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Are Green Bonds Just Another Financial Fad or Are They Here to Stay?

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Abstract

This paper analyses the existence of a **greemium** i.e., an investor or issuer green bond premium in the primary fixed income and securities market across time. To achieve this, I examine issue yield differentials and issue price differentials between matched samples of green and conventional bonds, which are examined through time series, regression and difference-in-difference analyses. The issuer premium is evaluated in terms of favorable price, while the investor premium is defined in terms of favorable yield. The results suggest that green bonds have had an investor premium based on a positive yield (3.6 basis points). There is no significant change in the price over time. The diff-in-diff analysis gives further clarity regarding the impact of the introduction of the Green Bond Principles in 2014. It was observed that prior to the introduction of the GBP there was an issuer price premium and an investor yield discount. However, after the GBP was introduced, the result was an issuer price discount or an investor yield premium. The target audience for this study is academics, along with issuers and investors in the bond market. The study expands upon academic research in the areas of environmentalism and finance to further understand the viability of green bonds both for improved social responsibility and financial performance.

Keywords

green bonds, greemium, green bond principles, gbp, price differential, yield differential, investor premium, investor discount, issuer premium, issuer discount

Disciplines

Business Analytics | Business Law, Public Responsibility, and Ethics | Corporate Finance | Portfolio and Security Analysis

ARE GREEN BONDS JUST ANOTHER FINANCIAL FAD OR ARE THEY HERE TO STAY?

By

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An Undergraduate Thesis submitted in partial fulfillment of the requirements for the

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Abstract

This paper analyses the existence of a **greemium** i.e., an investor or issuer green bond premium in the primary fixed income and securities market across time. To achieve this, I examine issue yield differentials and issue price differentials between matched samples of green and conventional bonds, which are examined through time series, regression and difference-in-difference analyses. The issuer premium is evaluated in terms of favorable price, while the investor premium is defined in terms of favorable yield. The results suggest that green bonds have had an investor premium based on a positive yield (3.6 basis points). There is no significant change in the price over time. The diff-in-diff analysis gives further clarity regarding the impact of the introduction of the Green Bond Principles in 2014. It was observed that prior to the introduction of the GBP there was an issuer price premium and an investor yield discount. However, after the GBP was introduced, the result was an issuer price discount or an investor yield premium. The target audience for this study is academics, along with issuers and investors in the bond market. The study expands upon academic research in the areas of environmentalism and finance to further understand the viability of green bonds both for improved social responsibility and financial performance.

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Introduction

For far too long, financial entities and environmental groups have been within their own bubbles – each faction only discussing aspects that matter to that particular group. Often, corporate entities are pitted against environmental organizations, in a rather dramatic fashion. However, for the number of clashes that the two groups face, they have never truly conversed with each other: they only highlight those matters that are relevant to them. "Green" Financial Instruments are possibly one of the most important tools in breaking down this well-established barrier. These instruments are not only relevant to financers to diversify their portfolios and companies that issue them to develop a more socially responsible image, they are also highly important to environmentalists who receive capital to do good for the earth.

My research examines how green bonds are accepted in the fixed income market and whether they are indeed valuable both for social responsibility and financial performance. Existing empirical evidence on these issues is mixed. A number of studies find that the "greenness" of the bond increases ownership effects and have a positive buyer premium. However, other studies believe there is neither interest nor disinterest in green bonds, and pro-environmental behavior does not affect their returns, and in fact hold negative returns. Further, there is not a lot of research about the incentive to issuers of green bonds.

Hence, my research targets towards understanding this conflicting evidence and finding a significant greemium to investors or issuers in this asset class. The research is useful in determining this financial instrument's viability in a growing environmentally conscious world. Thus, understanding whether green bonds provide incentives to issuers or investors, is important to both the financial and environmental actors of the society, and may help in eventually bridging the gap between them and creating more welfare for the world.

Literature Review

Introducing Green Bonds

Global Warming, Climate Change, Ice Cap Meltdown, Critically Endangered: These are just a sample of phrases we hear on a daily basis that are pointing towards insurmountable environmental crises. Recently, financial investors have taken on the pivotal challenge to transition towards a greener future, and rightly so, as they have the ability to mobilize vast amounts of wealth (Zerbib 2019).

Assets that have low environmental impact or are climate and environmental-friendly can be considered "green," and a sub-class of these assets are debt securities called *green bonds*. Morgan Stanley refers to their exponential and sustainable market popularity as the "green bond boom" (Morgan Stanley 2017). Financial actors are motivated to invest in green financial assets due to one or more of the following reasons:

1. Expectations of better financial performance as research suggests that there is a true non-altruistic motive for investing in socially responsible financial instruments (Nilsson 2007).
2. Lower risk and higher returns, where strong environmental responsibility gives rise to risk-adjusted returns (Derwall, Guenster, Bauer and Koedijk 2005).

3. Pro-social and pro-environmental norms can reduce financial motives and influence investors to invest more heavily in socially responsible companies (Riedl and Smeets, 2017). Further, as described by Zerbib (2019), the incentive needn't be propriety, and instead can be thought of a *philanthropic delegation*.

A key catalyst for the market development of green labelled bonds was the introduction of the Green Bond Principles by the International Capital Market Association in January 2014. This was the basis for many existing green labels, which make green bonds certifiably "green." Elhers and Packer (2017)

What Makes A Green Bond Green?

Elhers and Packer (2017) describe in detail the different forms of certification that qualify bonds for the designation "green." The **CBI Climate Bonds Certification** and the **Green Bond Indices** require that the use of funds be tied to a green investment and the eligibility criteria differ sector by sector. For **CICERO Second Opinions**, once again, the use of the funds must be tied to a green investment but there must also be granular assessments of greenness. **Moody's Green Bond Assessments** require funds to be used for green investments, ex-post monitoring, granular assessments of greenness and quantitative weights for specific factors. **Standard & Poor's Green Evaluations** are very similar to **Moody's Assessments**, except for the fact that they require eligibility criteria to differ sector by sector, and do not require ex-post monitoring.

Characteristics of different green bond identification and certification schemes — Table 1

	CBI Climate Bonds Certification	Green bond indices[1]	CICERO Second Opinions	Moody's Green Bond Assessments	Standard & Poor's Green Evaluations
Use of funds must be tied to green investment	Yes	Yes	Yes	Yes	Yes
Eligibility criteria differ by sector	Yes	Yes			Yes
Ex post monitoring/assessment				Yes	
Granular assessments of greenness			Yes	Yes	Yes
Quantitative weights for specific factors				Yes	Yes

[1] Bank of America Merrill Lynch, Barclays MSCI, Standard & Poor's and Solactive.

Table 1: Characteristics of different bond identification and certification schemes
Source: Elhers and Packer (2017)

Empirical Evidence for Green Assets

Corporate Environmental Performance has been measured in stock and equity markets since the early 2000s.

Stock Returns

Konar and Cohen (2001) find that bad environmental performance is negatively correlated with the intangible asset value of firms. Further, as earlier mentioned, Derwall, Guenster, Bauer and Koedijk (2005) measure "eco-efficiency premium," where portfolios of companies with strong environmental responsibility are able to generate risk-adjusted excess returns. Similarly, Kempf and Osthoff (2007) implemented the trading strategy of buying stocks with high socially responsible ratings and selling stocks with low socially responsible ratings. They observed that this strategy leads to high abnormal returns. Semenova and Hassel (2008) find that the relation between environmental performance and market value is stronger in low risk (e.g. banking)

industries than in high risk (e.g. mining) industries. On average, low risk industries also benefit from a higher market value. Finally, Statman and Glushkov (2009) observed that '*typical socially responsible investors tilt their portfolios toward stocks of companies with high scores on social responsibility characteristics and shun stocks of companies associated with tobacco, alcohol, gambling, firearms, and military or nuclear operations.'*

Most of the research in this field suggests that environmental performance has a positive impact on companies' financial performance (Zerbib 2019).

