, lacks credit rating data and does not have a clear consensus on what sets this market apart from other social impact securities. Further recommendations in order to establish an even better relationship between liquidity and green bond yield spreads would be to focus on how transparency between green bond issuers and investors affects the liquidity levels of the green bonds. However, this is only plausible if there is a sufficient amount of data available on green bonds.

Once there is an improvement in the data quantity further research can be applied by means of matching data sets. Matching data sets refers to identifying pairs consisting of a green bond and their conventional counterpart with identical characteristics regarding the issuer, credit rating, coupon type and frequency and maturity. By comparing the liquidity risk effect on the yield spreads of green bonds and on identical non-green bonds, the liquidity risk component of the bonds can be more accurately extracted and analyzed. Furthermore, there is more assurance on whether improved liquidity indeed leads to tighter spreads. Since this thesis examines a dataset of relatively young green bonds, another interesting aspect intended for further research could be to study what the effect of the liquidity proxies are over the years. More specifically, whether the impact of the liquidity measures found in this thesis still persist in the long run or whether they decrease over time. Decreasing results may hint at a growing maturity of the green bond market. However, determining whether liquidity effects on yield spreads are negligible or not in the long run, can only be done by analyzing data over a longer period of time.

Finally, the scope of this thesis can conclude that an increase in liquidity does result in tighter green bond yield spreads, which can be achieved through clearer guidelines on the issuance and definition of green projects, which in turn will reduce the risks associated with the issuance of green bonds while simultaneously increasing the confidence among investors.

6 Appendix

Table 1: List of green bonds

ISIN	Issuer Name	Curr	Cpn	Final Maturity	Amount Issued	Issue Date	S&P Rating
US89114QBT40	Toronto-Dominion Bank/The	USD	1,85	9/11/2020	1000000000	9/12/2017	AA-
XS1587035996	First Abu Dhabi Bank PJSC	USD	3	3/30/2022	587000000	3/30/2017	AA-
USP58072AL66	Inversiones CMPC SA	USD	4,375	4/4/2027	500000000	4/4/2017	BBB-
XS1512929842	Bank of China Ltd/London	USD	1,875	11/9/2019	500000000	11/9/2016	
XS1636000561	Intesa Sanpaolo SpA	EUR	0,875	6/27/2022	565590000	6/27/2017	BBB
XS1422841202	ABN AMRO Bank NV	EUR	0,625	5/31/2022	556940000	5/31/2016	A
XS1527753187	BNP Paribas SA	EUR	0,5	6/1/2022	531270000	12/1/2016	A
XS1410341389	Axis Bank Ltd/Dubai	USD	2,875	6/1/2021	500000000	6/1/2016	BBB-
XS1612940558	Kreditanstalt fuer Wiederaufbau	EUR	0,25	6/30/2025	2215160000	5/16/2017	AAA
XS1303791336	Agricultural Bank of China Ltd	USD	2,75	10/20/2020	500000000	10/20/2015	
XS1431730388	Nordic Investment Bank	EUR	0,125	6/10/2024	1127840000	6/10/2016	AAA
XS1308276168	Agricultural Bank of China Ltd	USD	2,125	10/20/2018	400000000	10/20/2015	
XS1244060486	ABN AMRO Bank NV	EUR	0,75	6/9/2020	563490000	6/9/2015	A
XS1500337644	Societe Generale SA	EUR	0,125	10/5/2021	560295000	10/5/2016	A
XS1324217733	ING Bank NV	EUR	0,75	11/24/2020	532340000	11/24/2015	A+
US29874QDG64	European Bank for Reconstruction & Development	USD	1,875	7/15/2021	500000000	10/5/2017	AAA
FR0013067170	BPCE SA	EUR	1,125	12/14/2022	330453000	12/14/2015	A
FR0013064755	HSBC France SA	EUR	0,625	12/3/2020	545085000	12/3/2015	AA-
US29874QCN25	European Bank for Reconstruction & Development	USD	1,625	4/10/2018	250000000	9/17/2013	AAA
XS1641457277	European Investment Bank	EUR	1,5	11/15/2047	1133840000	7/5/2017	
US49835LAB71	Klabin Finance SA	USD	4,875	9/19/2027	500000000	9/19/2017	BB+
FR0011637586	Electricite de France SA	EUR	2,25	4/27/2021	1899842000	11/27/2013	A-
XS1324923520	Societe Generale SA	EUR	0,75	11/25/2020	531160000	11/25/2015	A
US05674XAA90	Suzano Austria GmbH	USD	5,75	7/14/2026	700000000	7/14/2016	BB+
XS1292474282	Nordic Investment Bank	EUR	0,375	9/19/2022	565215000	9/17/2015	AAA
US44987CAJ71	ING Bank NV	USD	2	11/26/2018	800000000	11/24/2015	A+
FR0013015559	Schneider Electric SE	EUR	1,841	10/13/2025	341694000	10/13/2015	A-
US45950VHE92	International Finance Corp	USD	1,25	11/27/2018	500000000	11/27/2015	AAA
US29874QCW24	European Bank for Reconstruction & Development	USD	0,875	7/22/2019	650000000	7/20/2016	
US63983TBB08	Nederlandse Waterschapsbank NV	USD	2,375	3/24/2026	1250000000	3/24/2016	AAA
US059613AC35	Banco Nacional de Costa Rica	USD	5,875	4/25/2021	500000000	4/25/2016	
US05463CAD48	Axis Bank Ltd/Dubai	USD	2,875	6/1/2021	500000000	6/1/2016	BBB-
XS1242327325	BRF SA	EUR	2,75	6/3/2022	562745000	6/3/2015	BBB-
US45905UG408	International Bank for Reconstruction & Development	USD	2	4/12/2022	300000000	4/12/2017	AAA
US45905ULF92	International Bank for Reconstruction & Development	USD	1,5	7/12/2022	5000000	7/12/2012	
XS1238024035	Renewi PLC	EUR	3,65	6/16/2022	112419000	6/16/2015	
US45905UWE09	International Bank for Reconstruction & Development	USD	1,005	10/1/2018	280000000	4/21/2016	
US83417KDG04	SolarCity Corp	USD	2,65	8/20/2018	5000000	8/20/2015	
US83417KDM71	SolarCity Corp	USD	2,65	8/27/2018	5000000	8/27/2015	
US83417KEK07	SolarCity Corp	USD	4,7	10/16/2025	5000000	10/16/2015	
XS1684812255	International Finance Corp	USD	1,625	9/27/2021	150000000	9/27/2017	

