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Exploring the Green Premium in Corporate Green Bonds

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Abstract

This paper studies the pricing of green corporate bonds in the global bond market from January 2019 to July 2019 to determine the impact of pro-environmental preferences on bond prices. We employ a matching methodology in combination with regression analysis to isolate the difference in the yield that is attributable to the green label of a green corporate bond, where a negative yield difference indicates a positive green premium. We find a small green premium of -1.5 basis points, indicating a lower yield for green bond investors and a lower cost of funding for issuers than a comparative conventional bond. We find that financial green bonds and non-financial green bonds have green premia of -3.1 and 1.2 basis points, respectively. This negative green premium in non-financial green bonds is concentrated in green bonds issued by firms with high pollution, with transition bonds having a negative green premium of 2.2 basis points. These results indicate a willingness of investors to accept lower returns in exchange for the funding of environmental projects through green bonds, except when those green bonds are issued by highly environmentally damaging companies.

Keywords: Asset management; Corporate bonds; Green bonds; Market microstructure; Sustainable investing

JEL Classification: C23; G12; G14; G32; H12; Q56

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1. Introduction

As modern civilization and industrial activity continues to expand, the levels of atmospheric carbon dioxide continue to rise, and climate change has become an increasingly significant threat to the health of the earth. NASA outlines 9 key pieces of evidence for the existence of these trends: global temperature rise, warming oceans, shrinking ice sheets, glacial retreat, decreased snow cover, sea level rise, declining arctic sea ice, increased extreme weather events, and ocean acidification (NASA, 2019). In order to combat these changes, significant changes are required in the activities of humans, both individually and through the corporations that we operate. Not only do these climate changes pose significant health and safety risks to humans, but they also pose a real threat to economic output and the profitability of corporations. Extreme natural disasters alone cause a $520 billion loss in annual global economic output (IFC, 2018). These changes will require vast sums of capital to fund. One estimate suggests that $25 trillion will be required over the next 25 years in order to maintain the goal outlined in the Paris Climate Agreement to keep the global average temperature from rising to 2 degrees Celsius above pre-industrial levels (Bloomberg New Energy Finance, 2015). This 2 degree level is simply the baseline goal, with more ambitious reductions in climate change requiring vastly larger amounts of funding. Simply put, the combating of climate change will require enormous investments by individuals and corporations alike.

Investor interest in facilitating and financing environmentally beneficial projects has seen tremendous growth in the last decade. By signing the Montreal Carbon Pledge, more than 120 signatories with in excess of $10 trillion assets under management formalized their commitment to supporting the development of the green bond market and to measuring and reporting the environmental impact of their portfolio of investments (Zerbib, 2019). Many governing bodies have also continued to expand regulations and standards regarding green financing and reporting, making it easier for investors to track the environmental performance of corporations. The Technical Expert Group on sustainable finance of the European Commission, for example, published its Report on EU Green Bond Standard in June 2019. This report presents the group’s recommendations on a green bond standard to be implemented in the European Union. The main recommendation presented in this report is for the European Commission to create a voluntary and non-legislative EU Green Bond Standard. This standard will, according to the Technical Expert Group, encourage market participants to issue and invest in EU green bonds by enhancing transparency, comparability and credibility within the market for green bonds (EU Technical Expert Group on Sustainable Finance, 2019).

A green bond is a financial product that aims to address this need for the funding of projects beneficial to the health of the climate. A green bond is a fixed income product where the proceeds raised by the bond are allocated to projects that are beneficial to the sustainability of the environment. The International Capital Markets Association (ICMA) has emerged as a primary governing body for the green bond market. The Green Bond Principles, developed by the ICMA, have become accepted as the guidelines for determining whether a bond is a green bond. According to the ICMA, the Green Bond Principles provide guidelines within the green bond market that promote transparency, disclosure, reporting and integrity. A focus on the use of proceeds of the funds raised by the bonds facilitates the use of capital raised in the debt markets for environmental projects, while also making it easier to track the environmental impact of these bonds (ICMA, 2018). This process of standardization is a key aspect in ensuring the reliability of these products as investments with predictable cash flows and collateral amounts, particularly for insurance companies and pension funds, where bonds make up 64% and 53% of assets under management, respectively (OECD, 2015).

The foundations of green bond guidelines such as the Green Bond Principles are based on the United Nations Sustainable Development Goals established in 2015 as part of the 2030 Agenda for Sustainable Development, which outlines a total of 17 Sustainable Development Goals (SDG's) as a blueprint for a sustainable world (United Nations, 2019). Specifically, the Green Bond Principles apply to 3 of these SDG's. These SDG's are Clean Water and Sanitation, Affordable and Clean Energy, and Sustainable Cities and Communities, SDG numbers 6, 7, and 11 respectively. Banks such as ING also base their green bond frameworks on the Green Bond Principles and the United Nations SDG's when issuing their own green bonds (ING, 2019).

The processes and qualifications for certifying green bonds at issuance are crucial in normalizing the market and ensuring the traceability and impact of green bonds. But accountability is also necessary beyond the initial issuance period to ensure accountability and prevent greenwashing, the practice of deceptively using green marketing to create an appearance of an organization being environmentally friendly. Third-party auditors and consulting firms offer verification services to ensure that green mandates are being met with the funds that are raised through green bonds. This has provided another layer of credibility to the green bond as an investment product and has allowed the market to continue to grow in scale. Sustainalytics is a market leader in the third-party auditing and tracking of green bonds. Sustainalytics provides services to ensure that green bond frameworks laid out by green bond issuers appropriately comply with the Green Bond Principles. They also provide an extensive database of information regarding the continued "greenness" of companies. This is a valuable resource for investors to ensure that green bond issuers continue to use funds in environmentally friendly ways, and it is also an effective way of keeping green bond issuers accountable and honest, preventing things such as greenwashing and improving trust in the green bond market. Sustainalytics has also developed a research-based methodology of scoring companies based on their environmental, social and governance activities. Specifically, the environmental score can be an easy way for investors to quickly understand how environmentally friendly companies are, while also providing an insight into things like the fossil fuel involvement and carbon intensity of over 10,000 companies.

Since the inception of the green bond market, it has grown rapidly. The expansion and maturation of this market has been essential in allowing investors to gain access to reliable green investment options. The first green bond was issued by the European Investment Bank (EIB) in 2007, with the World Bank following suit with their own green bond issuance in 2008. The first $1 billion issuance took place in March

2013, being issued by the International Finance Corporation, and was sold within an hour of its issuance. November of 2013 saw the first issuance of corporate green bonds. Annual issuance of green bonds has increased year over year, every year since 2013, with $167.3 billion worth of green bonds being issued in 2018, according to the Climate Bonds Initiative (Climate Bonds Initiative, 2019). This 70% compound annual growth rate highlights the rapid growth in the size of the green bond market. The issuance of green bonds has grown in popularity in recent years and is expected to continue to do so in the future. Nearly all of the green bonds that have been issued in the past have been oversubscribed, which is indicative of the interest investors have taken in investing in bonds that dedicate the funds raised to projects that benefit the environment (EY, 2016). The steady growth of the green bond market has also led to the introduction of green bond products such as ETF's, mutual funds and indices that track the green bond market. Firms such as Bloomberg, MSCI, Bank of America Merrill Lynch, and S&P Dow Jones Indices offer green bond indices. Blackrock, Morningstar and Nationale Nederlanden, among others, offer mutual fund and ETF products that track green bond indices.

In the early years of the green bond market, governments and development banks made up the vast majority of green bond issuances, while corporate debt made up only a small portion of the green bond market. Sovereign green bonds have continued to be an important part of the green bond market. The State of the Netherlands, for example, was the first country with a AAA credit rating to issue a green bond in May 2019. The proceeds from the €5.98 billion issuance will be used to fund projects such as renewable energy, clean transportation and climate change adaptation (Dutch State Treasury Agency, 2019). However, corporate green bond issuances have also continued to increase, with financial and non-financial corporate green bonds accounting for 29% and 17% of the total green bond market, respectively. Financial corporate green bonds, which are issued by firms such as banks, asset managers and insurance companies, have seen a particularly strong rise, seeing a 15% rise in their share of the total green bond market compared to 2017 (Climate Bonds Initiative, 2019). Corporations and governing bodies alike see green bonds as an effective way to finance environmentally beneficial projects while also increasing social awareness of their environmental ambitions. As environmental concerns become more important in today's society, investors are increasingly seeking to make a positive impact with their capital, while still earning a competitive financial return.

Importantly, the green bond certification process depends on the issuance itself and the use of the proceeds raised by the bond, and not the issuing entity as a whole. This allows for any entity, even those that are not environmentally friendly by nature in their daily operations, to issue bonds that fund projects that benefit the environment. Shell, for example, is able to use green bonds to fund projects that benefit the environment, while still being a firm that operates in an industry with a strong fossil fuel stigma. A concern regarding carbon intensive firms is that they are often not able to issue green bonds due to a lack of necessary assets or a business model that simply does not warrant a green project, and thus are less incentivized to fund projects that are beneficial for the environment. This leaves the corporate green bond market largely dominated by firms that want to start new, green projects, as opposed to environmentally damaging firms such as energy producers or miners that want to become less environmentally damaging. The issuance of green bonds by highly pollutant companies may also draw skepticism from investors that doubt whether the bonds are really green. Transition bonds have recently been proposed as a way to bridge this gap. Where green bonds require the use of proceeds to be used for a green project, transition bonds simply require businesses to become *more green*, financing projects such as cogeneration plants, carbon storage facilities and waste-to-energy systems (AXA Investment Managers, 2019). The development of the transition bond market is in its infancy stages. While there is no agreed upon set of guidelines or qualifications to regulate the transition bond market, there have been green bond issuances that fit within the general parameters of a transition bond. These are green bonds that are issued by companies that operate in industries that are greenhouse gas intensive, such as the energy, chemicals and materials industries. Italian gas utility Snam, for example, issued a €500 million green bond in February 2019. AXA Investment Managers leads a working group that is hoping to develop a set of formal principles that define the transition bond market (AXA Investment Managers, 2019). While there is currently no established transition bond market, this potential market can be studied by examining green bonds that are issued by firms that, as part of their daily business operations, generate high levels of pollution.

With the push towards more environmentally friendly business practices, one of the key industries that will face rapid change is the utilities industry. While the demand for electricity continues to grow, the way that consumers want that energy to be generated is changing drastically. A large push is being made to replace fossil fuel burning techniques with renewable resources, such as solar and wind power. Utilities are responsible for 31% of the greenhouse gases that are emitted globally (Morrow et al., 2015). While most companies in the industry are making moves to become more environmentally friendly and less dependent on conventional energy sources like coal, the majority of utility companies still produce large amounts of greenhouse gases that are very damaging to the environment. Companies such as these are able to issue green bonds as a way to fund projects that allow them to become more dependent on renewable sources of energy. However, these are also the sorts of green bonds that investors can be skeptical of, wary of the potential for greenwashing.

The motivations for bond issuers to seek green bond certifications for their bond issuances can vary greatly. Agency motive and state-driven stakeholder motives are two of the significant drivers for enthusiasm in the issuance of green bonds as opposed to simply issuing a conventional bond (Glavas and Bancel, 2018). Green bonds can draw the attention and funds of new investors by enticing environmentally minded investors to invest in issuers that place their environmental values at the forefront. Additionally, the issuance and promotion of an institution or corporation's green bond can promote its brand as an environmentally friendly entity.

Within the green bond market, a balance must be found between the funding costs for green bond issuers and the yield provided to green bond investors. To facilitate the continued expansion of the corporate green bond market, a low funding cost is required to incentivize corporate issuers to continue to issue green debt. There are additional costs associated with certifying green bonds as green, so corporations must be able to obtain enough benefits from the issuance of green bonds to counteract those additional costs. Additionally, while investors certainly have social incentives to invest in green bonds, there must also be enough financial incentives to drive the growth of the green bond interest beyond a niche market for only the most socially responsible of investors.

There is a simple relationship between the funding cost for green bond issuers and the financial return for green bond investors: a higher financial return for investors of green bonds means that the issuers of those green bonds have higher funding costs, and vice versa.

This paper looks to answer the following question: *Do investors in corporate green bonds forgo financial returns in order to gain larger environmental benefits?* In other words, this paper looks to study whether there is a green premium, positive (meaning lower financing costs of green bonds for issuers and lower yields for green bond investors as compared to otherwise similar non-green bonds) or negative (meaning higher financing costs of green bonds for issuers and higher yields for investors as compared to otherwise similar non-green bonds), that exists within the corporate green bond market. Further, it also looks to study whether the financial returns that investors earn when investing in green bonds versus traditional bonds depends on whether the green bond is issued by a financial or non-financial firm. In other words, this paper looks to identify the difference in green premium in financial versus non-financial green corporate bonds. Finally, we also examine the green premium of bonds issued by highly polluting utility companies to study how the corporate bond market prices green bonds issued by decidedly non-environmentally friendly issuers. This paper seeks to understand the answers to these questions within the framework of a hypothesis that says that there is no significant green premium within the corporate green bond market, that there is no significant difference in green premium in financial versus non-financial green bonds, and that there is no significant difference in the green premium of bonds issued by highly polluting firms, referred to as transition bonds.

In order to answer these questions, a method is used to control for the various risks inherently priced into corporate bonds, so as to extrapolate any pricing difference due strictly to whether or not a bond carries a green label or not. To do this, a matching method is implemented to generate matched green and conventional bond pairs for a sample of 265 green corporate bonds, resulting in a sample of 79 matched pairs of green and conventional bonds. This sample is then further split into financial and non-financial green corporate bonds to identify whether this relationship varies in the two subsections of the green corporate bond market. We then finally construct a subsample of the most poorly environmentally performing companies within the sample, as determined by their Sustainalytics environmental score, to study the green premium in bonds that could be classified as transition bonds. Implementing a stricter set of matching criteria than other studies that have utilized similar matching methods ensures better controls of premia priced into the green bonds for reasons other than their green label. As this matching method does not allow for the full control of bond liquidity, a fixed panel regression is then utilized, with bond price bid-ask spread differences and bid-ask spread differences as a percent of the bond's price as liquidity proxies, to extract any premium associated with a corporate bond's green label.