Cost of Equity Capital

ElGhoul and Kowk (2011) look at CSR and its relationship with the cost of equity. Their findings suggest that firms with better CSR scores have cheaper equity financing. Sharfman and Fernando (2008) showed that improved environmental risk management is associated with a lower cost of capital. Chava (2014) finds that *'investors demand significantly higher expected returns on stocks excluded by environmental screens (such as hazardous chemical, substantial emissions, and climate change concerns) compared to firms without such environmental concerns.'* This once again shows us that environmental impact is strongly negatively correlated with the cost of equity capital.

That being said, Zerbib (2019) states that these findings are not easily transferable to the debt market for two reasons:

1. The difference of the payoff profile between debtholders and stockholders. As Zerbib (2019) and Merton (1973) describe it: little upside in the bond market implies that bondholders have to analyze all the downside risks, including environmental hazards.
2. Oikonomou, Brooks and Pavelin (2014) suggest that firms are more sensitive to pressure by bond market investors, as *'good performances are rewarded but corporate social transgressions are penalized through lower and higher corporate bond yield spreads, respectively.'*

Conflicting Results Regarding the Green Bond Market

Note: I define the **issuer premium** in terms of favorable price, while the **investor premium** is defined in terms of favorable yield. Hence, when the green bond has a higher price (lower yield) than the conventional bond, then it is considered to create an **issuer premium** or **investor discount**. On the other hand, when the green bond has a higher yield (lower price) than the conventional bond, then it is considered to create an **investor premium (issuer discount)**.

While there have been several studies that focus on environmental performance and corporate bond yield, no consensus has been reached yet.

Barclays (2015) shows that investors are currently paying issuers/sellers a premium to acquire green bonds that they see as partly attributable to opportunistic pricing based on strong demand from environmentally focused funds.

Flammer (2018) looks at green bonds from the perspective of the issuer to prove their effectiveness as financial instruments. She observes that green bonds yield

1. positive announcement returns

2. improvements in long-term value and operating performance
3. improvements in environmental performance
4. increases in green innovations
5. increase in ownership by long-term and green investors.

Once again strong pro-environmental ownership effects are suggested in this paper.

According to Baker, Bergstresser, Serafeim and Wurgler (2018), green municipal bonds are issued at a premium in the primary market i.e., the green bonds are traded at a lower yield/higher price, when compared to similar conventional bonds. They observe pricing and ownership effects to be the strongest for bonds that are externally certified as green.

Karpf and Mandel (2018) suggest that green bonds, specifically municipal bonds, have been penalized in the past by trading at lower prices. However, in recent years their credit quality has improved turning the investor premium positive. They suggest that investors receive green bond premium (positive yield differential – higher yield/ lower price) of approximately eight basis points.

Zerbib (2019) uses green bonds to observe whether pro-environmentalism preferences impact secondary bond market prices. He observes the yield differential to create a small investor discount (the yield of a green bond is lower than that of a conventional bond). The results show low impact of investors' attitudes towards pro-environmentalism on bond prices, thus showing that investors currently neither have an incentive nor a disincentive to support the green bond market.

Larcker and Watts (2019) suggest that the investor premium is essentially zero. They describe it as follows, "When risk and payoffs are held constant and are known to investors ex-ante, investors view green and non-green securities by the same issuer as almost exact substitutes. Thus, the greemium is essentially zero."

The contrasting opinions about green bonds in both primary and secondary markets and the impact of pro-environmentalism on their yields is highly contested and requires to be delved into. Thus, I will be trying to understand the existence or the lack of an issuer or investor premium.

Research Design

Hypothesis:

Through my thesis, I aim to determine the effect of yield and price differentials on the green bond premium ("the issuer and investor greemiums") in the primary fixed income and securities market.

I also want to analyze this "**greemium**" for investors and issuers over time. To do this, I observe both the yield and price differentials across time to understand the existence or absence of an investor yield premium or an issuer price premium. Based on my research, my hypothesis is that over time the issuer yield went from a discount to a substantial positive premium to at par presently. I would further like to understand the causes behind it using a diff-in-diff analysis.

In terms of the methods involved, I perform four major statistical tests, as shown below.

Matching:
The first method is matching, which is employed as it allows us to detect a difference between the conventional and green groups (i.e., statistical power) that share similar characteristics. The method also reduces noise, even though the green bond sample is relatively small to begin with.

Analyzing literature shows us that the method is similar across different papers, but with modifications to the variables utilized in the matching and regression design. Most authors ensure that the Issuer, Coupon Size, and Rating remain the same. However, maturity matching is varied between 1 to 2 years. Further, some papers (Zerbib, 2019) employ a liquidity control as well. Finally, the dependent variable is different from paper to paper – Some employ yield differentials, while others employ pricing differentials (Daily i-spreads).

Research methods and findings on green bond pricing. This table summarizes the research methods and empirical findings of studies on the relative pricing of green bonds in relation to conventional bonds.

	Barclays (2015)	HSBC (2016)	Bloomberg (2017)	Climate Bonds Initiative (2017)
Green bonds (Alignment with the GBP)	Yes	Yes	Yes	Yes
	(a) Literature prior to this paper.			
Scope	Global	Euro and US	European Investment Bank, Nordic Investment Bank and International Bank for Reconstruction and Development	EUR- and USD-denominated Govt.-related and corporate bonds
Primary / Secondary market	Secondary	Primary / Secondary	Secondary	Primary
Number of bonds	N.A.	30 / 4	12	14
Time period	Mar. 2014 - Aug. 2015	Nov. 2015 - Sep. 2016	Mar. 2014 - Dec. 2016	Jan. 2016 - Mar. 2017
Method	OLS regression	Comparison	Comparison	Comparison
Liquidity control	Date of issuance	No	No	No
Strict maturity control	No	No	No	No
Yield premium	−17bps	No	EUR-denominated Govt.-related bonds: -25ps USD-denominated and corporate bonds: No	No

	Ehlers and Packer (2017)	Karpf and Mandel (2018)	Baker et al. (2018)	Hachenberg and Schiereck (2018)
Green bonds (Alignment with the GBP)	Yes	No	No	Yes
	(b) Literature subsequent to and building on this paper.			
Scope	Euro and US	US Municpal bonds with a Bloomberg green flag	US Corporate and Municpal bonds with a Bloomberg green flag	Global
Primary / Secondary market	Primary	Secondary	Primary	Secondary
Number of bonds	21	1880	2083	63
Time period	2014–2017	2010–2016	2010–2016	Oct. 2015 - March. 2016
Method	Comparison	Oaxaca-Blinder decomposition	OLS regression	Matching + panel regression based on our paper's method
Liquidity control	No	Number of transactions within the past 30 days	Issue amount	Issue amount
Strict maturity control	Yes	Yes	Yes	Yes
Yield premium	−18 bps	+7.8 bps	−7 bps	−1 bp

Table 2: Research methods and findings on green bond pricing
Source: Zerbib (2019)

I match a green bond with a conventional bond by ensuring that the two bonds have the same rating and hold the date of maturity of the conventional bond within 60 days (greater/lesser than) of the green bond. I do not match for issuer, unlike previous papers, however, as I would like to look at similar bonds regardless of the company, in similar periods of time. That said, I do match for the issue date and hold the date of issue of the conventional bond, at a much tighter interval, within 7 days (greater/lesser than) of the green bond. This is done as we are trying to eliminate the time effects and see how bonds in similar periods of time compare against each other.

Thus, I measure the *yield to maturity at issue* differential and the *issue price* differential between these matched pairs while controlling for the *Rating*, *Maturity Date*, and *Issue Date*.
Since this method yields multiple matches, I employ the nearest neighbor search (NNS) to find the conventional bond among the given matches that has the closest issue date to the given green bond.

Finally, for the matched sample obtained, I calculate the **Difference in Issue Yield** for each observation:

$\delta(\text{Issue Yield}) = (\text{Issue Yield})_{\text{Green Bond}} - (\text{Issue Yield})_{\text{Conventional Bond}}$

Next, I calculate the **Difference in Issue Price** for each observation:

$\delta(\text{Issue Price}) = (\text{Issue Price})_{\text{Green Bond}} - (\text{Issue Price})_{\text{Conventional Bond}}$

Time Series Analysis:

For this step, I calculate the monthly and annual yield differential and issue price differential over time from 2007 (first green bond issue) to 2019 (latest green bond issue) using the procedure described above to determine the variation of the greemium for issuers and investors across time. Barclays (2015) did this for a period of 4 months from the buyers' perspective in their paper and the bps change was extremely interesting to observe. Hence, I would use the above suggested matching model to estimate this movement across time.