US83417KBR86	SolarCity Corp	USD	4,7	5/29/2025	10000000	5/29/2015	
US83417KBQ04	SolarCity Corp	USD	3,6	5/29/2020	10000000	5/29/2015	
XS1192988738	International Bank for Reconstruction & Development	EUR	1,0325	2/25/2045	34089300	2/25/2015	
US83417KBM99	SolarCity Corp	USD	4,7	5/21/2025	10000000	5/21/2015	
XS1684811794	International Finance Corp	USD	1,375	9/26/2019	200000000	9/26/2017	
US83417KAC27	SolarCity Corp	USD	3,6	3/19/2020	2800000	3/19/2015	
US83417KCL08	SolarCity Corp	USD	2,65	7/16/2018	10000000	7/16/2015	
US83417KCX46	SolarCity Corp	USD	3,6	8/6/2020	5000000	8/6/2015	
XS0963399257	Landwirtschaftliche Rentenbank	EUR	1,455	8/20/2020	67100500	8/20/2013	AAA
US83417KCY29	SolarCity Corp	USD	4,7	8/6/2025	5000000	8/6/2015	
US83417KAZ12	SolarCity Corp	USD	4,7	4/23/2025	10000000	4/23/2015	
USL5828LAB55	Klabin Finance SA	USD	4,875	9/19/2027	500000000	9/19/2017	BB+
US83417KBL17	SolarCity Corp	USD	3,6	5/21/2020	10000000	5/21/2015	
US83417KDD72	SolarCity Corp	USD	4,7	8/13/2025	5000000	8/13/2015	
US83417KAP30	SolarCity Corp	USD	4,7	4/2/2025	15000	4/2/2015	
US83417KAY47	SolarCity Corp	USD	3,6	4/23/2020	10000000	4/23/2015	
US83417KDN54	SolarCity Corp	USD	3,6	8/27/2020	5000000	8/27/2015	
USP14623AC98	Banco Nacional de Costa Rica	USD	5,875	4/25/2021	500000000	4/25/2016	
US83417KCW62	SolarCity Corp	USD	2,65	8/6/2018	5000000	8/6/2015	
US83417KDB17	SolarCity Corp	USD	2,65	8/13/2018	5000000	8/13/2015	
US83417KBA51	SolarCity Corp	USD	5,45	4/23/2030	10000000	4/23/2015	
US83417KEF12	SolarCity Corp	USD	5,45	10/1/2030	5000000	10/1/2015	
US45950VLH77	International Finance Corp	USD	2	10/24/2022	1000000000	10/24/2017	
US45950VHX73	International Finance Corp	USD	2,125	4/7/2026	1200000000	4/7/2016	AAA
US83417KAS78	SolarCity Corp	USD	2,65	4/9/2018	15000	4/9/2015	
US83417KCZ93	SolarCity Corp	USD	5,45	8/6/2030	5000000	8/6/2015	
US83417KDY10	SolarCity Corp	USD	3,6	9/17/2020	5000000	9/17/2015	
US83417KCS50	SolarCity Corp	USD	3,6	7/23/2020	5000000	7/23/2015	
US83417KBC18	SolarCity Corp	USD	4,7	4/30/2025	10000000	4/30/2015	
US83417KDQ85	SolarCity Corp	USD	5,45	8/27/2030	5000000	8/27/2015	
US83417KDU97	SolarCity Corp	USD	4,7	9/3/2025	5000000	9/3/2015	
USA9890AAA81	Suzano Austria GmbH	USD	5,75	7/14/2026	700000000	7/14/2016	BB+
US83417KCN63	SolarCity Corp	USD	4,7	7/16/2025	10000000	7/16/2015	
US83417KCM80	SolarCity Corp	USD	3,6	7/16/2020	10000000	7/16/2015	
US83417KCP12	SolarCity Corp	USD	5,45	7/16/2030	5000000	7/16/2015	
US83417KCT34	SolarCity Corp	USD	4,7	7/23/2025	5000000	7/23/2015	
US83417KCU07	SolarCity Corp	USD	5,45	7/23/2030	5000000	7/23/2015	
US83417KCR77	SolarCity Corp	USD	2,65	7/23/2018	5000000	7/23/2015	
US83417KDC99	SolarCity Corp	USD	3,6	8/13/2020	5000000	8/13/2015	
US83417KDE55	SolarCity Corp	USD	5,45	8/13/2030	5000000	8/13/2015	
US83417KAN81	SolarCity Corp	USD	3,6	4/2/2020	24000	4/2/2015	
US83417KEN46	SolarCity Corp	USD	2,65	11/5/2018	5000000	11/5/2015	
US83417KAV08	SolarCity Corp	USD	5,45	4/9/2030	12000	4/9/2015	
US83417KBS69	SolarCity Corp	USD	5,45	5/29/2030	10000000	5/29/2015	
US83417KBD90	SolarCity Corp	USD	5,45	4/30/2030	10000000	4/30/2015	
US83417KDP03	SolarCity Corp	USD	4,7	8/27/2025	5000000	8/27/2015	
US83417KCA43	SolarCity Corp	USD	5,45	6/18/2030	5000000	6/18/2015	
US83417KDV70	SolarCity Corp	USD	5,45	9/3/2030	5000000	9/3/2015	
US83417KDS42	SolarCity Corp	USD	2,65	9/3/2018	5000000	9/3/2015	
US83417KDT25	SolarCity Corp	USD	3,6	9/3/2020	5000000	9/3/2015	