Our findings indicate the existence of a small green premium in the corporate bond market of -1.5 basis points, indicating a financial sacrifice investors must make when investing in green bonds. We find a difference in the sign of the green premium depending on the industry segment of the green bond issuer, where financial green bonds have a green premium of -3.1 basis points, as opposed to those issued by non-financial institutions, with a negative green premium of 1.2 basis points. This negative green premium in non-financial green bonds, however, is dominated by those bonds issued by especially non-environmentally friendly firms, with transition bonds having a negative green premium of 2.2 basis points. All non-financial industries have positive green premia except for the utilities industry.

The remainder of this paper is structured as follows: Section 2 explores the findings of related literature both in the performance of green bonds and in the use of proxies of corporate bond liquidity. Section 3 describes the data used to conduct the study. Section 4 details the methodology used to explore the green premium in corporate green bonds. Section 5 presents the key results of the paper, and section 6 concludes in addition to exploring limitations and potential future research opportunities.

2. Literature Review

The research presented within this paper expands upon existing research in two fields: (1) analysis of the performance and pricing of green bonds in primary and secondary markets and (2) research that analyzes the impact of liquidity on the pricing of bonds, and that studies the effectiveness of different measurements of bond liquidity, namely in corporate bonds.

2.1 Green Bond Performance

The body of research analyzing the broad universe of environmental, social and governance (ESG) fixed income investing as well as the impact of the "greenness" of a company on their cost of raising financing in the debt market is extensive (Bauer and Hann (2014), Chowdhry et al. (2017), Derwall and Koedijk (2009), Drut (2010), Flammer (2018), and Vargas et al. (2014)). However, due to the youth of the green bond as a financial product and the small size of the green bond market compared to the overall bond market, the literature analyzing the performance of green bonds and green bond portfolios is limited in size, particularly with respect to the corporate green bond market.

Zerbib (2019) utilizes a matching methodology to extrapolate a green premium in the entire sample of investment grade green bonds. This green premium is extrapolated by creating a synthetic conventional bond for each green bond in the sample, with this synthetic conventional bond being constructed using the two conventional bonds, issued by the same issuer as the green bond, that are most similar to the green bond. These conventional bonds must have two of the following three qualifications: the maturity is within 2 years of the maturity of the green bond, the issue amount is within ¼ to four times that of the issue amount of the green bond, and the issue date is within 6 years of the issue date of the green bond. This method allows Zerbib (2019) to fully eliminate credit risk, as well as limit maturity and liquidity risk. There is no specific qualification for bond duration employed. They find that green bonds have lower yields than comparable conventional bonds from 2013 to 2016. This negative yield difference indicates a preference for green bonds in the bond market. Zerbib (2019) analyzes the determinants of this green premium, concluding that credit rating and issuer type are the main determinants of the green premium in green bonds. While they find an average green premium of -2 basis points, they report a wide variation of this green premium within the sample, with lower rated bonds and financial bonds experiencing larger green premia.

Ehlers and Packer (2017) use a similar matching method to find that US dollar and Euro denominated green bonds experience an average spread of 18 basis points lower than their matched conventional bonds at initial issuance in the primary market. This difference is attributed to increased investor demand driving green bond pricing at issuance. The matching method employed in this study allows for the control of credit risk, but does not enable for the controlling of a liquidity premium.

Multiple studies have analyzed the existence of a green premium in the US municipal bond market. Karpf and Mandel (2017) report that conventional US municipal bonds experience higher returns than US municipal green bonds on average. Specifically, they find that the average difference in returns between conventional and green bonds in their sample of 1,880 municipal bonds and 36,000 conventional bonds is 23 basis points. However, they express that the difference in performance can be explained by properties of the issuing entity and of the bond itself, rather than the bond being green or not. They also find that green bonds are traded at lower prices than comparable conventional bonds, indicating that "greenness" of a bond is penalized. Baker et al. (2018) develop and test an asset pricing framework for green bond pricing and portfolio choice. In contrast to Karpf and Mandel (2017), they find a lower after-tax yield for green US municipal bonds than conventional US municipal bonds. This green premium of -6 basis points, the authors argue, offsets the additional disclosure costs that issuers are required to pay when issuing green bonds. This study does not use a matching strategy, and the regression analysis performed does not specifically control for potential liquidity differences in green and conventional bonds. Partridge and Medda (2018) study the yield curves of green US municipal bonds to study the green premium in both the primary and secondary markets. A green bond premium of -4 basis points is found. This premium is shown to be increasing over time, and the authors highlight the possibility that it can be attributed to the increased costs of disclosure for green bonds.

Practitioner research presented by Shurey (2017) studies the pricing of 12 supranational Euro-denominated green bonds and finds a significant green premium. However, this green premium is not found to exist in USD-denominated supranational green bonds or corporate green bonds. A series of bank studies and reports explore the pricing and performance of green bonds in the primary and secondary markets by comparing the differences in the yield of green bonds and conventional bonds, albeit without the use of econometric methods that would allow them to effectively control for many of the risk factors other than their green label that may contribute to risk premia priced into green bonds. Barclays (2015) finds a premium for green bonds in the secondary market compared to similar conventional bonds of -17 basis points from 2014 to 2015. Similarly, Bloomberg (2017) identifies a green premium for EUR denominated green bonds. However, a green premium is not detected in USD denominated and corporate bonds. Nationale Nederlanden Investment Partners (2018) calculate the difference in the spread of green and conventional bonds within a sample of 27 bonds and identify a -1.1 basis point green premium from 2014 to 2017. HSBC (2016), however, studies a sample of 30 green bonds, in which a green premium is found not to exist in the primary market. In line with this result, Climate Bonds Initiative (2017) fails to find a significant yield difference in the primary market, although they do note the frequent oversubscription to green bonds, indicating unmet investor demand for green bonds. OECD (2017), however, shows the existence of flat pricing in the green bond market, indicating a lack of interest by investors to pay a premium for green bonds.

2.2 Bond Liquidity Proxies

As the matching method implemented in this study does not allow for the full control of liquidity difference between green and conventional bonds, it is important to utilize an additional control for liquidity. For this, a strong corporate bond liquidity proxy is necessary.

It is widely documented that the liquidity of a bond is priced into its price, with less liquid bonds having a higher liquidity premium (Houweling et al., 2005). Acharya and Pederson (2005) develop a liquidity adjusted capital asset pricing model that shows that the required return of an asset depends on its expected liquidity. Brandt and Kavajecz (2005) use U.S. Treasury market microstructure data to show that liquidity has a significant impact on price discovery as well as on the yield curve of U.S. Treasuries. This impact of liquidity on the price of bonds becomes particularly important when examining corporate bonds, as they typically trade less frequently than government-issued bonds (Helwege et al., 2014). This is often a unique problem as the age of the bond increases, due to a larger portion of the issuance finding its way into the portfolios of buy and hold investors that do not actively trade the bond. Helwege et al. (2014) study the effectiveness of eight different liquidity measures as proxies for corporate bond liquidity by comparing multiple bonds issued by the same firm. They find that, when credit risk is controlled for, the liquidity proxies studied adequately capture the difference in liquidity, although not perfectly. Among the liquidity proxies studied are age, issued amount, and percentage of zero trading days. Similarly, Galliani et al. (2014) study the effectiveness of various liquidity measures by examining corporate, covered and government bonds in the European market. They find that bond-specific measures, specifically a bond's rating, time to maturity, issue size, and duration, drive the liquidity of bonds.

However, there are many additional potential measures that can be used as a proxy for liquidity. Further literature has examined these measures more closely to determine their effectiveness as liquidity proxies for financial securities. Broadly, these proxies can be broken into two categories: direct proxies based on market trading activity and indirect proxies based on characteristics of the bond. The proxies studied in existing literature are further discussed here.

Bid-Ask Spread

The bid-ask spread has been examined by various studies to evaluate its effectiveness as a liquidity proxy for securities, and is frequently used in studies as a measure of liquidity of an asset. The bid-ask spread of an asset is the difference between its bid and ask price. A larger spread between the price a buyer is willing to pay and the price a seller is willing to accept reflects a lower level of liquidity for that security, and vice versa. Decreased spreads in the prices of an asset reflect a larger trading volume, which may lead to smaller price fluctuations with steadier price movements (Febrian & Herwany, 2008).

Amihud and Mendelson (1986) develop a stock pricing model to show that there is a positive and concave relationship between the bid-ask spread of an asset and its market-observed expected return. This positive function is reflective of investors requiring a larger return for assets that are less liquid.

Zerbib (2019) employs the closing yield bid-ask spread to proxy the liquidity of a sample of bonds that includes corporate bonds, as well as other types of bonds. This liquidity proxy is found to be effective in modeling the liquidity of bonds in the secondary market. Similarly, Chakravarty and Sarkar (1999) study the determinants of the realized bid-ask spread in the US municipal, government, and corporate bond markets and find bond liquidity is a significant factor in the realized bid-ask spread in all three bond markets.

While bid-ask spread can be an effective liquidity proxy for equities, the limited availability of this data for bonds can make it difficult to use when studying the liquidity present in bond markets, particularly for more thinly traded bonds (Chen et al., 2007) as well as for bonds with a higher age (Helwege et al., 2014). Many studies have therefore posited models with varying levels of complexity to estimate the effective bid-ask spread of a security where high frequency spread data is unavailable. Roll (1984) estimates the effective bid-ask spread of a security as $2\sqrt{-cov}$, where "cov" is the first order serial covariance of the price changes of the asset. This estimator is based on the intuition that trading costs of an asset induce a negative serial dependence in sequential market price observations.

Zhao and Wang (2015) study the LOT estimator as a model of the effective bid-ask spread where high frequency data is not available for a security. The LOT model, first proposed by Lesmond et al. (1999), reflects the impact that transaction costs have on the daily return of a security that results in the occurrence of a return of zero. Zhao and Wang (2015) find that the LOT estimator, when using the correct estimation procedure, can be an appropriate measure of liquidity of a security.

Corwin and Schultz (2012) develop a simple bid-ask spread estimator using daily high and low prices of an equity. This spread estimator, derived as a function of the ratio between the high and low prices over one and two day intervals, is empirically tested and found to be effective in modeling bid-ask spread in ideal conditions. But it is found to underestimate bid-ask spreads when asset prices are observed sporadically or when asset prices change drastically from the close of one trading day to the open of the next. Corwin and Schultz (2012) find this high-low estimator to be a more accurate bid-ask spread estimator than other existing estimation models, including the LOT estimator (Lesmond et al., 1999) as well as the Roll (1984) covariance spread estimator.

Longstaff et al. (2005) study corporate bond spreads to study the pricing components associated with different risks within the spreads by studying credit default swaps. They find that a significant portion of corporate bond spreads reflect default risk. They also find that the component not related to default risk is strongly related to bond-specific and macroeconomic illiquidity levels.

Pelizzon et al. (2013) study microstructure data from sovereign debt markets during the Euro-zone sovereign debt crisis to examine micro-level liquidity in Italian sovereign bonds, and how liquidity reacts to changes in policy, and how it interacts with credit risk during a crisis. They use this micro-level pricing data to show that, during times of crisis, frequent price quote revisions do not reflect a larger level of liquidity, and that the effective spread is an effective method in analyzing the market-marking behavior of market makers in a market that is experiencing a crisis. They also find, by analyzing bid-ask spreads of

Italian sovereign bonds, that illiquid bonds can have a contagion effect during liquidity crises in that they can cause illiquidity to spread to other bonds in the same and other countries.

Van Loon et al. (2015) develop a liquidity measure based on the bid-ask spread of corporate bonds to study the behavior of the liquidity of corporate bonds prior to, during, and after the financial crisis of 2008. They create the liquidity measure Relative Bid Ask Spread (RBAS), defined by the following equation:

$$RBAS_{i,t} = e^{\epsilon BAS_{i,t}} \tag{1}$$

Where i, t is bond i at time t, and BAS is the bid ask spread. They use this liquidity measure to show that the liquidity premium in the corporate bond market varies with time, and that there is a widening of the liquidity premium during the years after the crisis.

Zero-Trading Days

The zero-trading days (ZTD) measure is calculated as the percentage of days during a specified trading period where a security did not trade. It is defined by the following equation:

$$ZTD_{i,t} = \frac{\#\ of\ zero\ trading\ days_t}{\#\ of\ trading\ days_t} \tag{2}$$

where i, t is bond i in time period t. A higher ZTD value represents a higher portion of days where the asset experienced zero trading activity, and thus represents a lower level of liquidity for the asset.

Chen et al. (2007) study the association between bond liquidity and yield bid-ask spreads in a sample of 4,000 corporate bonds. They find a high and significant association between the percentage of zero trading days and the underlying bid-ask spread, indicating that liquidity is a key determinant in yield spreads, and that the ZTD measure is an effective predictor for liquidity in the corporate bond market. Dick-Nielson et al. (2012) study corporate bond spread data from 2005-2009 to determine the effectiveness of the ZTD measure as a metric for liquidity during the subprime mortgage crisis of 2008. They find that the effectiveness of the ZTD measure as a proxy for corporate bond liquidity disappears in large part during the crisis. Their results show that the number of zero-trading days during the crisis decreased due to the trades of less liquid bonds being divided up into smaller trades, causing a larger number of days that experienced some form of trading activity. While these less liquid corporate bonds experienced a dramatic widening of bid-ask spreads during the crisis, the ZTD measure actually indicated the opposite.

Zerbib (2019) uses a form of the ZTD measure as a liquidity proxy when modeling the green premium of matched green and conventional bond pairs in the entire bond universe. They employ a binary variable whereby the ZTD variable is defined as equal to 1 for trading day *t* if the price of the bond does not vary during that trading day, and zero if it does vary. While Zerbib (2019) finds that the ZTD measure provides significant results as a proxy of bond liquidity, significance levels are lower than when using the closing yield bid-ask spread as a measure of bond liquidity.

ILLIQ Measure

The ILLIQ measure is a measurement of price impact of a security. It measures how the price of an asset responds to a unit change in its volume. Specifically, it is the daily ratio of the absolute return of a security to its daily volume, averaged over a period of time. ILLIQ is defined by the following equation:

$$ILLIQ_{i,t} = \frac{1}{D_{i,t}} \sum_{t=1}^{D_{i,t}} \frac{|R_i|}{VOL_i} \qquad (3)$$

where i and t denote 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. A higher ILLIQ measure for a security indicates a higher level of price change for a given change in its volume, indicating a lower level of liquidity. In other words, an illiquid bond will experience higher levels of price change than a liquid bond, and thus would have a higher ILLIQ measure.