Regression Analysis:

I finally run a regression analysis on the sample matched earlier to determine if, after controlling for the maturity date, (which was not constricted as strictly as the issue date) the Yield is significantly correlated to the Green Indicator along with the nature of the coefficient. The regression equation is as shown below:

$$\text{Yield (Predicted)} \sim \beta_0 + \beta_1 * \text{Green Indicator(Predictor Dummy)} + \beta_2 * \text{Maturity Date(Predictor Date)} + \varepsilon$$

I also perform similar regressions on the Issue Price and Issue Amount to shed some light on the relation between these variables and the Green Indicator. The equations are as shown below

$$\text{Issue Price} \sim \beta_0 + \beta_1 * \text{Green Indicator(Predictor Dummy)} + \beta_2 * \text{Maturity Date(Predictor Date)} + \varepsilon$$

$$\text{Issue Amount} \sim \beta_0 + \beta_1 * \text{Green Indicator(Predictor Dummy)} + \beta_2 * \text{Maturity Date(Predictor Date)} + \varepsilon$$

Difference-in-Difference Analysis:

On the matched sample created earlier, I further perform a difference-in-difference(diff-in-diff) analysis to study the differential effect of the introduction of the GBP on green bonds' versus 'conventional bonds. This test was run specifically to observe how the effect of the 'green indicator' (whether a bond is green or not) changed after the Green Bond Principles (GBP) went into effect in 2014 and guarantee that the bonds were certifiably 'green'.

The regression equation for the analysis is:

$$\text{Yield} = \beta_0 + \delta_0(\text{Post GBP i.e., >= 2014}) + \beta_1(\text{Green Indicator - Dummy Variable}) + \delta_1(\text{Green Indicator} \times \text{Post GBP}) + \varepsilon$$

where,

$\boldsymbol{\delta_1}$ = Difference-in-Difference Coefficient

I also perform similar diff-in-diff analyses for the Issue Price to provide some clarity on the reasons behind the 'conventional' and 'green' yield trends, which will be discussed further in the Results and Conclusion sections below. The regression equation for this model, similar to the equation for the Yield, is provided below:

$$\text{Issue Price} = \beta 0 + \delta 0(\text{Post GBP i.e., >= 2014}) + \beta 1(\text{Green Indicator – Dummy Variable}) + \delta 1(\text{Green Indicator} \times \text{Post GBP}) + \varepsilon$$

where,

δ1 = Difference-in-Difference Coefficient

Data

Data Gathering:

My data comes primarily from WRDS and the Bloomberg Terminal. The two datasets I use are Mergent from WRDS for conventional bonds and the Green Bond Database from the Bloomberg Terminal.

Most of the research papers in my literature review use the Green Bond Database from the Bloomberg, as it is considered one of the most comprehensive databases of both mature and available bonds. Zerbib (2019), Baker et. al (2018), Larcker & Watts (2019) and Karpf & Mandel (2018) have used this dataset for similar research.

Regarding the conventional bond dataset, there is more variation in the literature. Zerbib (2019) continues to use the Bloomberg dataset for conventional bonds as well. However, Larcker & Watts (2019) discuss the mislabeling of securities in Bloomberg and recommend the use of Mergent instead to remove such securities. Bloomberg and Mergent are two of the most well-known sources to get municipal, federal and corporate issued bonds – all in one dataset. Karpf & Mandel (2018) utilize "EMMA," specifically created for municipal bonds. However, since I want to analyze corporate green bonds against corporate conventional bonds, I limited myself to the earlier described datasets. When it came to choosing between Bloomberg and Mergent, I used Mergent to avoid the error of incorporating mislabeled securities within my dataset.

Data Cleaning:

To maintain uniformity between the dataset variables, I utilize the following variables from the Bloomberg and Mergent datasets: CUSIP, Issue Date, Maturity Date, S&P Rating, Coupon, Issue Amount, Issue Price and Yield. Once I have my completed datasets, I remove outliers in both datasets. These outliers are defined as those bonds with Yield > 200 bps and 50 > Issue Price > 150, along with manually parsed erroneous data that were accidental copies of the issue amount or coupon.

Summary Statistics

The key variables for green and conventional bonds are summarized below.

Green Bonds

Yield (bps)

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
-1.19	0.59	2.21	3.37	3.90	156.09

Issue Price ($)

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
60.00	99.93	100.00	99.73	100.00	112.19

Issue Amount ($)

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
1.00×10^4	2.99×10^7	1.06×10^8	3.05×10^8	4.48×10^8	8.23×10^9

It is important to note that the minimum green bond yield is negative. However, I do not discard these negative yield observations as outliers because, according to the Financial Times (2019), "Bonds worth $15tn — roughly a quarter of the debt issued by governments and companies around the world — are currently trading with **negative yields**. That means prices are so high that investors are certain to get back less than they paid, via interest and principal, if they hold the bond to maturity. They are, in effect, paying someone to look after their money." Since, this is common in the bond market today, I do not drop these observations.

Conventional Bonds

Yield (bps)

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.00	2.40	4.90	6.17	8.80	200.00

Issue Price ($)

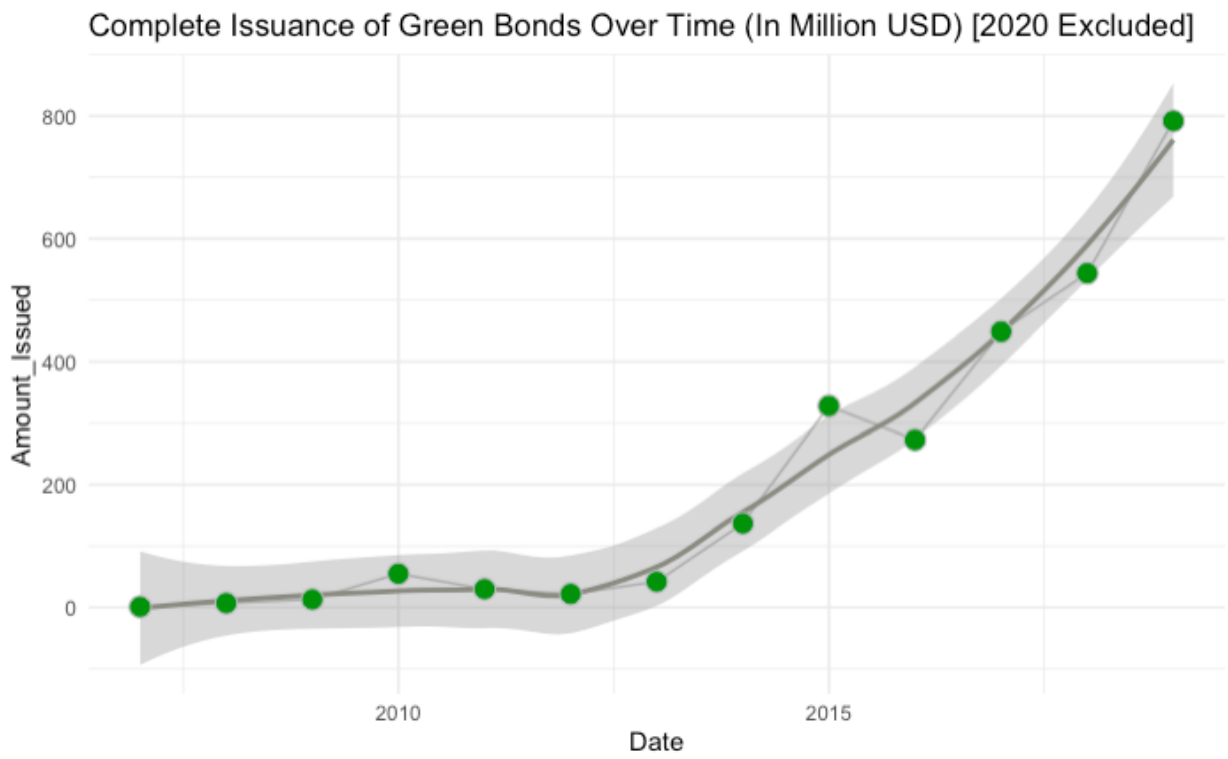
Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
53.25	100.00	100.00	99.91	100.00	131.81