US83417KEC80	SolarCity Corp	USD	2,65	10/1/2018	5000000	10/1/2015
US83417KED63	SolarCity Corp	USD	3,6	10/1/2020	5000000	10/1/2015
US83417KEE47	SolarCity Corp	USD	4,7	10/1/2025	5000000	10/1/2015

Table 2: Correlation values between bid-ask spreads and %ZTD

	Bid-ask spread	Zero-trading days
Bid-ask spread	1	
Zero-trading days	0.3742	1

Table 3: Correlation values between independent variables

	Maturity	GovernmentBond	Term slope	Volatility	Rating Scale	I/S	D/A	D/C
Maturity	1.00							
GovernmentBond	0.06	1.00						
Term slope	-0.05	-0.42	1.00					
Volatility	0.48	0.15	-0.10	1.00				
Rating Scale	0.31	0.07	0.17	0.43	1.00			
I/S	-0.12	0.08	0.12	-0.20	-0.36	1.00		
D/A	0.25	0.13	0.11	0.11	0.42	0.32	1.00	
D/C	-0.26	-0.18	0.06	-0.32	-0.43	0.14	0.21	1.00

Table 4: Breusch and Pagan Lagrangian multiplier test for random effects

	Model 1	Model 2
Bid-ask spread	0.0001***	0.0095***
%ZTD	0.0014***	0.0013***
ILLIQ	0.4435	0.2594

Notes: the cell values represent the chi-square values

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