Amihud (2002) studies the relationship between stock illiquidity and stock returns over time, using the ILLIQ measure to measure stock illiquidity. They posit that ILLIQ is an effective stock liquidity proxy in the absence of market microstructure data on quotes and transactions, as only stock prices and volumes are required in calculating ILLIQ. Amihud (2002) shows that the ILLIQ measure is strongly priced in the cross section of equity returns. Amihud et al. (2005) explore empirical applications of ILLIQ as a liquidity measure in various asset classes. They find that ILLIQ has been effectively implemented as a proxy for asset liquidity in studying the cross-sectional returns of equities, closed end funds, corporate bonds, and American Depository Receipts (ADRs).

Brennan et al. (2013) further explore the ILLIQ measure by decomposing it into elements that correspond with days of positive and negative returns. They find that the element corresponding with the negative return days commands a return premium in equities while the element of positive return days does not.

Age

The age of a bond, defined as the time since its original issuance, is often used as a proxy for its liquidity, with age often assumed to have a positive correlation with illiquidity. Sarig and Wargo (1989) observe that, as a bonds age increases, a larger percentage of the issuance ends up in buy-and-hold portfolios, which decreases its trading liquidity in the market. This conclusion was confirmed by Schultz (2001), who found that, in a sample of bonds, a high number of bonds were purchased but not sold. This indicates that the bonds are ending up in the portfolios of buy-and-hold investors that do not actively trade them. An interesting distinction with this metric is that there is no agreed upon threshold as to at what point a bond transitions from “young” to “old”. Elton et al. (2002) define the threshold as 1 year, while Alexander et al. (2000) define it as 2 years. Other studies offer yet different time thresholds, both longer and shorter.

Alexander et al. (2000) study individual high yield bond issuances as well as US treasuries to study the effect of a bond’s age on its volume. They find that corporate bond issues that have an age of less than two years old have higher volumes than corporate bond issues that are older than two years, and are thus more liquid. They argue that this provides an extension of the empirical results of earlier studies that found that the Treasury securities experience a drop off in liquidity after a period of initial trading during the first few months after issuance. Similarly, Bao et al. (2011) utilize corporate bond transaction data from 2003 to 2009 to show that the illiquidity of corporate bonds increases with the age of a bond, meaning that as a bond matures, it becomes less liquid.

Quoted Volume

The market volume represents the total number of transactions conducted by market participants in a specific market over a period of time. Volume is a metric often used to describe the activity of the stock market, giving the number of shares that changed hands during a single day. A higher volume indicates a larger number of units of a security changing hands. Higher volume for an asset is often associated with higher liquidity. Demsetz (1968) developed the original intuition that larger, more active markets are more liquid by showing that more frequently traded stocks experienced lower bid-ask spreads. Similarly, Kyle (1985) developed a model of asymmetric information where there is an inversely proportional relationship between illiquidity and uninformed demand for an asset (and thus its volume). This, then, leads to the conclusion that a higher volume indicates a higher level of liquidity.

However, many recent studies have found results that contradict results that indicate this positive relationship between volume and liquidity. Evans and Lyons (2002) study time varying liquidity in foreign exchange markets. They find that there is no relationship between the level of trading activity in the foreign exchange markets and liquidity. Danielson and Payne (2002) study high frequency DEM/USD exchange rate data, and find a negative relationship between quoted volume and liquidity. Foster and Viswanathan (1993) find this same negative association in stocks traded on the NYSE. Fleming (2001) studies the effectiveness of various liquidity measures within U.S. Treasury market, and finds that trading frequency and trading volume exhibit low correlations with bid-ask spread and price impact, indicating their weakness as a measure of liquidity.

Issue Size

The issue size of a bond is a metric often used to determine the liquidity of a bond. This is simply the face value of the bond multiplied by the number of bonds issued. Issue size is frequently used as a criterion for determining whether a bond is liquid enough to be included in a bond index or not. A potential reason for this relationship between issued amount and liquidity may be that small bond issues may more quickly end up in buy-and-hold portfolios, significantly reducing their trade activity (Sarig and Warga, 1989). Crabbe and Turner (1995) argue that information costs are lower for large issue bonds, since a larger portion of investors own the bond, or have researched it, leading to an illiquidity premium for smaller issues for which this is not the case.

Bao et al. (2011) study transaction data from the corporate bond market from 2003 to 2009 to prove the existence of a positive relationship between a bonds liquidity and the size of its issuance. Similarly, Alexander et al. (2000) confirm that, in corporate bond markets, bonds with larger initial issuances experience higher trade volumes. Houweling et al. (2005) consider nine liquidity proxies including issued amount, listed, euro, on-the-run, age, missing prices, yield volatility, number of contributors, and yield dispersion to price liquidity risk in corporate bonds. They find that all proxies except for "listed" are effective proxies for liquidity. However, they find that the strongest proxies are the issue amount and the yield dispersion.

Pelizzon et al. (2013) study microstructure data of Italian sovereign bonds, and find a relationship between bid-ask spread, issue size and age. Specifically, they find that, from June 2011 to November 2012, recently issued bonds with larger issue sizes have smaller quoted bid-ask spreads.

Existing literature has studied the existence of a green premium priced into green bonds. However, the current body of literature remains inconclusive as to whether there is a positive or negative green premium, or no premium at all. Many existing studies also fail to properly control for liquidity premiums priced into bonds. The present body of literature also fails to account for inflation risk in bond pricing models. Kang and Pflueger (2014) find that corporate bond yields in the corporate bond markets of 6 developed countries reflect fears of debt deflation, and argue that inflation volatility is priced into corporate bond yields. In addition, the existing literature has focused predominantly on municipal and government bonds, or on the entire bond market as a whole. To the knowledge of the author, no study has examined exclusively the green premium priced into corporate bonds, particularly when explicitly also controlling for the liquidity premium.

This paper provides multiple contributions to the existing body of literature examining the green premium priced into bonds, with the main objective being to provide clarity to the currently inconclusive determination as to whether green bonds carry a green bond premium. First, to the knowledge of the author, this is the first study using the matching methodology, which also explicitly controls for liquidity differences, to study the green bond premium in the corporate green bond market. This study also employs more stringent matching criteria in creating matched green and conventional bond pairs, ensuring that the premium derived by this study can confidently be attributed to a green bond's green label, and not to another unspecified factor. Additionally, this study uses bond data from January 2019 to July 2019, which is more recent data than all other existing literature. This is particularly significant in the case of this study due to the youth of the green bond market. Using this most recent data allows for the opportunity to gain insight into the market in its most mature form possible, while studies that incorporate older bond data consider a market that is in a much more immature stage of development, which can impact bond pricing. We also provide insight into the distribution of the green premium within the corporate bond market by studying different subsamples within the corporate bond market. This paper builds on results found in previous literature to test the following null hypotheses:

Hypothesis 1: There is no statically significant green premium in the corporate bond market, meaning there is no difference in risk-adjusted yield between green and conventional bonds.

Hypothesis 2: There is no significant difference in the green premium in green bonds issued by financial firms versus green bonds issued by non-financial firms.

Hypothesis 3: There is no significant difference in the green premium in green bonds issued by highly environmentally damaging firms than green bonds issued by other non-financial firms.

Hypothesis 4: The bid-ask spread and bid-ask spread as a percentage of a bond's ask price are effective proxies for liquidity in the corporate bond market.

These hypotheses are tested using a series of tests based on the construction of a corporate bond database that allows for the isolation of any existing green premium by controlling for all other factors that may contribute to a difference in pricing when comparing a green bond to a conventional bond. The database construction and regression methodology employed in this study is further explained in Sections 3 and 4.

3. Data

In order to evaluate the yield difference between the yield of a green bond and its comparable conventional bond, a bond database is created by merging bond data obtained from Bloomberg and Thomson Reuters. To determine whether green bonds contain a green premium, we compare two identical bonds, where the only difference is the classification of one of the bonds being green. This process of matching green bonds to their identical conventional bonds, issued by the same corporation, allows for the elimination of all pricing premiums and biases not attributable to the green classification. A similar matching methodology, used to study the effects of liquidity on corporate bond spreads, is used by Helwege et al. (2014).

Similarly, this matching method is also used by Zerbib (2019) to study the green premium in the entire investment grade green bond market. Our research expands on the study of green bond premiums in multiple ways. Primarily, our research studies the corporate green bond specifically, and studies the difference in green premium in financial and non-financial corporate green bonds. We also study the green premium in green bonds issued by firms that operate produce large amounts of pollution in their daily business operations. While these are not officially labeled as transition bonds within the Bloomberg database, these bonds are referred to as transition bonds throughout this paper as these are the types of bonds that would likely be eligible for the transition bond label upon the development of a regulated set of transition bond standards. Additionally, we use more recent data than was available during previous studies, and we use more restrictive guidelines when creating matched bond pairs to further limit the possibilities for premiums not attributable to the green classification to persist in the model.

The bond universe from which the green bonds are selected includes all corporate high yield and investment grade actively traded bonds designated as green bonds in Bloomberg. This includes both financial and non-financial corporate bond issuances. All bonds are identified by their ISIN codes, which are obtained from Bloomberg. A green bond classification in Bloomberg is achieved if the bond complies with the Green Bond Principles. Only green bonds issued on or before January 5th, 2019 are studied, ensuring an age of at least 6 months. Unrated bonds are excluded from the sample. Additionally, any bond issued by an organization with a BICS (Bloomberg Industry Classification Systems) classification of Government is excluded. This yields a universe of 265 corporate green bonds as of July 5th, 2019. A final sample of 79 matched pairs of green and conventional bonds are used in this study. This sample contains 28 non-financial corporate bond pairs and 51 financial corporate bond pairs.

To create matched green and conventional bond pairs, we identify a conventional bond for each green bond that is identical for characteristics where possible, including being issued by the same corporation, and as similar as possible for characteristics where a perfectly identical characteristic match does not exist. If, for a given green bond, there does not exist a conventional bond that meets the matching criteria, that green bond is excluded from the sample. While strict criteria are employed to create matched bond pairs, it is important to identify that it is very difficult, if not impossible, to create perfectly matched green and conventional bond pairs. In order for a conventional bond to be a perfect match for a specific green bond, all bond characteristics must be identical to that of the green bond, which is something that, while hypothetically possible, is something that does not realistically occur in financial markets.

Many characteristics of bonds exist that are priced into bonds and which thus need to be controlled in order to eliminate the potential of diluting the premium that is attributable to the green classification of green bonds. Initially, bond structure and issuer characteristics are controlled for by matching green bonds with conventional bonds that have the same issuing entity, are issued in the same currency, and have the same Bloomberg Composite Rating, callability features, seniority, collateral structure, and coupon type. Matching these characteristics allows for not only the elimination of pricing bias due to the rating of the bond, but also due to many of the individual characteristics that contribute to a bond's rating and thus its credit risk. Matching the Bloomberg Composite Rating allows for the limitation of default risk, a significant risk priced into bonds (Fisher, 1959). The Bloomberg Composite Rating of a bond is calculated as the average of the DBRS, Fitch, Moody's and Standard & Poor's ratings. All non-rated bonds are removed from the sample.

Maturity is also a significant factor in the pricing of bonds, and thus is something that also needs to be controlled for (Fama and French, 1993). While possible, it is not always the case that a bond issuer has an active green bond and conventional bond with the same maturity. For this reason, the difference in bond maturity within the matched pair is limited to 2 years to limit the impact of the difference in maturity. This method of controlling for maturity bias is similar to that employed by Helwege et al. (2014) and Zerbib (2019). The difference in the modified duration of the matched bond pair is limited to 1.5 in either direction to further limit the difference in sensitivity to interest rate changes between the green and conventional bonds in a pair.

In addition to the maturity bias controlled for by the aforementioned qualifications, the liquidity bias is also controlled for. As defined in Zerbib (2019), the issued amount and date of issuance are effective ways to control for this when employing a matching methodology. Thus, a conventional bond is matched to a green bond if the issued amount is no less than ¼ the amount of the green bond, and no more than 4 times that of the green bond. All data for bonds is downloaded in USD. For bonds that are issued in currencies other than USD, their issued amount is converted to the USD equivalent, at the exchange rate at the time of issuance. Additionally, the issue date of the conventional bond must be within 3 years of the issue date of the green bond. These steps allow for the limitation, but not elimination, of the liquidity bias. The additional steps taken to control for liquidity bias are controlled with a fixed effect regression process, which will be outlined in the methodology section.

These liquidity and maturity bias controls employed are more stringent than those employed by Zerbib (2019) in that Zerbib (2019) requires only two of the following three qualifications to be met: difference in maturity, difference in issued amount, and difference in issue date. We require all qualifications to be met in order to create a matched conventional and green bond pair, along with the other requirements identified throughout this section.

To ensure the availability of a complete set of pricing data, only bonds with an age of at least 183 calendar days (6 months) as of July 5, 2019 are included in the sample. This is equivalent to 131 trading days. This ensures a full 6-month period of yield data for the matched bond pairs. It also means that only actively traded bonds are included in the study sample, and matured and off the run bonds are excluded. Additionally, when multiple conventional bonds are available that fulfill all other previously mentioned matching criteria, the bond with the lowest age is selected. This is to ensure the highest possible effectiveness of the price bid-ask spread as a liquidity proxy, as Houweling et al. (2015) finds that the liquidity of a bond decreases as its age increases.