Issue Amount ($1000)

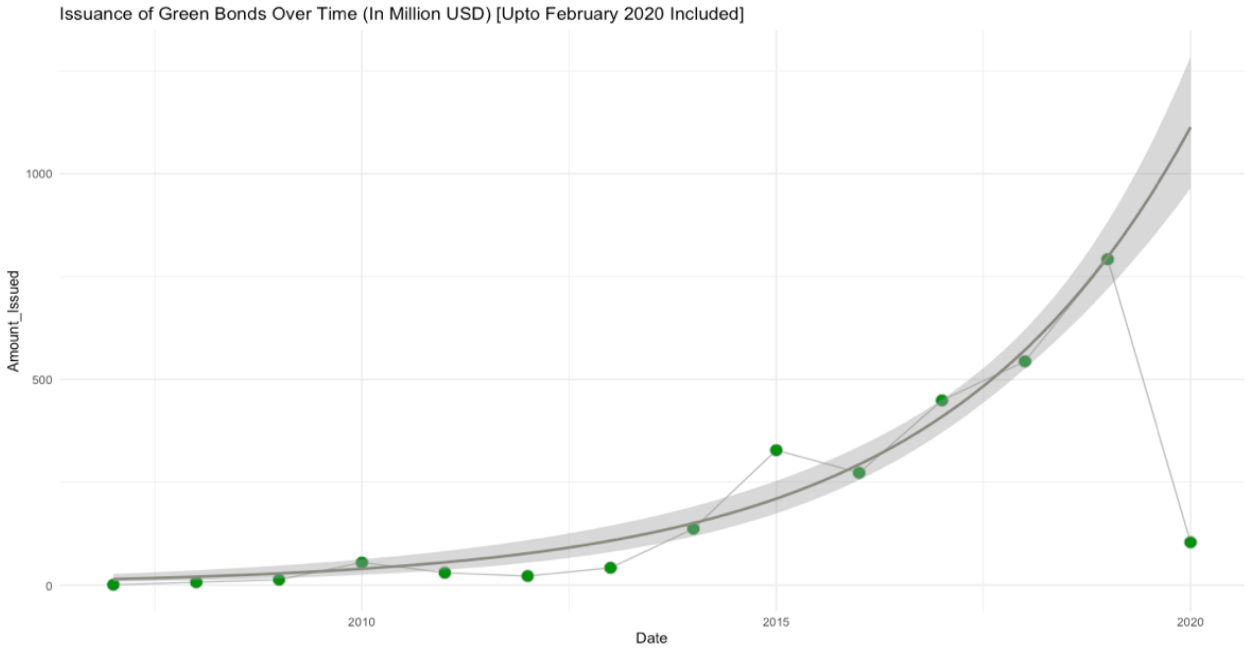
Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
1.00	2.40×10^3	2.60×10^4	2.65×10^5	2.00×10^5	1.93×10^9

Issue Amount Analysis

This analysis was conducted on the issuance dataset to observe the main market trend. Graph 1 shows the issuance of green bonds annually and only includes completed years, i.e., it excludes 2020. Graph 2 shows the datapoint for green bond issuance so far as of February 2020, along with a prediction curve based on the issuance in completed years. The main motivation behind the issue amount analysis was to observe any interesting spikes or troughs in the trending structure: in this case, there was a sudden increase from 2014, which spiked in 2015 and then slipped in 2016, after which it started to grow exponentially once again. It is interesting to note that this occurred during the introduction for the GBP and was thus my major motivation for conducting the diff-in-diff analysis.



Graph 1: Issuance of Green Bonds Over Time (In Million USD) excluding 2020



Graph 2: Issuance of Green Bonds Over Time (In Million USD) w/ Predicted 2020 Results

Results

Matching:
As stated earlier a SQL Matching was performed on the dataset using the following controls: *Date of Issue +/- 7 Days, Maturity Date +/- 60 Days* and *Rating*. Further, a propensity score matching was also conducted. However, convergence was not obtained.

Once the SQL Match was performed, a dataset with 1 Green Bond : Many Conventional Bonds was obtained. Among these matches the conventional bond kept for the 1:1 match had the closest issue date to the given green bond. The final dataset had 157 observations with 18 variables. The R-Code for the SQL match is shown in the Appendix.

The Yield Differential is calculated by the subtraction of the Yield of the Green Bond from the Yield of the Conventional Bond as shown below:

```
matched_sample_final$YieldDifferential <-
matched_sample_final$Yield - matched_sample_final$Yield..15
```

The Issue Price Differential is calculated by the subtraction of the Issue price of the Green Bond from the Issue Price of the Conventional Bond as shown below:

```
matched_sample_final$IssuePriceDifferential <-
matched_sample_final$Issue_Price -
matched_sample_final$Issue_Price..13
```

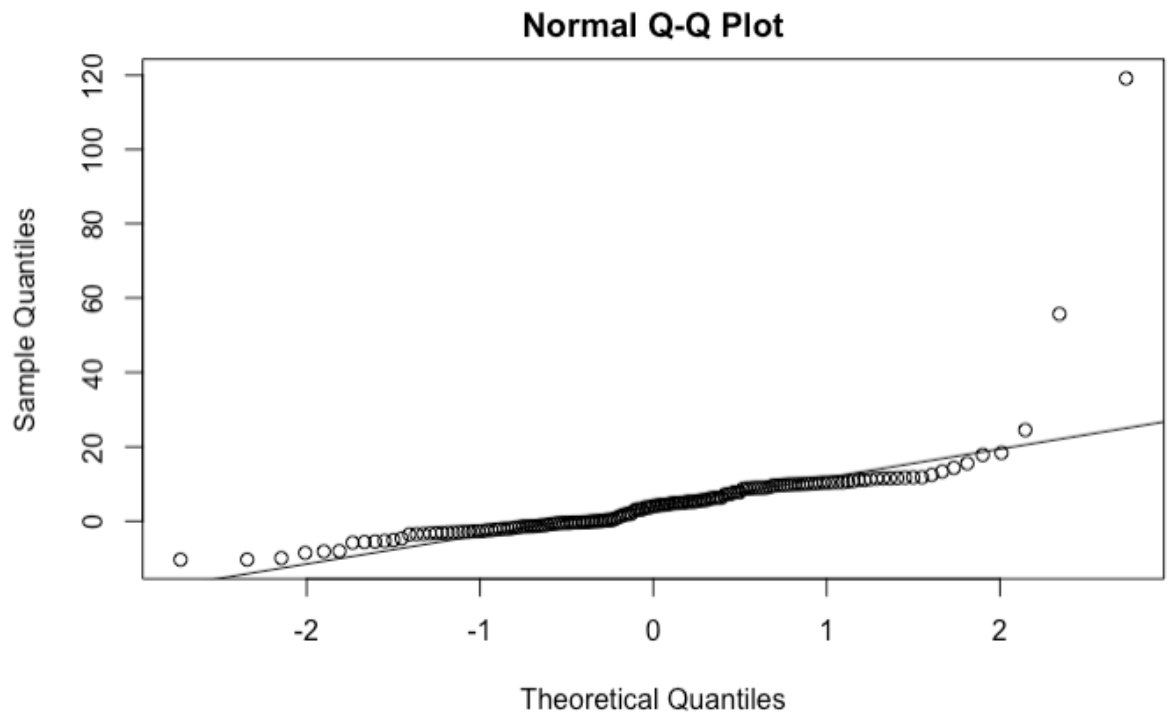
The summary statistics for the Yield Differential are as shown below:

```
Min.    1st Qu.  Median   Mean   3rd Qu.    Max.
-10.39  -1.28    4.05     4.66   9.17       119.17
```

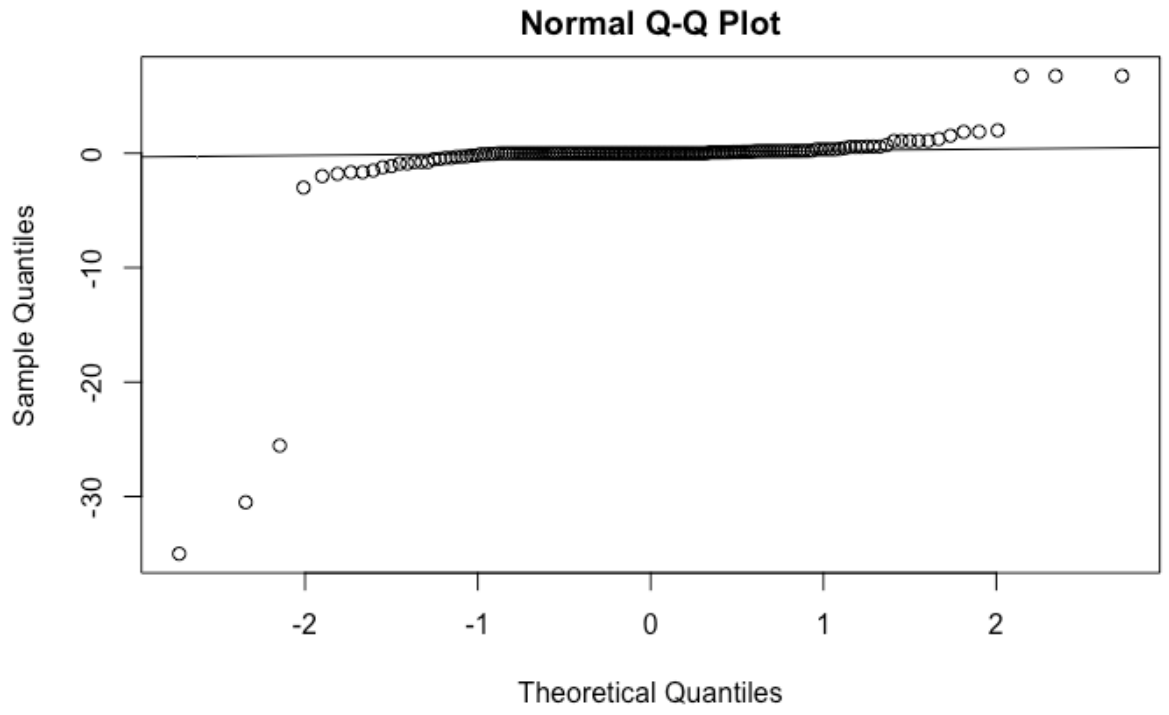
The summary statistics for the Issue Price Differential are as shown below:

```
Min.    1st Qu.  Median  Mean   3rd Qu. Max.
-35.00  0.00     0.00    -0.43  0.19    6.76
```

Additionally, I create normal quantile plots of the yield differential (Graph 3) and issue price differential (Graph 4) to observe the normality of the data and identify and remove outliers. Random outliers were observed as shown below.



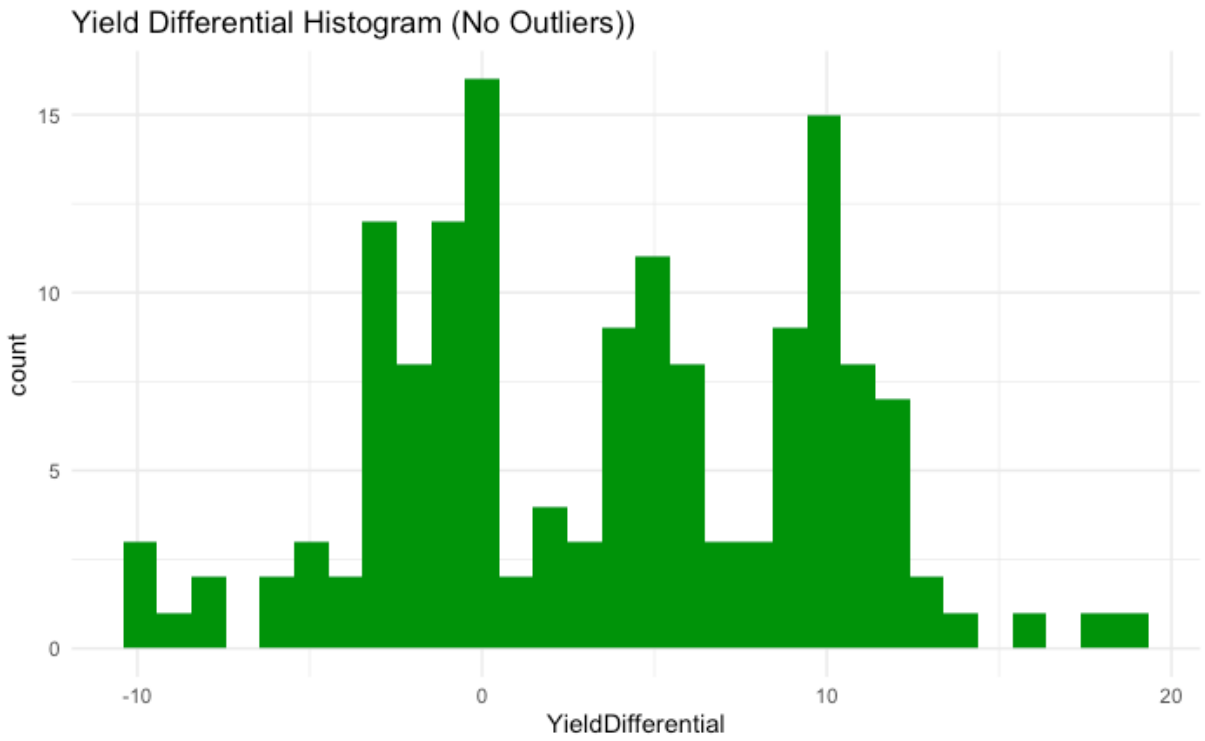
Graph 3: Normal Quantile Plot – Yield Differential



Graph 4: Normal Quantile Plot – Issue Price Differential

Once the outliers were identified and removed, the final dataset that would be analyzed for the time series, diff-in-diff and regressions had 151 observations with 18 variables. Additionally, the following histograms for yield differential and issue price differential were obtained.

In Graph 5, we see that the yield differential majorly is between the frequencies of -10bps and +20bps.