After studying the full bond sample, the sample is divided into subsamples of financial and non-financial green bonds to study the difference in green premium based on the issuers industry. We then create another subsample, denoted as the transition bond subsample. This sample includes green bonds issued by utility firms that earn low Sustainalytics environmental scores, and can thus be described as green bonds issued by non-environmentally friendly firms. Specifically, bonds are included in this subsample if their BICS industry is classified as utility, and their Sustainalytics score is below the average industry environmental average score of 59. Sustainalytics environmental scores are obtained from the Sustainalytics Thematic Research utilities report[1]. Sustainalytics environmental scores are available for 18 of the 21 utilities matched bond pairs in the full sample. The transition bond subsample includes 11 bonds. The composition of this sample, as well as energy production capacity information for each issuer, can be found in Table 18. It is notable to note that this is a relatively small sample size compared with the other samples studied in the report, which may have an adverse impact on the explanatory power of any results obtained when studying this sample. Additionally, the determination to make the cutoff of whether a bond pair is to be included in the sample at the mean environmental score of the industry is arbitrary, and a different score cutoff may lead to different results. The Sustainalytics environmental score is based on various indicators, including preparedness, disclosure, quantitative performance, and qualitative performance. Within each indicator, a company's score is based on a wide variety of factors, including ESG reporting, management policies, carbon intensity metrics, and environmental disasters. While Bloomberg specifically identifies green bonds due to their specified use of proceeds, there is no such designation in Bloomberg for transition bonds.

Once the matched bond pairs have been created, yield data is extracted for each green and conventional bond from the Thomson Reuters database. Specifically, the yield to maturity for each green and conventional bond from January 5th, 2019 to July 5th, 2019 is obtained. Using the most recent 6 months of yield data ensures that the most recent market data is used. Due to the relative youth of the green bond market and its continued rapid expansion in recent years, using only the most recent bond pricing data ensures that the market is observed in its most mature form. The yield to maturity data is used as the

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[1] https://marketing.sustainalytics.com/acton/attachment/5105/f-08be/1/-/-/-/-/Sector%20Report%202015%2003%20Utilities.pdf

dependent variable in the regression analysis, further described in Section 4. Specifically, we let $y_{i,t}^{GB}$ and $y_{i,t}^{CB}$ represent the bond i yield to maturity on day t for the green and conventional bond, respectively. To obtain the yield difference between the green and conventional bond for a matched bond pair, we take $\Delta y_{i,t} = y_{i,t}^{GB} - y_{i,t}^{CB}$. This represents the difference in the yield to maturity that is used as the dependent variable in the regression analysis. A positive difference indicates the green bond having a higher yield to maturity than its matched conventional bond. There is a drawback inherent in the calculation of yield to maturity that is important to acknowledge. Namely, it carries the assumption that all future coupon payments are reinvested at the current yield to maturity. With the knowledge that capital markets are constantly changing, this may be an imperfect assumption to make. However, previous literature has shown the effectiveness in using the yield to maturity of bonds in to understand their pricing patterns in markets.

***Table 1** – Descriptive statistics of green and conventional bond samples.*

Green and Conventional Bond Sample Descriptive Statistics				
	Green Bonds			
	Min	**Median**	**Mean**	**Max**
Rating	B	A	A-	AAA
Modified Duration	0.01	3.37	4.23	17.61
Amount Issued	$93,090,750	$ 531,270,000	$ 618,601,982	$ 2,250,000,000
Age (Years)	0.6	2.0	2.2	5.2
Maturity (Years)	3.0	5.1	7.6	30.5
	Conventional Bonds			
	Min	**Median**	**Mean**	**Max**
Rating	B	A	A-	AAA
Modified Duration	0.03	3.69	4.26	17.25
Amount Issued	$80,542,500	$ 600,000,000	$ 752,867,919	$ 2,250,000,000
Age (Years)	0.7	2.3	2.5	7.6
Maturity (Years)	2.0	7.0	7.9	30.5

With the approach described in this section, matched bond pairs, each with one green and one conventional bond, are created that remove all unobservable factors common among both bonds. Additionally, the liquidity bias is reduced significantly. Descriptive statistics of the green and conventional bonds are given in Table 1. The green and conventional bonds within the sample have relatively similar descriptive statistics, which comes as little surprise due to the rigorous criteria employed in matching green and brown bonds. The mean and median maturity of the conventional brown bonds is slightly higher than that of the green bonds, reflecting a slight maturity bias towards the conventional bonds within the sample. The median age of both the green and conventional bonds in the sample are less than half of their maturities. This is significant, as Sarig and Wargo (1989) show that a bond's liquidity decreases as its age increases. While there is no single cutoff point that is agreed upon in existing literature, this is a significant point in ensuring the effectiveness of the liquidity proxies utilized in this study. The average age of the bonds in the constructed database is less than half of the average maturity for both the green and conventional bonds, which means that, on average, the bonds in the sample are less than halfway to their maturity. Additionally, while the maximum maturity for both green and conventional bonds is 30.5 years, the median maturities for both the green and conventional bonds are much closer to the minimum maturities, indicating a large concentration of bonds with lower maturities than large maturities.

As the duration is matched to within 1.5 in either direction and is not the same for the green and conventional bond in a matched pair, it is likely that there could be a convexity difference between the green and conventional bond. Convexity is not explicitly controlled for within the database construction methodology employed. This may present a lack of control of bond pricing factors in the construction of the matched bond pairs as convexity is a pricing factor in the bond market (Christensen and Sorensen, 1994). However, the average difference in duration in bonds within a bond pair is 0.03. So, while there is a possibility for a difference in convexity within the bond pairs, it would be very limited due to the very small difference in duration in the sample. This ensures that it is, through the control of duration, convexity is also controlled to an acceptable level.

Table 2 provides descriptive statistics of the matched bond pairs. The sample includes pairs of bonds issued in 7 currencies, with the majority being issued in EUR and USD (36 and 31, respectively). The sample includes both investment grade and high-yield bonds, although there are only 4 high-yield bonds, with the other 75 being investment grade bonds. 51 of the bond pairs in the sample are issued by corporations in the financial industry, while 28 are non-financial bonds. This is significant in that we study both the entire sample as well as the financial and non-financial industries separately. A significant amount of both financial and non-financial bond pairs ensures complete samples of both, and thus results that are robust.

The bid and ask prices for each green and conventional bond are obtained using the Thomson Reuters database. These are used to construct the liquidity proxies which are employed as the independent variable in the regression, the process of which is described in Section 4. The result is a 10,349-line time series panel of data with 6 months of yield to maturity and price bid-ask spread data for each of the 79 matched bond pairs.

Table 2 *- Descriptive statistics of green and conventional bond pairs. The number represents the number of matched bond pairs that fit within each qualification.*

Matched Pairs Descriptive Statistics			
Currency		**BICS Level 1 Industry**	
AUD	4	Financials	51
CAD	2	Non-financial	28
CNY	1	Consumer Discretionary	4
EUR	36	Industrials	1
INR	1	Technology	2
SEK	4	Utilities	21
USD	31	**BICS Level 2 Industry**	
Coupon Type		Financials	
Fixed	72	Banks	33
Floating	5	Commercial Finance	2
Variable	2	Diversified Banks	9
Maturity Type		Life Insurance	1
Bullet	54	Real Estate	6
Callable	25	Non-financial	
Rating		Automobiles Manufacturing	3
AAA	1	Communications Equipment	2
AA+	2	Power Generation	8
AA	1	Travel & Lodging	1
AA-	17	Utilities	13
A+	5	Waste & Environment Services & Equipment	1
A	17	**Collateral Type**	
A-	9	1st Mortgage	4
BBB+	12	Company Guarantee	11
BBB	6	Covered	1
BBB-	5	General Ref Mortgage	1
BB+	1	Sr Unsecured	61
BB	2	Subordinated	1
BB-	0		
B+	0		
B	1		

As a robustness test, the methodology is also implemented using a sample of 1-year data for 64 matched bond pairs. This sample includes the matched bond pairs within the constructed database where both the green and corporate bond have an age of at least 1 year, and thus have at least a year of available yield and bid-ask spread data available as of July 5th, 2019. This acts as a robustness check by seeing whether the relationship identified within 6 months of data is the same relationship that is found within a year, albeit for a slightly smaller bond sample size. This sample results in a 16,768-line time series panel with data for each bond pair from July 5, 2018 to July 5, 2019. This sample is used as a robustness check as opposed to being used as the primary study sample due to the limited number of non-financial bonds in the sample. This would limit the significance of any results obtained by studying strictly non-financial bonds.

4. Methodology

The following section lays out the methodology used within this paper to study the corporate green bond premium. Specifically, it outlines the methodology used in selecting the appropriate liquidity proxy for the corporate bond market, and lays out the design of the model used in order to isolate the green premium in the sample of corporate bond matched pairs. Section 4.1 presents the methodology used to address *Hypothesis 4*, while section 4.2 presents the methodology implemented to investigate *Hypothesis 1, Hypothesis 2* and *Hypothesis 3*.

4.1 Liquidity Proxy Variable

In order to control for the difference in liquidity between the green and conventional bond within a matched bond pair, an appropriate corporate bond liquidity proxy must be selected that satisfies two constraints. Firstly, as a within regression is being performed, the liquidity proxy must be time-varying, with time series data available. This eliminates the possibility of using many variables that do not change over time, such as issue amount and issue date. Additionally, only low-frequency data is available for green and conventional bond yield data. For this reason, this eliminates the possibility of using liquidity proxies that utilize intraday data, such as the ILLIQ measure.

Due to the given liquidity proxy constraints, the bid-ask spread ($BAS_{i,t}$) is selected as the proxy to control for the differences in liquidity in green and conventional bonds within each matched pair. The $BAS_{i,t}$ is defined as the difference between the ask price and bid price, which can be defined by the following equation:

$$BAS_{i,t} = Ask\ Price_{i,t} - Bid\ Price_{i,t} \tag{4}$$

A variant of the $BAS_{i,t}$liquidity measure is also used as an additional measure of liquidity. This measure, the big-ask spread as a percentage of the ask price ($BASP_{i,t}$), is a similar measure to the $BAS_{i,t}$, with the key difference being that it is a relative measure, relative to the ask price of the bond. The $BASP_{i,t}$ is defined by the following equation:

$$BASP_{i,t} = \frac{Ask\ Price_{i,t} - Bid\ Price_{i,t}}{Ask\ Price_{i,t}} \tag{5}$$

These liquidity measures are then used to construct the liquidity factor that measures and controls for the difference in the liquidity between a green bond and its otherwise comparable matched conventional bond. This liquidity factor is denoted $\Delta Liquidity$. Table 3 provides descriptive statistics for both liquidity proxies used to define $\Delta Liquidity$, namely $BAS_{i,t}$ and $BASP_{i,t}$. It shows that both proxies are concentrated around zero, with a slightly negative median and mean for both measures. A low standard deviation for both proxies indicates that the liquidity constraints employed in the matching methodology are effective in limiting the liquidity differences to acceptable levels. Both liquidity proxies have distributions that are skewed to the left.

Table 3 *– Descriptive statistics of the two liquidity proxies,* $BAS_{i,t}$ *and* $BASP_{i,t}$

Liquidity Factor Descriptive Statistics							
	Min	**1st Quart**	**Median**	**Mean**	**3rd Quart**	**Max**	**Std. Dev.**
BAS	-0.531	-0.053	-0.006	-0.013	0.032	0.332	0.105
BASP	-0.523%	-0.053%	-0.003%	-0.013%	0.028%	0.337%	0.104%

Matched bond pairs are equally weighted within the sample. Due to there being evidence that liquidity increases with a bond's issue size, a value weighted liquidity measure would likely exhibit a liquidity bias towards larger bonds with more liquidity, minimizing the weight of bonds with smaller issue size that thus are more illiquid (Pelizzon et al., 2013). An equally weighted sample is thus utilized to eliminate this bias.

4.2 Green Bond Premium Estimation

In order to determine the green premium that can be attributed to a green bond being green, all other factors that may attribute to a difference in the yield of a green and conventional bond need to be controlled for. The matching process outlined in the Data section ensures for the control of many of these factors that can attribute to a yield difference. However, it fails to fully control for the liquidity difference between the green and conventional bonds. As shown in Table 4, the issue amounts for green and conventional bonds are similar, but are still different. A slight liquidity bias towards conventional bonds may exist within the constructed bond database, indicated by the higher median and average issued amounts for conventional bonds than green bonds. This highlights the difference in liquidity between the green and conventional bonds. For this reason, this liquidity difference needs to be controlled for.

***Table 4** – Issued amounts (in USD) broken down by type of bond and currency.*

Average Issued Amounts (USD)		
	Green Bond	**Conventional Bond**
AUD	$ 277,564,375.00	$ 262,557,656.25
CAD	$ 349,659,900.00	$ 491,430,000.00
CNY	$ 151,451,000.00	$ 80,542,500.00
EUR	$ 745,068,013.89	$ 948,234,291.67
INR	$ 299,596,000.00	$ 311,674,000.00
SEK	$ 115,370,937.50	$ 118,706,000.00
USD	$ 623,387,096.77	$ 723,870,967.74
Median	$ 531,270,000.00	$ 600,000,000.00
Average	$ 618,601,981.65	$ 752,867,919.30

The liquidity factor, $\Delta Liquidity$, is employed as an independent variable in the regression. $\Delta Liquidity_{i,t}$ represents the difference in the liquidity proxy of a green bond and its matched conventional bond. It is defined by the following equation:

$$\Delta Liquidity_{i,t} = Liquidity_{i,t}^{GB} - Liquidity_{i,t}^{CB} \qquad (6)$$

By regressing the difference in the yield to maturity of the matched bond pair $\Delta y_{i,t}$ on the difference in the liquidity factor $\Delta Liquidity$, we are able to extract the green bond premium as the unobserved effect in the fixed effect panel regression:

$$\Delta y_{i,t} = \alpha_i + \beta \Delta Liquidity_{i,t} + \varepsilon_{i,t} \qquad (7)$$

where α_i is the green bond premium and $\varepsilon_{i,t}$ is the error term. A fixed effect regression is employed to estimate α_i for multiple reasons. First, we want to identify the bond specific time invariant green premium, which is the unobserved effect in the regression, without exposing it to information about the other bonds. The cross-sectional bond data within the constructed database contains characteristics for specific bonds, which does not hold for more generalized groups. Additionally, using a fixed effect regression ensures that the estimator is consistent and unbiased by ensuring strict exogeneity.

The green premium, as defined in equation $\Delta y_{i,t} = \alpha_i + \beta \Delta Liquidity_{i,t} + \varepsilon_{i,t}$, is equal to α_i, where a negative α_i indicates that the yield of the green bond is lower than the yield of the otherwise identical conventional bond, and vice versa. A negative difference in yield indicates that the green bond investors are accepting a lower yield in order to invest in a green bond, where they would be able to get a higher yield by investing in an otherwise identical conventional bond. A negative α_i is therefore indicative of the existence of a green premium, whereas a positive α_i would indicate a negative green premium.