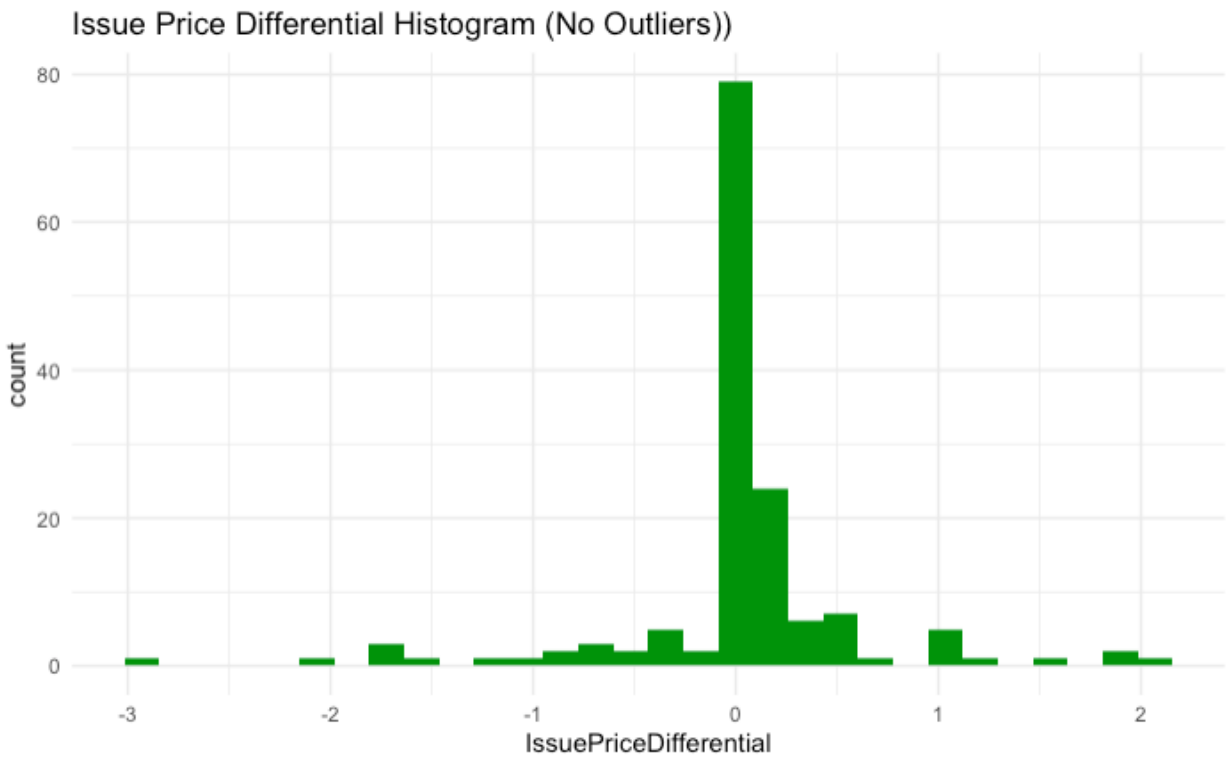


Graph 5: Histogram – Yield Differential [No Outliers]

Additionally, summary statistics for the Yield Differential, without the outliers, were observed as shown below:

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
-10.39	-1.28	4.12	3.60	9.00	18.40

In Graph 6, we see that the issue price differential majorly is between the frequencies of (-$3) and $2, with a mode of $0.



Graph 6: Histogram – Issue Price Differential [No Outliers]

The summary statistics for the Issue Price Differential, without the outliers are:

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
-3.00	0.00	0.00	0.026	0.18	2.00

Time Series Analysis:

As described in the research design earlier, I calculate the monthly and annual yield and issue price differentials over time from 2010 (first matched green bond observed) to 2016 (latest matched bond observed) using the matched sample above to determine the variation of the investor yield premium and the issuer price premium across time. The following graphs show the movement of the yield differential and the issue price differential across time.

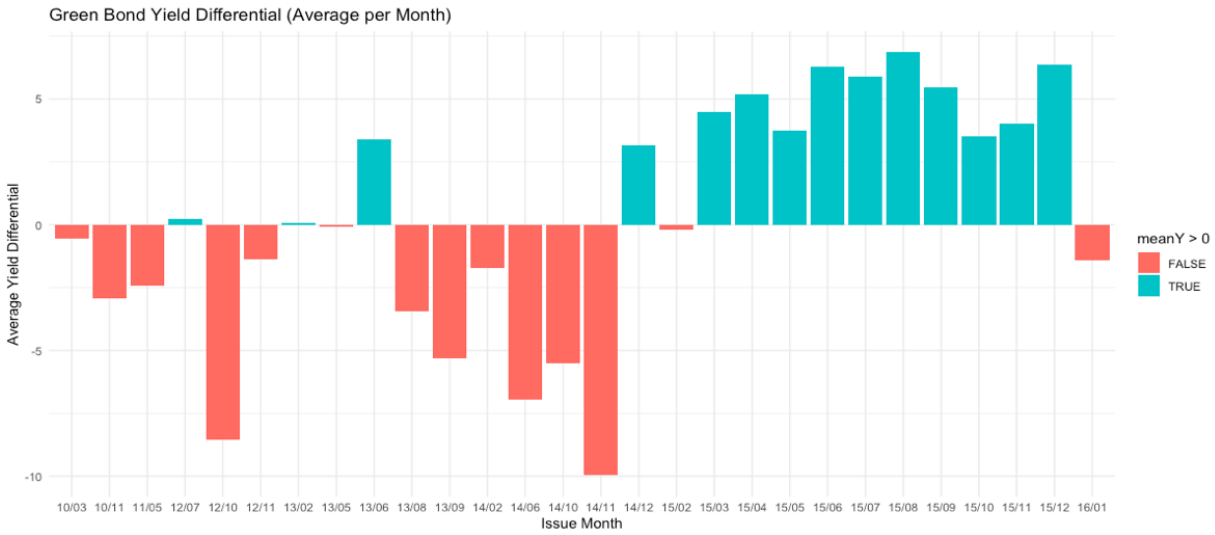
Graph 7: Green Bond Yield Differential [No Outliers, By Year]

Observing the yield differentials annually in Graph 7, we see that 2015 has the greatest number of observations in the time period. Further, the regression line drawn shows an upward slope suggesting increasing yield differentials over time, which would translate to a discount for the issuer and a premium for the investor.

Graph 8: Green Bond Issue Price Differential [No Outliers, By Year]

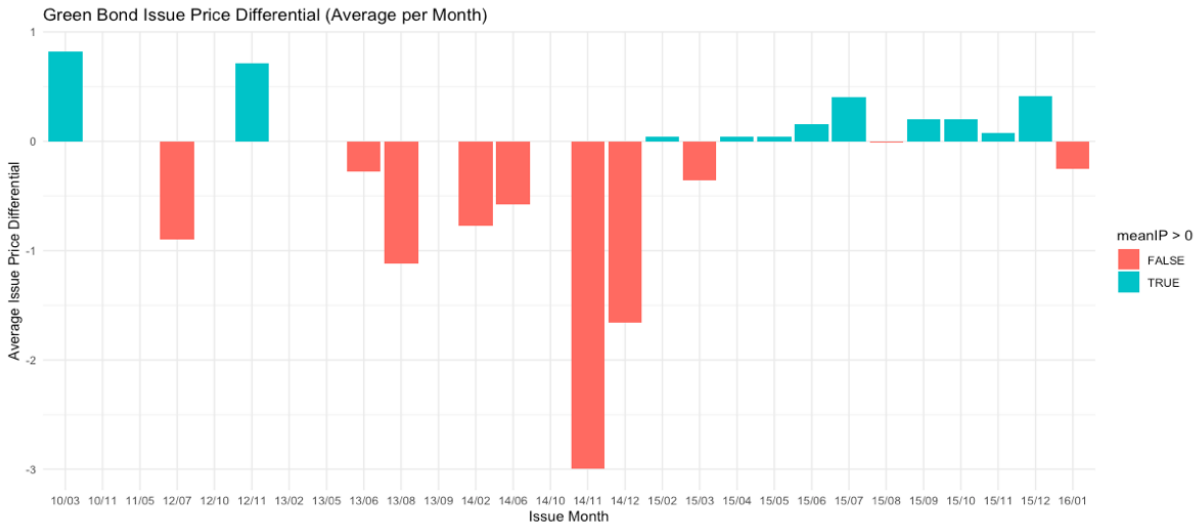
Next, we observe the issue price differentials annually in Graph 8. Here, we see that once again, 2015 has the greatest number of observations in the time period. That said, the regression line drawn shows a slight negligible slope suggesting no observable issuer premium over time.

Now, we observe the yield and issue price differentials on a monthly basis after averaging them by month. This gives us a single data point for each month as shown here.



Graph 9: Average Green Bond Yield Differential [No Outliers, By Month]

When Graph 9 is observed, as suggested in my hypothesis, the investor yield greemium went from mostly negative between 2010 and 2014, to a substantial yield premium in 2015 as shown in the graph. As of 2016, a single matched sample was observed, which does not allow us to conclusively determine if the green bond is at par with the conventional bond presently.



Graph 10: Average Green Bond Issue Price Differential [No Outliers, By Month]

When Graph 10 is observed, we see anomalous activity in terms of the direction of the yield and issue price. Issue price and yield have an inverse relationship, however, here there is movement in the same direction in certain parts of the graph. This anomaly is discussed in further detail in the conclusion. Other than this, the price mostly stayed at par, as suggested by Graph 8.

Regression Analysis:

Additionally, I perform regression analysis to understand the effect of the greenness of a bond on the yield and issue price as shown below.