When working with a panel dataset, it is possible for there to be a certain degree of heteroscedasticity. This occurs when the variability of the error term of the independent variable is not equally distributed within the sample. In the case of clustered standard errors, individual observations are grouped into clusters, and the standard errors within the model experience correlation within individual clusters, but not between clusters. Additionally, there may also be a degree of serial correlation of the error term, where the error terms have a degree of correlation over a period of time. To test for this, we compute a Modified Wald statistic for groupwise heteroscedasticity in the residuals of the fixed effect regression, as indicated by Greene (2000). The probability of the error residuals being equally distributed for all observations is 0.0000, indicating that the errors exhibit groupwise heteroscedasticity as well as serial correlation. We also run a Breusch-Pagan test, which confirms this. Therefore, in addition to standard fixed effect regressions, we also allow for this groupwise heteroscedasticity and serial correlation, and use clustered standard errors in the dataset in a second set of regressions on all samples. To do so, we employ hierarchical clustering method as defined by the Lance-Williams recurrence formula (Everitt et al. 2011).

The outlined methodology allows us to control for the differences in liquidity between green bonds and conventional bonds in our sample in two ways. First, the construction of the database limits the differences in liquidity by using multiple liquidity-related constraints in forming matched green and conventional matched bond pairs such as issue date and issue amount. Secondly, the fixed effect regression outlined in equation (7) enables us to control for the residual liquidity bias. By doing so, the green premium is able to be extracted and identified by estimating the unobserved bonds' specific α_i. The result of this methodology is that α_i tells us how much of a change in yield between a green and conventional bond is due to the green label of a green bond, when all other differences between the two bonds are controlled for. This methodology is employed on the full sample of 79 bonds, as well as the subsamples of the financial, non-financial bonds and transition bonds, in addition to the smaller sample of 64 bonds with a full year of yield and bid-ask spread data as a robustness check.

5. Results

The following section presents the results found for the effectiveness of the liquidity proxies, the existence of a green premium in the entire corporate bond sample, the difference in the green premium when the market is segmented into financial and non-financial corporate bonds, and the green premium in transition bonds. First, the effectiveness of the liquidity proxies employed is analysed. The existence of the green premium is then explored, first by analysing the yield difference across the constructed database, and then by presenting and analysing the regression results.

5.1 Liquidity Proxies

In order to effectively isolate any premium attributable to the "greenness" of the green bond, the liquidity difference needs to be effectively controlled for. Thus, the regression results of the liquidity proxies are first studied to determine their effectiveness in controlling for the differences in liquidity within the matched bond samples. We compute a Modified Wald statistic and run a Breusch-Pagan test, both of which indicate the presence of heteroscedasticity as well as serial correlation in the residuals. To allow for the heteroscedasticity and serial correlation in the residuals, we complement the standard fixed effect regression with a fixed effect regression that allows for heteroscedasticity and serial correlation using a hierarchical clustering method defined by the Lance-Williams recurrence formula. Table 5 presents regression results for fixed effects regressions for both liquidity factors, $BAS_{i,t}$ and $BASP_{i,t}$, as well as fixed effects regressions when allowing for clustered standard errors.

Panel (1) of Table 5 shows highly significant coefficients for $BAS_{i,t}$ and $BASP_{i,t}$ in the fixed effect regression, with coefficients of 0.0474 and 6.889, respectively. Although both regressions result in weak *within* R^2 values that are both less than 1%, the highly significant coefficients indicate that both liquidity factors employed are effective liquidity proxies. The residual difference in liquidity has significant explanatory power in explaining the yield difference. Thus, these results indicate that there is a weak but positive correlation between the difference in yield and the difference in liquidity. Specifically, a 1% increase in the price bid-ask spread differential results in a 4.74 basis point increase in $\Delta y_{i,t}$, while a 1 basis point increase in the differential of the bid ask spread as a percentage of the ask price results in a 6.889 basis point increase in $\Delta y_{i,t}$. This positive correlation between liquidity and yield presents a puzzling result, as the vast majority of existing literature finds a negative correlation between liquidity and yield, meaning that investors have a higher required return for illiquid bonds (Houweling et al., 2015). These results seem to reject that conclusion.

Table 5 *– Regression results for the liquidity factors. This table presents the coefficients and other results for both* $\Delta Liquidity_{i,t}$ *measures, for the classical fixed effect regressions and clustered fixed effect regressions.*

Liquidity Factor Coefficients		
	(1)	(2)
	Fixed Effect	**Clustered FE**
$\boldsymbol{BAS_{i,t}}$	0.0474***	0.0474
	(4.00)	(0.94)
Observations	10,349	10,349
Within R^2	0.0016	0.0016
F-Statistic	15.97***	0.88
$\boldsymbol{BASP_{i,t}}$	6.8890***	6.8890
	(5.76)	(1.37)
Observations	10,349	10,349
Within R^2	0.0032	0.0032
F-Statistic	33.18***	1.88
Note: *p<0.1, **p<0.05, ***p<0.01		

Column (2) of Table 5 provides results of the fixed effect regression when allowing for clustering. A Modified Wald statistic for groupwise heteroscedasticity shows that the standard errors are clustered. While the coefficients of the liquidity factors are the same as in the standard fixed effect regression, namely 0.0474 for $BAS_{i,t}$ and 6.889 for $BASP_{i,t}$, the coefficients are no longer significant. This indicates that both liquidity factors in fact do not have explanatory power in explaining the $\Delta y_{i,t}$ in the sample. This is indicative that the criteria employed in the matching methodology are effective in restricting the difference in liquidity within each matched bond pair, and that the residual difference in liquidity is insignificant. Due to the insignificance of the liquidity proxies in the clustered fixed effect regressions, we are unable to conclude that these are effective liquidity proxies in the corporate bond market. However, due to the fact that there is only a small amount of residual liquidity difference in the matched bond pairs after employing the matching criteria, we can conclude that the liquidity controls employed during the construction of the bond pairs, namely age and issue size, are effective in controlling for liquidity differences in the corporate bond market. This is further evidenced by Table 3, where the median and mean liquidity differences are nearly zero.

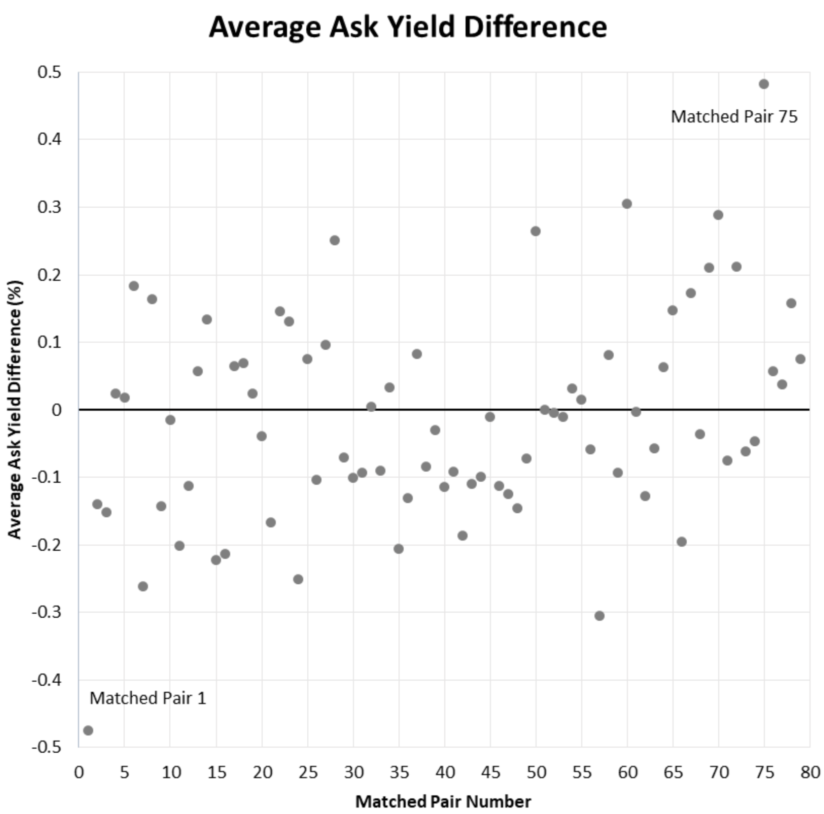
5.2 Yield Difference Analysis

Analyzing the difference in the yield between the green and conventional bonds in each matched bond pair allows for an initial study of the possible existence of a green premium in corporate green bonds. Table 6 presents distribution statistics for the $\Delta y_{i,t}$, by first taking the average yield difference for each matched pair, and then finding the minimum, 1st quartile, median, mean, 3rd quartile, and maximum of those average yield differences.

Table 6 *– Distribution of $\Delta y_{i,t}$ in percentages. A negative number represents a lower yield for the green bond than the conventional bond and vice versa. Time series averages are first calculated for each bond pair, resulting in a single average yield difference for each bond pair over the full sample time period. Distributions statistics are then calculated based on those averages.*

Ask Yield Difference Distribution (%)						
Min	**1st Quart**	**Median**	**Mean**	**3rd Quart**	**Max**	**St. Dev.**
-0.475	-0.112	-0.030	-0.016	0.072	0.483	0.154

Figure 1 *- The time series average ask yield difference $\Delta y_{i,t}$ for each matched bond pair.*



The distribution of $\Delta y_{i,t}$ is shown in Table 6. $\Delta y_{i,t}$ has a median green premium of -3 basis points and a mean green premium of -1.6 basis points. A negative $\Delta y_{i,t}$ indicates a lower yield for a green bond than its comparable conventional bond. Thus, a negative mean and median $\Delta \mathrm{y_{i,t}}$ indicate that, on average, the sample of matched bond pairs reflect a small green premium. Of the 79 matched bond pairs in the sample, 45 (57%) have a negative $\Delta y_{i,t}$, while 34 (43%) have a positive $\Delta y_{i,t}$. The distribution has a standard deviation of 15.4 basis points, indicating a relatively concentrated distribution of $\Delta y_{i,t}$ around the mean.

Figure 1 presents the distribution of the average ask yield difference $\Delta y_{i,t}$ for each matched bond pair. Consistent with the distribution values of $\Delta y_{i,t}$ in Table 6, the distribution is relatively closely distributed around zero, with a slight negative bias indicating more green bonds having lower yields when compared to their matched conventional bonds than vice versa. The sample contains two outliers, namely Matched Pair 1 and Matched Pair 75. These matched pairs are issued by Ferrovie dello Stato Italiane SpA and Terna Rete Elettrica Nazionale Spa, which have $\Delta y_{i,t}$ values of -47.5 basis points and 48.3 basis points, respectively. Of the 79 matched bond pairs in the sample, 64 (81%) have a $\Delta y_{i,t}$ within the range of -20 basis points to 20 basis points.

5.3 The Green Bond Premium

While studying the difference in yield is an effective way to study the potential existence of a green premium in corporate bonds, this method does not fully control for liquidity, and thus any conclusions drawn from these results regarding a green premium cannot be argued with full confidence. For this reason, the results of the regression analysis are studied to gain a more complete understanding of the green premium in corporate green bond markets.

***Table** 7 – Regression results for the green premium α_i for the fixed effect and clustered fixed effect regressions $\Delta y_{i,t} = \alpha_i + \beta \Delta Liquidity_{i,t} + \varepsilon_{i,t}$.*

Green Bond Premium α_i Results - All Bonds		
	Fixed Effect	**Clustered FE**
Fixed Effect α^{FE} ($BAS_{i,t}$)	-0.0155***	-0.0155***
	(-18.61)	(-24.64)
Observations	10,349	10,349
Fixed Effect α^{FE} ($BASP_{i,t}$)	-0.0153***	-0.0153***
	(-18.29)	(-24.20)
Observations	10,349	10,349
Note: *p<0.1, **p<0.05, ***p<0.01		

***Table 8** – Distribution of estimated green premia α_i for the full bond sample.*

Estimated Green Bond Premia α_i Distribution					
Min	**1st Quart**	**Median**	**Mean**	**3rd Quart**	**Max**
-1.240	-0.116	-0.036	0.083	0.122	4.801

The value of the green premium α_i in corporate bonds is the significant contribution of this study. The green bond premium is found to be small and highly significant in both the fixed effect and clustered fixed effect regressions for both liquidity measures (Table 7). Green bond premia of -1.55 basis points and -1.53 basis points are found when $BAS_{i,t}$ and $BASP_{i,t}$ are used as liquidity proxies, respectively. The distribution of the green bond premium for each bond pair (Table 8) has a median and mean of -3.6 basis points and 8.3 basis points, respectively. This positive average green premium initially presents a conflict for the conclusion of the existence of a green premium. The distribution of this green premium, however, ranges from -124 basis points to 480.1 basis points, indicating the existence of large outliers. Figure 3 provides further evidence of the existence of strong outliers, with Matched Bond Pairs 10, 57, 75, 78, and 79 having α_i values with a magnitude larger than 100 basis points. These bonds are issued by Bank of America Corp, Covanta Holding Group, Terna Rete Elettrica Nazionale SpA, Southern Power Co, and Westar Energy Inc., respectively. Matched pairs 10, 75, and 78, in particular, are strong outliers with green premia of 215.4, 442.9, and 480.1 basis points respectively (see Table 17 in the appendix). These have a significant impact on the mean of the distribution, causing the distribution to have a mean that is positive. Significantly, though, the median green premium of -3.6 basis points reflects the same result found in the regression of the whole sample, namely the existence of a small green premium. The majority of the matched pairs in the sample are concentrated around the zero point, with a small negative bias.

Figure 2 *- The green premium α_i (in percentage points) for each matched bond pair in the sample over the sample period, where $BAS_{i,t}$ is the liquidity proxy.*

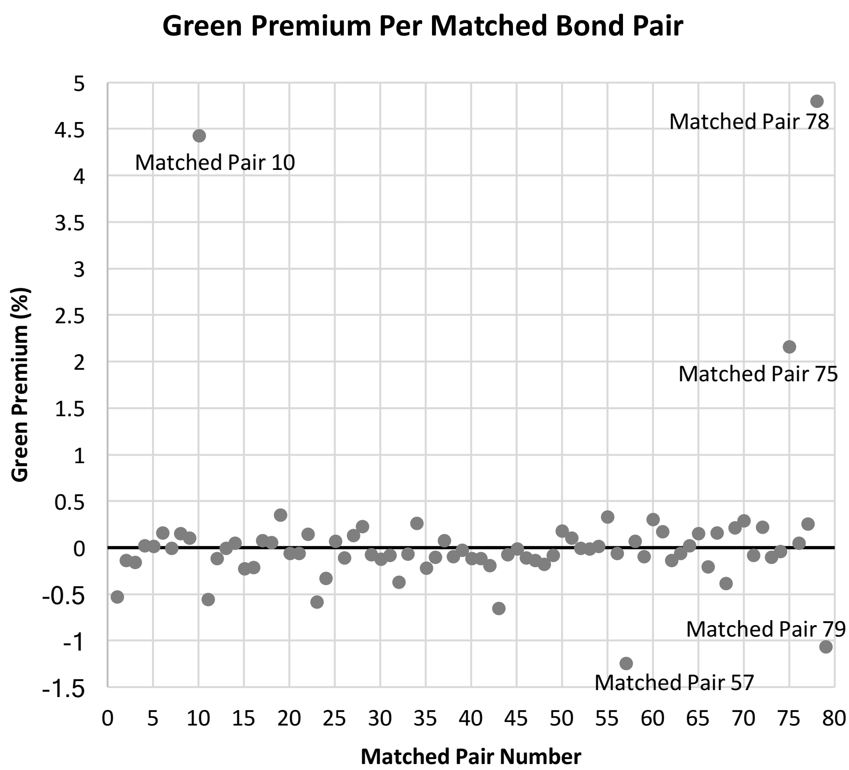
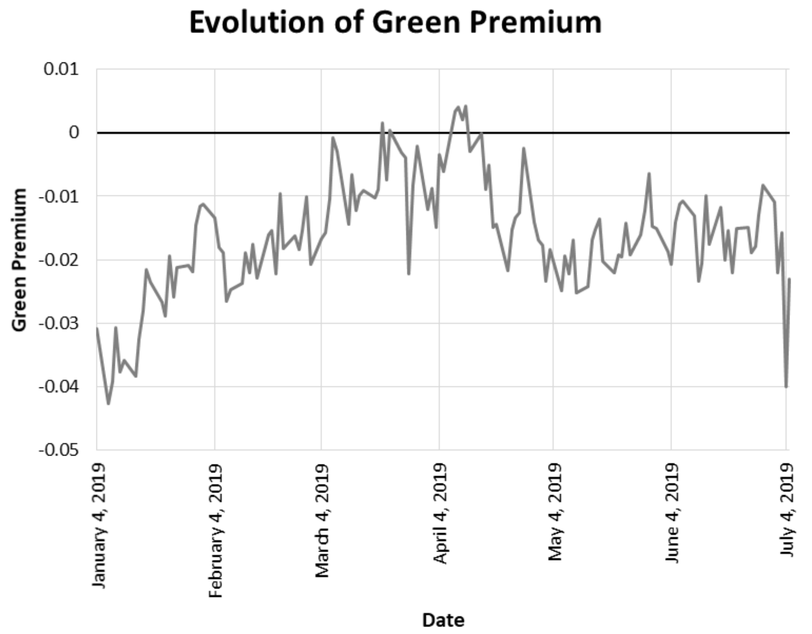


Figure 3 *- The daily evolution of the green premium (in percentage points) during the sample period across all bonds in the sample, where $BAS_{i,t}$ is the liquidity proxy.*



The evolution of the daily green premium over the time of the sample period is presented in Figure 3. The green premium remained within an approximate band of -4 basis points to zero basis points. We find that 6 days during the full sample period of 131 trading days experienced a negative green premium (positive α_i), while 125 days during the sample had positive green premia. 95.4% of the days in the sample period had a green premium (negative α_i). We also find no days as significant outliers, with the daily green premium being concentrated around the green premium found for the entire sample of -1.5 basis points, as presented in Table 7. The distribution of the daily green premium ranges from the minimum of -4.3 basis points on January 7th, 2019 to the maximum of 0.4 basis points on April 9th, 2019.

5.3.1 Green Premium Decomposition

Next, we examine whether the green premium differs depending on the industry of the issuing entity. The green premium is isolated for each matched pair. The green premia distributions are then examined for each BICS (Bloomberg Industry Classification Systems) level 1 and level 2 industry level (Table 9). Similar to the regression results of the entire sample, we find that both the financial and non-financial subsamples have median green premia that are small but significant, with median α_i of -5.6 basis points and -0.7 basis points, respectively. We also find that both subsamples have average green premia that are small and positive. However, just as with the full sample, both the financial and non-financial subsamples have large positive outliers that may have an impact on the mean values of the distributions.

Interestingly, the only BICS level 1 industry with a positive mean of median α_i is utilities, with a mean and median α_i of 5.0 and 31.1 basis points, respectively. Similarly, the only BICS level 2 industries with positive mean and median α_i are utilities and power generation. All other BICS level 1 and 2 industries have negative α_i mean and median values, indicating positive green premia. When we exclude the utilities industry from the non-financials, we find a negative mean and median α_i of -13.7 and -29.4 basis points for the non-financials (ex-utilities) subsample. This indicates that the matched pairs issued by utilities issuers, which have a strong positive α_i, cause an otherwise negative non-financial subsample mean α_i to become positive. The non-financials (ex-utilities) subsample displays a large negative bias, with a mean α_i that is twice the magnitude of the median α_i.

Next, we divide the sample into financial and non-financial subsamples, based on the industry of the issuer of the bond, with non-financial including all bond pairs that are not issued by financial entities, in order to study the green premium in each subsample as a whole, in isolation. The financial subsample contains 51 matched bond pairs and the non-financial subsample contains 28 matched bond pairs. Both subsamples are utilized in standard fixed effect and clustered fixed effect regression models where both liquidity measures $BAS_{i,t}$ and $BASP_{i,t}$ are employed as liquidity proxies. The results of these regressions are presented in Table 10. As we found in the full sample, both the standard fixed effect regressions as well as the clustered fixed effect regressions result in significant α_i values, while only the standard fixed effect regression results in significant coefficients for the liquidity measures. The signs and magnitudes of the green premium, however, are not the same.

We find that a green premium of -3.1 basis points exists for financial green corporate bonds, while non-financial bonds have a green premium of 1.2 basis points. Both are small in magnitude, but the financial bonds have a positive green premium, while non-financial bonds have a negative green premium. This finding presents evidence that while green corporate bonds issued by financial entities have a lower yield than otherwise identical conventional bonds, green corporate bonds issued by non-financial entities have higher yields (and financing costs for issuers) than otherwise identical conventional bonds. These results are robust when both liquidity proxies are used.

Table 9 *– Distribution of the green bond premium α_i for each BICS level 1 and 2 industry. This table shows the distribution of the green bond premia for each industry segment, using the fixed effect regression model with $BAS_{i,t}$ as the liquidity proxy. Results are the same when using the clustered fixed effect regression model instead.*

Green Bond Premium α_i Distribution Per Industry

	# Bond Pairs	Min	1st Quart	Median	Mean	3rd Quart	Max
All Pairs	79	-1.240	-0.116	-0.036	0.083	0.122	4.801
BICS Level 1 Industry							
Financials	51	-0.648	-0.112	-0.056	0.041	0.081	4.429
Non-Financials	28	-1.240	-0.141	-0.007	0.160	0.186	4.801
Consumer Discretionary	4	-0.526	-0.247	-0.146	-0.199	-0.098	0.021
Industrials	1	-1.240	-1.240	-1.240	-1.240	-1.240	-1.240
Technology	2	-0.093	-0.051	-0.009	-0.009	0.032	0.074
Utilities	21	-1.065	-0.099	0.050	0.311	0.222	4.801
Non-Financials (Ex-Utilities)	7	-1.240	-0.340	-0.137	-0.294	-0.036	0.074
BICS Level 2 Industry							
Financials							
Banks	33	-0.582	-0.108	-0.010	-0.010	0.107	0.351
Commercial Finance	2	-0.190	-0.171	-0.151	-0.151	-0.132	-0.113
Diversified Banks	9	-0.555	-0.111	-0.079	0.397	-0.003	4.429
Life Insurance	1	-0.064	-0.064	-0.064	-0.064	-0.064	-0.064
Real Estate	6	-0.648	-0.248	0.006	-0.130	0.043	0.135
Non-financial							
Automobiles Manufacturing	3	-0.154	-0.146	-0.137	-0.090	-0.058	0.021
Communications Equipment	2	-0.093	-0.051	-0.009	-0.009	0.032	0.074
Power Generation	8	-0.222	-0.096	0.036	0.026	0.154	0.305
Travel & Lodging	1	-0.526	-0.526	-0.526	-0.526	-0.526	-0.526
Utilities	13	-1.065	-0.099	0.175	0.487	0.258	4.801
Waste & Envir. Services & Equip	1	-1.240	-1.240	-1.240	-1.240	-1.240	-1.240

Table 10 *– Fixed effect and clustered fixed effect regression results for financial and non-financial bond subsamples. The financial bond subsample includes 51 bonds and the non-financial bond subsample includes 28 bonds.*

Regression Results - Financials and Non-Financials Subsamples					
Financials			**Non-Financials**		
	Fixed Effect	**Clustered FE**		**Fixed Effect**	**Clustered FE**
Fixed Effect $\boldsymbol{\alpha}^{\mathbf{FE}}$ $(\boldsymbol{BAS_{i,t}})$	-0.0309***	-0.0309***	**Fixed Effect** $\boldsymbol{\alpha}^{\mathbf{FE}}$ $(\boldsymbol{BAS_{i,t}})$	0.0122***	0.0122***
	(-30.31)	(-22.67)		(8.31)	(25.91)
$\boldsymbol{BAS_{i,t}}$	0.0423**	0.0423	$\boldsymbol{BAS_{i,t}}$	0.0515***	0.0515
	(2.46)	(0.43)		(3.06)	(1.08)
Observations	6,681	6,681	Observations	6,681	6,681
Within R^2	0.0009	0.0009	Within R^2	0.0026	0.0026
F-Statistic	6.03**	0.19	F-Statistic	9.36***	1.16
	Fixed Effect	**Clustered FE**		**Fixed Effect**	**Clustered FE**
Fixed Effect $\boldsymbol{\alpha}^{\mathbf{FE}}$ $(\boldsymbol{BASP_{i,t}})$	-0.0306***	-0.0306***	**Fixed Effect** $\boldsymbol{\alpha}^{\mathbf{FE}}$ $(\boldsymbol{BASP_{i,t}})$	0.0125***	0.0125***
	(-30.13)	(-24.01)		(8.5)	(25.37)
$\boldsymbol{BASP_{i,t}}$	5.7100***	5.7100	$\boldsymbol{BASP_{i,t}}$	7.9926***	7.9926
	(3.43)	(0.63)		(4.54)	(1.56)
Observations	3,668	3,668	Observations	3,668	3,668
Within R^2	0.0018	0.0018	Within R^2	0.0056	0.0056
F-Statistic	11.79***	0.4	F-Statistic	20.62***	2.44

Note: *p<0.1, **p<0.05, ***p<0.01

5.3.2 Transition Bonds

Finally, we examine the green premium in the transition bond subsample. The subsample includes green bonds issued by utilities companies that have high levels of pollution in their business operations. As with the other samples, we use both a standard fixed effect regression and a fixed effect regression that allows for clustering in order to isolate a green premium. Table 11 presents the results of these regressions (Table 18 provides composition details of the transition bond subsample, including the Sustainalytics environmental score for each issuer). We find a positive and significant α_i in both regression models of 2.2 basis points. These results are robust when both liquidity proxies are employed. This positive α_i therefore indicates a negative green premium in the transition bond market. This result supports the result presented in Table 9 that shows that, while the non-financial subsample as a whole has a positive mean α_i, this is heavily influenced by the strong positive α_i found within the utilities industry while all other industries within the non-financial subsample have a negative mean α_i. All of the bonds within the transition bond subsample are issued by utilities firms, so the positive α_i found within the transition bond subsample is complementary of the results that find a negative green premium for green bonds issued by utilities companies.

Table 11 *– Fixed effect and clustered fixed effect regression results for the transition bonds subsample. The transition bond subsample includes 11 bonds.*

Green Bond Premium α_i Results - Transition Bonds		
	Fixed Effect	**Clustered FE**
Fixed Effect α^{FE} ($BAS_{i,t}$)	0.0222***	0.0222***
	(8.77)	(26.90)
$BAS_{i,t}$	0.0609***	0.0609
	(3.08)	(1.07)
Observations	1,441	1,441
Within R^2	0.0852	0.0852
F-Statistic	9.51***	1.14
	Fixed Effect	**Clustered FE**
Fixed Effect α^{FE} ($BASP_{i,t}$)	0.0222***	0.0222***
	(8.81)	(30.19)
$BASP_{i,t}$	6.9315***	6.9315
	(3.35)	(1.14)
Observations	1,441	1,441
Within R^2	0.1245	0.1245
F-Statistic	11.25***	1.30
Note: *p<0.1, **p<0.05, ***p<0.01		

5.4 Robustness Tests

As a measure of robustness, the green premium is also studied in the sample that contains a full year of data. This sample contains all matched bond pairs from the original constructed bond database where both bonds have a full year of yield and bid-ask spread data available. This sample includes 64 bond pairs. This sample is only studied as a robustness check as opposed to being utilized as the full sample due to it containing fewer bond pairs, especially non-financial bonds. Of the 64 matched pairs in the sample, 42 are issued by financial entities, while 22 are issued by non-financial entities (see Table 17). Table 12 presents the results from fixed effect regressions as well clustered fixed effect regressions on both liquidity proxies.