Model 1: `Yield ~ β0 + β1* Green Indicator + β2*Maturity Date + ε`

```
Residuals:
    Min      1Q  Median      3Q     Max
  -8.06   -2.23   -0.70    4.64   18.88

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)   -3.2859766 51.4711624  -0.064    0.949
Green          3.5961944  0.5174947   6.949 2.36e-11 ***
Maturity_Date  0.00        0.00        0.14    0.89
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.46 on 295 degrees of freedom
Multiple R-squared:  0.14,  Adjusted R-squared:  0.13
F-statistic: 24.16 on 2 and 295 DF,  p-value: 00
```

The green indicator coefficient (β1) is statistically significant (p-value = 2.36e-11 ***) and is correlated with the yield with a value of 3.6 bps. The β1 represents the higher yield of 3.6 bps in the estimated value of the Yield for the difference between a green bond and non-green bond, if the Maturity Date remains constant. This suggests an investor premium and issuer discount across the entire matched sample.

Model 2: `Issue Price ~ β0 + β1* Green Indicator + β2*Maturity Date + ε`

```
Residuals:
     Min       1Q   Median       3Q      Max
   -1.76     -0.01  0.04         0.08    3.06

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)    1.082e+02  5.084e+00  21.278   <2e-16 ***
Green          2.208e-02  5.111e-02   0.432    0.666
Maturity_Date -4.473e-04  2.753e-04  -1.625    0.105
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4408 on 295 degrees of freedom
Multiple R-squared:  0.01,  Adjusted R-squared:  0.00
F-statistic: 1.445 on 2 and 295 DF,  p-value: 0.2374
```

The intercept(β0) has a value of $108.2. Looking at the green indicator coefficient (β1), it has a value of $0.02. However, there is no statistically significant correlation with the issue price (p-value = 0.666). Hence, we cannot determine with certainty the direction of the movement of the data. This lack of significance may stem from the anomaly observed in Graph 10.

Difference-in-Difference Analysis:

To understand the possible causes behind the changing patterns of the yield and issue price based on the time series analysis, I run a diff-in-diff analysis as shown below.

Here, a possible explanation is based on the introduction of the Green Bond Principles in 2014 (Elhers and Packer 2017). To understand its effect on the green bond market, the difference-in-difference equation is created as follows:

`Yield ~ β0 + δ0(Post GBP i.e., >= 2014) + β1(Green Indicator – Dummy Variable) + δ1(Green Indicator× Post GBP) + ε`

`Issue Price ~ β0 + δ0(Post GBP i.e., >= 2014) + β1(Green Indicator – Dummy Variable) + δ1(Green Indicator× Post GBP) + ε`

This is regressed against the issue price and yield to observe the effects of the introduction of the Green Bond Principles on green vs. non-green bonds.

Note: The ‘True’ Green Indicator or the green line states that the bond is green, while the ‘False’ Green Indicator or the red line states that the bond is conventional.

Model 3: Yield ~ β0 + δ0(Post GBP i.e., >= 2014) + β1(Green Indicator – Dummy Variable) + δ1(Green Indicator× Post GBP) + ε

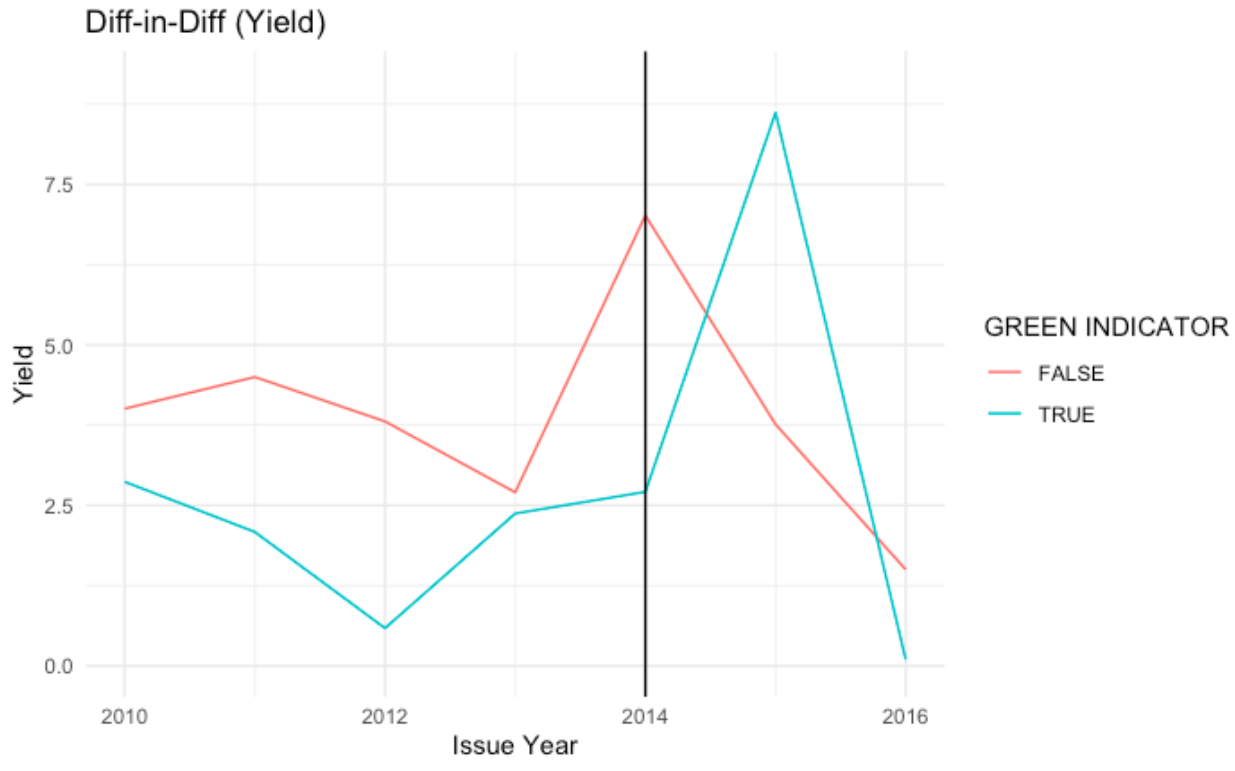
where,

δ1 = Difference-in-Difference Coefficient

```
Residuals:
    Min      1Q  Median      3Q     Max
  -8.58   -1.92   -0.63    4.16   18.29

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   3.4408     1.1484   2.996  0.00297 **
DID           5.4334     1.7062   3.185  0.00161 **
Green        -1.3297     1.6240  -0.819  0.41359
GBP           0.4889     1.2064   0.405  0.68559
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.297 on 294 degrees of freedom
Multiple R-squared:  0.21,  Adjusted R-squared:  0.20
F-statistic: 25.45 on 3 and 294 DF,  p-value: 1.146e-14
```



Graph 11: Diff-in-Diff Analysis [Yield]

The diff-in-diff regression indicates that the introduction of the GBP on a green bond (Green indicator = True, GBP >= 2014) increased the yield by 5.43bps with statistical significance. Prior to the introduction of the GBP on a green bond (Green indicator = True, GBP < 2014), the yield coefficient was -1.32bps with a p-value of 0.41. The low yield coefficient of green bonds before the introduction of the GBP suggests the existence of an issuer premium or an investor discount. On the other hand, the high yield of green bonds after the introduction of GBP shows an issuer discount or investor premium. This holds with the time series analysis that suggested the investor yield premium went from mostly negative between 2010 and 2014, to a substantially positive yield premium. This can be observed in Graph 11, as the green line (Green Indicator = True) goes from about 2.5bps in 2013, prior to the GBP introduction, to about 8bps in 2015, after the GBP has been introduced.

Model 4: Issue Price ~ β0 + δ0(Post GBP i.e., >= 2014) + β1(Green Indicator – Dummy Variable) + δ1(Green Indicator× Post GBP) + ε

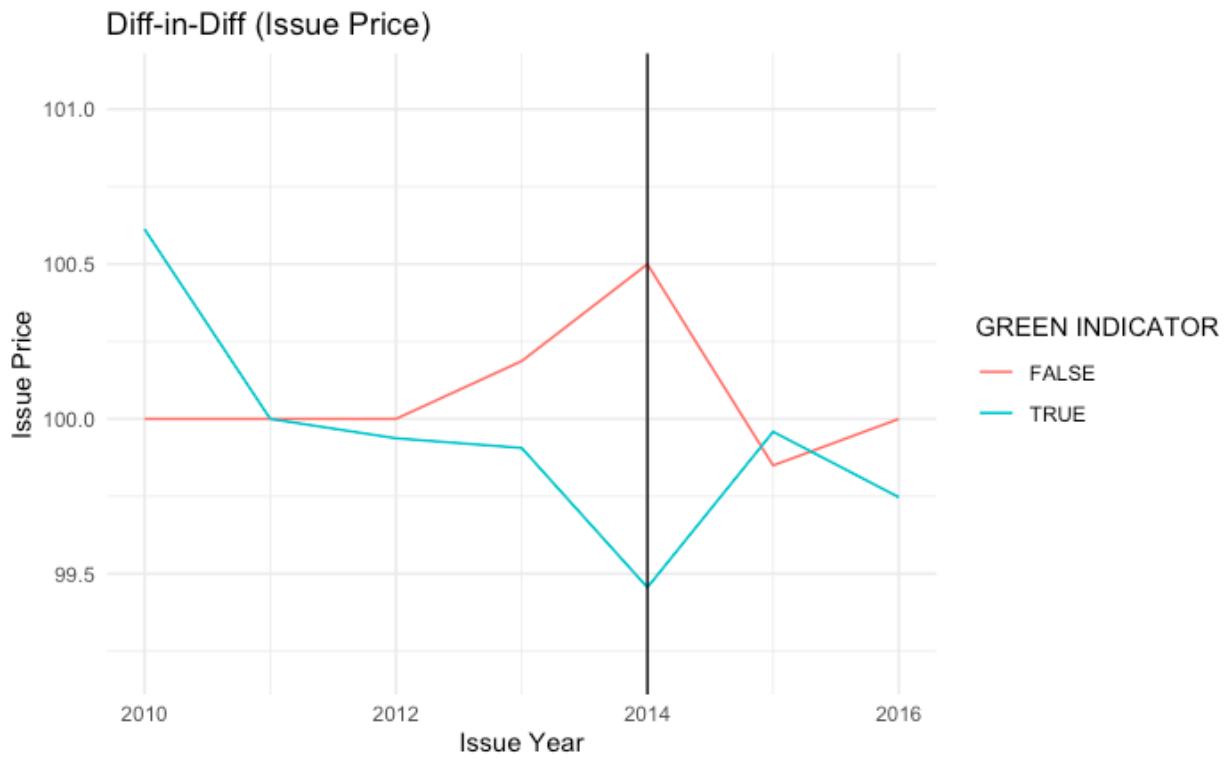
where,

δ1 = Difference-in-Difference Coefficient

```
Residuals:
     Min       1Q   Median     3Q      Max
    -1.93    -0.08  0.08      0.10    3.10

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 100.07993    0.11757 851.260   <2e-16 ***
DID          -0.01756    0.17467  -0.101    0.920
Green         0.04143    0.16626   0.249    0.803
GBP          -0.18357    0.12351  -1.486    0.138
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.44 on 294 degrees of freedom
Multiple R-squared:  0.02,  Adjusted R-squared:  0.01
F-statistic: 1.704 on 3 and 294 DF,  p-value: 0.1663
```



Graph 12: Diff-in-Diff Analysis [Issue Price]

When looking at the issue price, the diff-in-diff regression indicates that the introduction of the GBP on a green bond (Green indicator = True, GBP >= 2014) decreased the issue price by $0.017 per $100 with a p-value of 0.920. Prior to the introduction of the GBP on a green bond (Green indicator = True, GBP < 2014), there was an increase in the issue price by $0.04 with a p-value of 0.803. While not statistically significant, the low-price coefficient of green bonds after the introduction of the GBP suggests the existence of an issuer discount or investor premium. On the other hand, the high-price coefficient of green bonds before the introduction of GBP shows an issuer premium or investor discount. This holds with the previous diff-in-diff study for yield (Model 3).

That said, the difference between the effect on the green bond issue price before and after the introduction of the GBP is positive overall (-$0.02+$0.04 = $0.02). This can be observed Graph 12, as the green line (Green Indicator = True) goes from about $97 in 2013, prior to the GBP introduction, to about $99 in 2015, after the GBP has been introduced. Since, the difference between the effect on the green bond yield before and after the introduction of the GBP is also positive(4.1bps), this ties with the anomaly observed in Graph 10, where there is movement of yield and issue price in the same direction. This is discussed further in the conclusion.

Conclusion

This study's main findings are:

1. The regression analysis showed a positive yield coefficient (3.6bps) and no significant change in the issue price coefficient for green bonds across the entire matched sample. The yield regression analysis suggests that green bonds have had an investor premium and issuer discount historically.
2. The diff-in-diff gave further clarity regarding the impact of the introduction of the Green Bond Principles (GBP) in 2014. Based on Models 3 and 4, it was observed that prior to the introduction of the GBP there was an issuer premium and an investor discount. However, once the GBP was introduced, an issuer discount or an investor premium was observed.
3. The time series analysis showed us that the investor yield greemium went from mostly negative between 2010 and 2014, to a substantial yield premium in 2015. As of 2016, there was only a single matched sample, which does not allow us to conclusively determine if the green bond is at par with the conventional bond presently.

The study's main limitation is in terms of the issue price anomaly. As discussed in the diff-in-diff analysis for the issue price, the difference between the effect on the green bond issue price and the green bond yield before and after the introduction of the GBP is positive overall. This ties with the anomaly observed in Graph 10 and the statistically insignificant positive issue price value from the regression analysis, where there is movement of yield and issue price in the same direction. A possible explanation for this is that after the 2014 GBP introduction, there were a large number of green bond issues, due to possible increase in the confidence of the certifiability of this bond. This could have caused the yield to increase even as the price increased slightly right after 2014. However, this is speculation and further research can be conducted regarding this anomaly.

Appendix

SQL Match Code

```
#Creating intervals to match on
con_bonds$Issue_Date_Min <- as.Date(con_bonds$Issue_Date) - 7
con_bonds$Issue_Date_Max <- as.Date(con_bonds$Issue_Date) + 7
con_bonds$Maturity_Date_Min <- as.Date(con_bonds$Maturity_Date)
- 60
con_bonds$Maturity_Date_Max <- as.Date(con_bonds$Maturity_Date)
+ 60

con_bonds$Issue_Date_Min<-
as.character(con_bonds$Issue_Date_Min)
con_bonds$Issue_Date_Max <-
as.character(con_bonds$Issue_Date_Max)
con_bonds$Maturity_Date_Min <-
as.character(con_bonds$Maturity_Date_Min)
con_bonds$Maturity_Date_Max <-
as.character(con_bonds$Maturity_Date_Max)
gbonds$Issue_Date_Char <- as.character(gbonds$Issue_Date)
gbonds$Maturity_Date_Char  <- as.character(gbonds$Maturity_Date)

#SQL Matching
library(sqldf)
matched_sample <- sqldf("
select gbonds.CUSIP, con_bonds.CUSIP, gbonds.Issue_Date,
gbonds.Issue_Year, con_bonds.Issue_Date, gbonds.Maturity_Date,
con_bonds.Maturity_Date, gbonds.Coupon, con_bonds.Coupon,
gbonds.Issue_Amount, con_bonds.Issue_Amount, gbonds.Issue_Price,
con_bonds.Issue_Price, gbonds.Yield, con_bonds.Yield
from gbonds inner join con_bonds on
gbonds.Rating = con_bonds.Rating and
gbonds.Issue_Date_Char  > con_bonds.Issue_Date_Min and
gbonds.Issue_Date_Char  < con_bonds.Issue_Date_Max and
gbonds.Maturity_Date_Char  > con_bonds.Maturity_Date_Min and
gbonds.Maturity_Date_Char  < con_bonds.Maturity_Date_Max
")

library(data.table)
matched_sample_final <- data.table(matched_sample)

#Creating 1:1 Match
matched_sample_final <-
unique(matched_sample_final[order(Issue_Date..5)], by="CUSIP",
fromLast=TRUE)
matched_sample_final$CUSIP <-
make.unique(as.character(matched_sample_final$CUSIP))
```

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