Table 12 *– Regression results for fixed effect and clustered fixed effect regressions on the sample of 64 matched bond pairs with a full year of data.*

Regression Results - 1 Year Sample		
	Fixed Effect	**Clustered FE**
Fixed Effect $\boldsymbol{\alpha}^{\mathbf{FE}}$ $(\boldsymbol{BAS_{i,t}})$	-0.0319***	-0.0319***
	(-46.46)	(-79.16)
$\boldsymbol{BAS_{i,t}}$	0.0734***	0.0734
	(8.80)	(1.31)
Observations	16,768	16,768
Within R^2	0.0046	0.0046
F-Statistic	77.38***	1.72
Fixed Effect $\boldsymbol{\alpha}^{\mathbf{FE}}$ $(\boldsymbol{BASP_{i,t}})$	-0.0318***	-0.0318***
	(-46.39)	(-83.39)
$\boldsymbol{BASP_{i,t}}$	8.7008***	8.7008
	(10.43)	(1.59)
Observations	16,768	16,768
Within R^2	0.0065	0.0065
F-Statistic	108.72***	2.54
Note: *p<0.1, **p<0.05, ***p<0.01		

Upon applying the same regression full year sample, the results are confirmed. As with the 6-month sample, the full year sample produces a small green premium. Specifically, this green premium α_i is found to be -3.2 basis points for the full corporate bond sample, which is highly significant in both fixed effect regressions as well as when allowing for clustering. This green premium is confirmed for both liquidity proxies, $BAS_{i,t}$ and $BASP_{i,t}$. Notably, this green premium is larger in magnitude than that in the 6-month sample. The robustness check also confirms that both liquidity proxies are positive and significant in the fixed effect regressions. But when allowing for clustering in the fixed effect regression we again find that the liquidity proxies become insignificant and no longer have explanatory power in explaining changes in $\Delta y_{i,t}$ in the regression. This again confirms that the matching criteria employed when constructing the matched pairs is effective in controlling for liquidity differences. Both liquidity factors are also slightly larger in magnitude in the full year sample.

6. Conclusion

This paper studies bond pricing in global corporate bond markets to study the financial impact on corporate bond investors that arises from non-financial incentives, namely pro-environmental preferences. We use a matching method in combination with regression analysis to isolate any premium attributable to the green label of a green bond by creating a bond database of matched bond pairs that control for differences in pricing factors and then separately controlling for differences in liquidity within that constructed database. Any difference in yield between green and conventional bond that is then observed in the yield can be attributed to the green premium. A negative difference in yield indicates a lower yield for green than conventional bonds, and thus a positive green premium. We find evidence of a small green premium in the corporate bond market of -1.5 basis points, implying a lower return for green bond investors, and a lower cost of fundraising for green bond issuers. This finding of a small green premium is in line with the findings of other studies examining the green premium in other assets or parts of the bond market (Zerbib (2019), Karpf and Mandel (2017), and Partridge and Medda (2018)). We find that this green premium is concentrated in green bonds issued by financial entities as opposed to non-financial entities. We find a green premium in financial green corporate bonds of -3.1 basis points, but we find a negative green premium in non-financial green corporate bonds, with a difference in yield of 1.2 basis points. However, we find that the negative premium found in non-financial bonds is concentrated in bonds issued by utilities companies, with all other industries having a positive average green premium. Specifically, we find a negative premium of 2.2 basis points in utilities that have a below industry average Sustainalytics environmental score. These results are indicative that investors are willing to take a lower return for the opportunity to invest in a bond that is beneficial for the environment. However, the negative green premium in the green bonds issued by the most environmentally damaging firms is indicative of a penalty green bond investors place on these firms, requiring higher returns, and thus higher costs of fundraising for issuers, for green bonds than otherwise comparable conventional bonds. This supports the recent argument proposed by AXA Investment Partners, among others, of the establishment of a transition bond market where firms that operate businesses with high pollution are able to issue bonds that allow them to fund projects that allow them to become less environmentally damaging, without necessarily being fully green (AXA Investment Partners, 2019).

Finally, although not the primary objective of this paper, an ancillary result of this paper is that we are able to study the effectiveness of liquidity measures as proxies for the modeling of liquidity in the corporate bond market. We find that issue size and age are effective in controlling for differences in liquidity, but are unable to conclusively determine whether yield bid-ask spread and yield bid-ask spread as a percentage of ask price are effective liquidity proxies.

The primary limitation of this study is driven by the quality of data. As the green corporate bond market is still in its relative infancy compared to the greater bond market, there is no large body of green bonds with which to compile a sample. The matching methodology employed in this paper requires matching green bonds with conventional bonds, based on a set of strict matching criteria. A less stringent set of matching criteria would allow for a larger sample size to study, but it would also likely decrease the explanatory power of any results obtained. As the size of the corporate green bond market continues to grow at a fast pace, future studies will be able to employ larger samples of bond pricing data. This may allow for even more stringent matching criteria when constructing the sample, which would lead to more robust results. Future research may also be able to examine in more detail the difference in financial and non-financial corporate green bonds that leads to the difference in their respective green premia, and in particular the difference in the sign of their green premia.

References

Acharya, V. V., & Pedersen, L. H. (2005). Asset pricing with liquidity risk. *Journal of financial Economics*, *77*(2), 375-410.

Alexander, G. J., Edwards, A. K., & Ferri, M. G. (2000). The determinants of trading volume of high-yield corporate bonds. *Journal of Financial Markets*, 3(2), 177-204.

Amihud, Y. (2002). Illiquidity and stock returns: cross-section and time-series effects. *Journal of Financial Markets*, *5*(1), 31-56.

Amihud, Y., & Mendelson, H. (1986). Asset pricing and the bid-ask spread. *Journal of financial Economics*, *17*(2), 223-249.

Amihud, Y., Mendelson, H., & Pedersen, L. H. (2006). Liquidity and asset prices. *Foundations and Trends in Finance*, *1*(4), 269-364.

AXA Investment Partners. (2019, June 11). *AXA Investment Managers calls for new "transition bonds" to help companies go green* [Press release]. Retrieved from https://www.axa-im.com/content/-/asset_publisher/alpeXKk1gk2N/content/axa-investment-managers-calls-for-new-transition-bonds-to-help-companies-go-green/23818?utm_source=t.co&utm_medium=referral

Baker, M., Bergstresser, D., Serafeim, G., & Wurgler, J. (2018). Financing the response to climate change: The pricing and ownership of US green bonds (No. w25194). National Bureau of Economic Research.

Bao, J., Pan, J., & Wang, J. (2011). The illiquidity of corporate bonds. *The Journal of Finance*, *66*(3), 911-946.

Barclays (2015). The Cost of Being Green. Credit Research. URL https://www.environmental-finance.com/assets/files/US_Credit_Focus_ The_Cost_of_Being_Green.pdf

Bloomberg (2017). Investors are willing to pay a "green" premium. Bloomberg New Energy Finance report.

Bloomberg New Energy Finance (2015). Mapping the Gap: The Road to Paris.

Bloomberg New Energy Finance (2016). Guide to Green Bonds on the Bloomberg Terminal.

Brandt, M. W., & Kavajecz, K. A. (2004). Price discovery in the US Treasury market: The impact of orderflow and liquidity on the yield curve. *The Journal of Finance*, *59*(6), 2623-2654.

Brennan, M., Huh, S. W., & Subrahmanyam, A. (2013). An analysis of the Amihud illiquidity premium. *The Review of Asset Pricing Studies*, *3*(1), 133-176.

Breusch, T. S., & Pagan, A. R. (1979). A simple test for heteroscedasticity and random coefficient variation. *Econometrica: Journal of the Econometric Society*, 1287-1294.

Chakravarty, S., & Sarkar, A. (1999). Liquidity in US fixed income markets: A comparison of the bid-ask spread in corporate, government and municipal bond markets. *FRB of New York Staff Report*, (73).

Chen, L., Lesmond, D. A., & Wei, J. (2007). Corporate yield spreads and bond liquidity. *The Journal of Finance*, *62*(1), 119-149.

Chowdhry, B., Davies, S., & Waters, B. (2017). Investing for impact. *Available at SSRN 2437238*.

Christensen, P. O., & Sorensen, B. G. (1994). Duration, convexity, and time value. *Journal of Portfolio Management*, *20*(2), 51.

Climate Bonds Initiative (2017). Green Bonds Highlights 2016 . URL https://www.climatebonds.net/files/files/2016%20GB%20Market%20Roundup.pdf

Climate Bonds Initiative (2019). Green Bonds Highlights 2018 . URL https://www.climatebonds.net/files/reports/2018_green_bond_market_highlights.pdf

Corwin, S. A., & Schultz, P. (2012). A simple way to estimate bid- ask spreads from daily high and low prices. *The Journal of Finance*, *67*(2), 719-760.

Crabbe, L. E., & Turner, C. M. (1995). Does the liquidity of a debt issue increase with its size? Evidence from the corporate bond and medium- term note markets. *The Journal of Finance*, *50*(5), 1719-1734.

Danıelsson, J., & Payne, R. (2002). Real trading patterns and prices in spot foreign exchange markets. *Journal of International Money and Finance*, *21*(2), 203-222.

Della Croce, R., C. Kaminker and F. Stewart (2011). The Role of Pension Funds in Financing Green Growth Initiatives.

Demsetz, H. (1968). The cost of transacting. *The quarterly journal of economics*, *82*(1), 33-53.

Derwall, J., & Koedijk, K. (2009). Socially responsible fixed- income funds. *Journal of Business Finance & Accounting*, *36*(1- 2), 210-229.

Dick-Nielsen, J., Feldhütter, P., & Lando, D. (2012). Corporate bond liquidity before and after the onset of the subprime crisis. *Journal of Financial Economics*, *103*(3), 471-492.

Drut, B. (2010). Sovereign bonds and socially responsible investment. *Journal of Business Ethics*, *92*(1), 131-145.

Dutch State Treasury Agency (2019). Transaction Review: Green DSL 0.50% 15 January 2040. URL https://english.dsta.nl/binaries/dsta-english/documents/publication/2019/05/21/one-pager-20-year-green-dda/One-pager+20-year+Green+DDA.pdf

Ehlers, Torsten, and Frank Packer (2017). "Green bond finance and certification." *BIS Quarterly Review September*.

Elton, E. J., Gruber, M. J., Agrawal, D., & Mann, C. (2011). Factors affecting the valuation of corporate bonds. In *Investments and Portfolio Performance* (pp. 53-73).

Evans, M. D., & Lyons, R. K. (2002). Time-varying liquidity in foreign exchange. *Journal of Monetary Economics*, *49*(5), 1025-1051.

Everitt, B. S., Landau, S., Leese, M., & Stahl, D. (2011). Hierarchical clustering. *Cluster analysis*, *5*.

EU Technical Expert on Sustainable Finance. (2019). *Report on EU Green Bond Standard*.

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

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

Febrian, E., & Herwany, A. (2008). Liquidity measurement based on bid-ask spread, trading frequency, and liquidity ratio: The use of GARCH model on Jakarta Stock Exchange (JSX). *Economic Journal, University of Padjadjaran*.

Fisher, L. (1959). Determinants of risk premiums on corporate bonds. *Journal of political economy*, *67*(3), 217-237.

Flammer, C. (2018). Corporate Green Bonds.

Fleming, M. J. (2001). Measuring treasury market liquidity. *FRB of New York Staff Report*, (133).

Foster, F. D., & Viswanathan, S. (1993). Variations in trading volume, return volatility, and trading costs: Evidence on recent price formation models. *The Journal of Finance*, *48*(1), 187-211.

Galliani, C., Petrella, G., & Resti, A. (2014). The liquidity of corporate and government bonds: drivers and sensitivity to different market conditions. *Joint Research Center*, *26498*.

Greene, W. H. (2000). Econometric Analysis: Prentice Hall: Upper Saddle River. *New Jersey*.

Glavas, D., & Bancel, F. (2018). *Are agency problems a determinant of green bond issuance?* (No. 88377). University Library of Munich, Germany.

Helwege, J., Huang, J. Z., & Wang, Y. (2014). Liquidity effects in corporate bond spreads. *Journal of Banking & Finance*, *45*, 105-116.

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

HSBC (2016). Green Bonds 2.0. Fixed Income Credit report.

ICMA (2018). Green Bond Principles. URL https://www.icmagroup.org/assets/documents/Regulatory/Green-Bonds/June-2018/Green-Bond-Principles---June-2018-140618-WEB.pdf

IFC (2018). Green Bonds. URL https://www.ifc.org/wps/wcm/connect/959ff937-aa7b-4294-991f-e848f28be5fb/Green+Bonds+factsheet_UPD_Sept2018.pdf?MOD=AJPERES

ING (2018). ING Green Bond Framework. URL https://www.ing.com/web/file?uuid=0ed3cc97-8d5d-4078-b43d-e291eba6a39c&owner=b03bc017-e0db-4b5d-abbf-003b12934429&contentid=45211

Johnson, T. C. (2008). Volume, liquidity, and liquidity risk. *Journal of Financial Economics*, 87(2), 388-417.

Kang, J., & Pflueger, C. E. (2015). Inflation risk in corporate bonds. *The Journal of Finance*, *70*(1), 115-162.

Karpf, A., & Mandel, A. (2017). Does it pay to be green?

Kyle, A. S. (1985). Continuous auctions and insider trading. *Econometrica: Journal of the Econometric Society*, 1315-1335.

Lesmond, D. A., Ogden, J. P., & Trzcinka, C. A. (1999). A new estimate of transaction costs. *The Review of Financial Studies*, *12*(5), 1113-1141.

Longstaff, F. A., Mithal, S., & Neis, E. (2005). Corporate yield spreads: Default risk or liquidity? New evidence from the credit default swap market. *The journal of finance*, *60*(5), 2213-2253.

Mahanti, S., Nashikkar, A., Subrahmanyam, M., Chacko, G., & Mallik, G. (2008). Latent liquidity: A new measure of liquidity, with an application to corporate bonds. *Journal of Financial Economics*, 88(2), 272-298.

Marrow, D., Koizumi R.M., Garz, H. (2015). Sector Report: Utilities. The Great Transformation Begins. Retrieved from Sustainalytics website: https://marketing.sustainalytics.com/acton/attachment/5105/f-08be/1/-/-/-/-/Sector%20Report%202015%2003%20Utilities.pdf

Nationale Nederlanden Investment Partners. (2018). Unravelling the Green Bond Premium. Retrieved from https://www.nnip.com/Default-Display-on-2/Unravelling-the-Green-Bond- Premium.htm

NASA (2019). Climate Change: How Do We Know? URL https://climate.nasa.gov/evidence/

OECD (2015). Mapping Channels to Mobilise Institutional Investment in Sustainable Energy. Green Finance and Investment, OECD Publishing, Paris . URL https://www.oecd.org/g20/topics/energy-environment-green-growth/ mapping-channels-to-mobilise-institutional-investment-in-sustainable-energy-9789264224582-en. htm

OECD (2017). Green bonds: Mobilising Bond Markets for a low-carbon transition. OECD Publishing, Paris. URL http://www.oecd.org/env/mobilising-bond-markets-for-a-low-carbon-transition-9789264272323-en.htm

Partridge, C., & Medda, F. (2018). Green Premium in the Primary and Secondary US Municipal Bond Markets. Available at SSRN 3237032.

Pelizzon, L., Subrahmanyam, M. G., Tomio, D., & Uno, J. (2013). The microstructure of the European sovereign bond market: A study of the Euro-zone crisis. *Unpublished working paper. New York University, New York, NY*.

Roll, R. (1984). A simple implicit measure of the effective bid- ask spread in an efficient market. *The Journal of Finance*, *39*(4), 1127-1139.

Sarig, O., & Warga, A. (1989). Some empirical estimates of the risk structure of interest rates. *The Journal of Finance*, *44*(5), 1351-1360.

Schultz, P. (1998). Corporate bond trading costs and practices: A peek behind the curtain. *Unpublished manuscript, University of Notre Dame*.

Shurey, D. (2017). Investors are willing to pay a `green' premium. Bloomberg New Energy Finance note (February), pp. 1-8.

United Nations (2019). The Sustainable Development Goals Report 2019. URL https://unstats.un.org/sdgs/report/2019/

Van Loon, P. R., Cairns, A. J., McNeil, A. J., & Veys, A. (2015). Modelling the liquidity premium on corporate bonds. *Annals of Actuarial Science*, *9*(2), 264-289.

Vargas, M., Vicente, R., & Muñoz, F. (2014). Searching for the most profitable and sustainable investment strategy: evidence from sovereign bond funds. *Journal of Business Economics and Management*, *15*(5), 1034-1053.

Zerbib, O. D. (2019). The effect of pro-environmental preferences on bond prices: Evidence from green bonds. *Journal of Banking & Finance*, *98*, 39-60.

Zhao, W., & Wang, M. (2015). On the Computation of LOT liquidity measure. *Economics Letters, 136*, 76-80.

Appendix

Table 13 *- Names of issuing entities of bonds within the sample, and how many bonds issued by that entity are in the sample.*

Issuing Entities			
ABN AMRO Bank NV	2	ING Bank NV	1
Alexandria Real Estate Equities Inc	1	innogy Finance BV	1
Apple Inc	2	Intesa Sanpaolo SpA	1
Axis Bank Ltd/Dubai	1	KBC Group NV	1
Bank of America Corp	2	Landesbank Baden-Wuerttemberg	1
Bank of China Ltd/Paris	1	Manulife Financial Corp	1
BNP Paribas SA	2	MidAmerican Energy Co	2
Boston Properties LP	1	Mitsubishi UFJ Financial Group Inc	3
BPCE SA	1	National Australia Bank Ltd	3
Brookfield Renewable Partners ULC	1	Nordea Bank Abp	1
Clearway Energy Operating LLC	1	NTPC Ltd	1
Commerzbank AG	1	Power Finance Corp Ltd	1
Commonwealth Bank of Australia	2	Public Service Co of Colorado	1
Cooperatieve Rabobank UA	1	REC Ltd	1
Covanta Holding Corp	1	Regency Centers LP	1
Credit Agricole SA/London	1	SBAB Bank AB	4
DBS Group Holdings Ltd	2	Skandinaviska Enskilda Banken AB	1
Digital Realty Trust LP	1	Societe Generale SA	1
DNB Boligkreditt AS	1	Southern Power Co	1
DTE Electric Co	1	State Bank of India/London	1
DZ Bank AG	1	Sumitomo Mitsui Banking Corp	1
EDP Finance BV	1	Svenska Handelsbanken AB	1
Engie SA	5	Swedbank AB	1
ERP Operating LP	1	Swire Properties MTN Financing Ltd	1
Ferrovie dello Stato Italiane SpA	1	Terna Rete Elettrica Nazionale SpA	1
Georgia Power Co	1	Toronto-Dominion Bank/The	1
Hyundai Capital Services Inc	2	Toyota Motor Credit Corp	1
Iberdrola International BV	3	Westar Energy Inc	1
IDBI Bank Ltd	1	Westpac Banking Corp	1

Table 14 *– Acronyms for all currencies*

Currency Acronyms	
AUD	Australian Dollar
CAD	Canadian Dollar
CNY	Chinese Yuan
EUR	Euro
INR	Indian Rupee
SEK	Swedish Krone
USD	US Dollar

Figure 4 *– Distribution of the time-series average bid-ask spread difference for each matched bond pair*

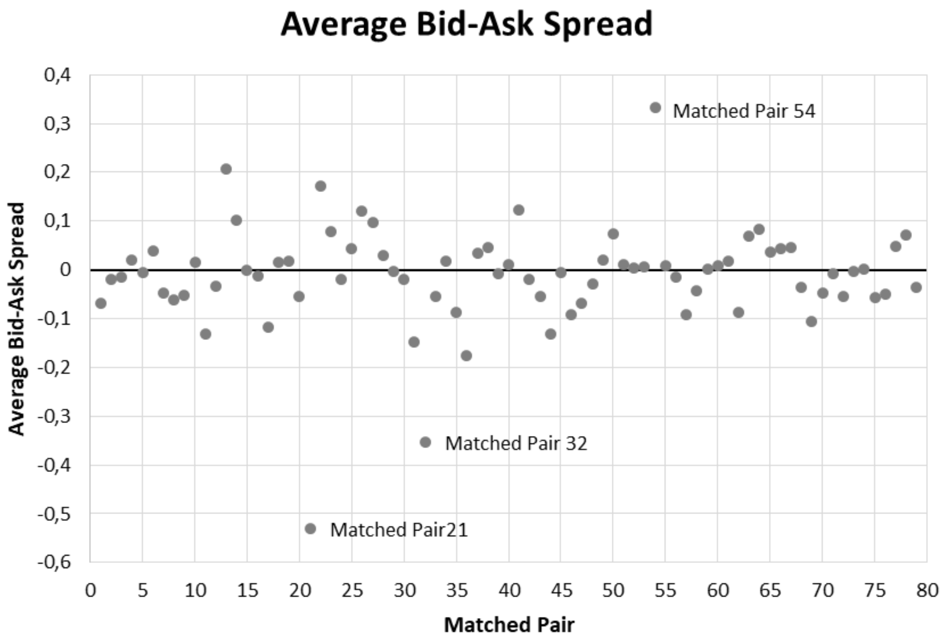


Table 15 *– The issuing entity for each matched bond pair and the green premium for each matched pair*

Green Premium Per Matched Bond Pair					
Matched Bond Pair	**Issuer Name**	**Green Premium**	**Matched Bond Pair**	**Issuer Name**	**Green Premium**
1	Ferrovie dello Stato Italiane SpA	-0.526	41	Power Finance Corp Ltd	-0.113
2	Hyundai Capital Services Inc	-0.137	42	REC Ltd	-0.190
3	Hyundai Capital Services Inc	-0.154	43	Regency Centers LP	-0.648
4	Toyota Motor Credit Corp	0.021	44	SBAB Bank AB	-0.075
5	ABN AMRO Bank NV	0.020	45	SBAB Bank AB	-0.010
6	ABN AMRO Bank NV	0.161	46	SBAB Bank AB	-0.109
7	Alexandria Real Estate Equities	-0.003	47	SBAB Bank AB	-0.137
8	Bank of China Ltd/Paris	0.157	48	Skandinaviska Enskilda Banken	-0.176
9	Axis Bank Ltd/Dubai	0.110	49	Societe Generale SA	-0.079
10	Bank of America Corp	4.429	50	State Bank of India/London	0.179
11	Bank of America Corp	-0.555	51	Sumitomo Mitsui Banking Corp	0.107
12	BNP Paribas SA	-0.111	52	Svenska Handelsbanken AB	-0.004
13	BNP Paribas SA	-0.003	53	Swedbank AB	-0.009
14	Boston Properties LP	0.053	54	Swire Properties MTN Financing	0.016
15	Clearway Energy Operating LLC	-0.222	55	Toronto-Dominion Bank/The	0.333
16	BPCE SA	-0.210	56	Westpac Banking Corp	-0.059
17	Commerzbank AG	0.082	57	Covanta Holding Corp	-1.240
18	Commonwealth Bank of Australia	0.060	58	Apple Inc	0.074
19	Commonwealth Bank of Australia	0.351	59	Apple Inc	-0.093
20	Cooperatieve Rabobank UA	-0.057	60	Brookfield Renewable Partners	0.305
21	Credit Agricole SA/London	-0.056	61	DTE Electric Co	0.175
22	DBS Group Holdings Ltd	0.147	62	EDP Finance BV	-0.134
23	DBS Group Holdings Ltd	-0.582	63	Engie SA	-0.060
24	Digital Realty Trust LP	-0.330	64	Engie SA	0.021
25	DNB Boligkreditt AS	0.072	65	Engie SA	0.151
26	DZ Bank AG	-0.108	66	Engie SA	-0.204
27	ERP Operating LP	0.135	67	Engie SA	0.162
28	IDBI Bank Ltd/GIFT-IFC	0.228	68	Georgia Power Co	-0.385
29	ING Bank NV	-0.070	69	Iberdrola International BV	0.218
30	Intesa Sanpaolo SpA	-0.119	70	Iberdrola International BV	0.292
31	KBC Group NV	-0.081	71	Iberdrola International BV	-0.077
32	Landesbank Baden-Wuerttemberg	-0.367	72	innogy Finance BV	0.222
33	Manulife Financial Corp	-0.064	73	MidAmerican Energy Co	-0.099
34	Mitsubishi UFJ Financial Group Inc	0.267	74	MidAmerican Energy Co	-0.036
35	Mitsubishi UFJ Financial Group Inc	-0.215	75	Terna Rete Elettrica Nazionale	2.159
36	Mitsubishi UFJ Financial Group Inc	-0.103	76	NTPC Ltd	0.050
37	National Australia Bank Ltd	0.080	77	Public Service Co of Colorado	0.258
38	National Australia Bank Ltd	-0.090	78	Southern Power Co	4.801
39	National Australia Bank Ltd	-0.027	79	Westar Energy Inc	-1.065
40	Nordea Bank Abp	-0.113			

Table 16 *– Names of issuing entities of bonds within the full year sample, and how many bonds issued by that entity are in the full year sample employed in the robustness test.*

Issuing Entities			
ABN AMRO Bank NV	2	KBC Group NV	1
Alexandria Real Estate Equities Inc	1	Landesbank Baden-Wuerttemberg	1
Apple Inc	2	Manulife Financial Corp	1
Axis Bank Ltd/Dubai	1	MidAmerican Energy Co	2
Bank of America Corp	2	Mitsubishi UFJ Financial Group Inc	2
Bank of China Ltd/Paris	1	National Australia Bank Ltd	2
BNP Paribas SA	2	Nordea Bank Abp	1
BPCE SA	1	NTPC Ltd	1
Commonwealth Bank of Australia	2	Public Service Co of Colorado	1
Cooperatieve Rabobank UA	1	REC Ltd	1
DBS Group Holdings Ltd	2	Regency Centers LP	1
Digital Realty Trust LP	1	SBAB Bank AB	4
DNB Boligkreditt AS	1	Skandinaviska Enskilda Banken AB	1
DTE Electric Co	1	Societe Generale SA	1
Engie SA	4	Southern Power Co	1
Ferrovie dello Stato Italiane SpA	1	Sumitomo Mitsui Banking Corp	1
Georgia Power Co	1	Svenska Handelsbanken AB	1
Hyundai Capital Services Inc	2	Swedbank AB	1
Iberdrola International BV	3	Swire Properties MTN Financing Ltd	1
IDBI Bank Ltd/GIFT-IFC	1	Toronto-Dominion Bank/The	1
ING Bank NV	1	Toyota Motor Credit Corp	1
innogy Finance BV	1	Westar Energy Inc	1
Intesa Sanpaolo SpA	1	Westpac Banking Corp	1

Table 17 *– Industry breakdown of full year sample used for robustness tests. The number indicates the number of matched bond pairs that are in each industry.*

Industry Breakdown - Robustness Sample	
BICS Level 1 Industry	
Financials	42
Non-financial	22
Consumer Discretionary	4
Technology	2
Utilities	16
BICS Level 2 Industry	
Financials	
Banks	29
Commercial Finance	1
Diversified Banks	7
Life Insurance	1
Real Estate	4
Non-financial	
Automobiles Manufacturing	3
Communications Equipment	2
Power Generation	5
Travel & Lodging	1
Utilities	11

Table 18 *- Composition of the transition bond subsample. All utility companies within the full sample are listed. Panel (2) provides the number of bonds of each issuer that are included in the subsample. A 0 indicates that it is not included in the subsample, either due to there not being a Sustainalytics score available, or the score being above the full industry average of 59. Panel (4) provides the Sustainalytics environmental score. N/A indicates that the company's score was not available in the report.*

Transition Bonds Subsample Composition

(1) **Issuer Name**	(2) **# Bonds in Subsample**	(3) **BICS Level 2 Industry**	(4) **Sustainalytics Environmental Score**
Brookfield Renewable Partners	0	Power Generation	61.1
Clearway Energy Operating LLC	0	Power Generation	N/A
DTE Electric Co	1	Utilities	52.6
EDP Finance BV	1	Utilities	49.6
Engie SA	5	Power Generation	53.4
Georgia Power Co	1	Utilities	53.9
Iberdrola International BV	0	Utilities	70.5
innogy Finance BV	0	Utilities	61.5
MidAmerican Energy Co	0	Utilities	N/A
NTPC Ltd	1	Power Generation	44.2
Public Service Co of Colorado	0	Utilities	63.8
Southern Power Co	1	Utilities	53.9
Terna Rete Elettrica Nazionale SpA	0	Utilities	80.2
Westar Energy Inc	1	Utilities	48.0