Effect of Joining Paris Agreement to Green Bond Premium in US Market

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ผลกระทบของการเข้าร่วมความตกลงปารีสต่อราคาเพิ่มของตราสารหนี้สีเขียวในตลาดสหรัฐอเมริกา

น.ส.อรจิรา สุกิจจาคามิน

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อรจิรา สุกิจจาคามิน : ผลกระทบของการเข้าร่วมความตกลงปารีสต่อราคาเพิ่มของตราสารหนี้สีเขียวในตลาดสหรัฐอเมริกา. (Effect of Joining Paris Agreement to Green Bond Premium in US Market) อ.ที่ปรึกษาหลัก : ผศ. ดร.ธนากร ลิขิตาภิวัฒน์

การศึกษานี้มีจุดประสงค์เพื่อศึกษาราคาของตราสารหนี้สีเขียวและตราสารหนี้ทั่วไปว่าราคาของตราสารหนี้สีเขียวจะมีราคาสูงกว่าตราสารหนี้ทั่วไปหรือไม่ และปัจจัยอะไรที่มีผลต่อความแตกต่างของราคาระหว่างตราสารหนี้สีเขียวและตราสารหนี้ทั่วไป รวมถึงผลกระทบของการเข้าร่วมในข้อตกลงปารีสต่อราคาที่เพิ่มขึ้นของตราสารหนี้สีเขียว ในเบื้องต้นการศึกษาคาดว่าราคาของตราสารหนี้สีเขียวนั้นจะมีราคาสูงกว่าตราสารหนี้ทั่วไปเนื่องจากนักลงทุนพร้อมที่จะยอมรับผลตอบแทนที่ต่ำกว่าเพื่อประโยชน์ด้าน ESG ที่เกี่ยวข้องกับโครงการสีเขียว อย่างไรก็ตามจากการศึกษาพบว่าตราสารหนี้สีเขียวและตราสารหนี้ทั่วไปให้ผลตอบแทนที่คล้ายกัน ซึ่งขัดแย้งกับข้อสันนิษฐานข้างต้น และการเข้าร่วมในข้อตกลงปารีสไม่สามารถใช้อธิบายการตวามต่างของราคาระหว่างตราสารหนี้สีเขียวและตราสารหนี้ทั่วไปในตลาดสหรัฐฯได้

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The paper investigates whether green bonds are priced at a premium compared to conventional bonds by analyzing the yield spread between green bonds and comparable conventional bonds (where a negative yield spread indicates a premium). The study also examines the factors influencing the yield difference including the effect of participating in Paris Agreement to the green bond premium. Initially, the paper expected to find a negative green bond premium, indicating that green bonds have lower yields than comparable conventional bonds, as investors are willing to accept lower yields for the ESG benefits associated with green projects. However, the paper obtained contradictory results. Additionally, participating in the Paris Agreement cannot be used to explain the green bond premium in US markets.

Field of Study:	Finance	Student's Signature .....
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1. Introduction

The world has become hotter by 1 degree Celsius since the Industrial Revolution (Turrentine, 2021). The rise in temperature causes significant impacts on the environment which affect our lives and animal lives including more severe natural disasters, loss of habitats, and increasing sea levels, etc. According to the European Commission, China was the largest carbon emitter with 12.5Gt (33% of the global emission) in 2021 while the United States came second with 4.7Gt CO2 emission (13% of the global emission). The United Nations is at the forefront of addressing the effort to solve climate change. In 1997, Kyoto Protocol was launched and became effective in 2005. The Kyoto Protocol was the first legitimately binding climate treaty that required economically developed nations to reduce their emission by a typical of 55% below 1990 levels. The United States signed the agreement in 1998 but failed to ratify it so the United States never officially signed the agreement (Maizland, 2022). Later in 2015, United Nations Climate Change Conference 21 (COP 21) took place in Paris in which members agreed to accelerate and intensify actions and financing for sustainable low carbon. COP21 is a foundation for the Paris Agreement, the most current significant global climate agreement, which was effective on 4 November 2016. Members are broader than the Kyoto Protocol as it also includes developing countries which currently 194 countries participated in the agreement. Its goal is to limit the rising temperature to 2 degrees Celsius above the pre-industrial level and aim for 1.5 degrees Celsius in order to reach the goal, countries have to become net-zero by 2050. Nations are pushing toward the goal by heavily investing in greener and more sustainable projects. Additionally, many countries implemented regulations to promote GHG reduction including carbon credit and carbon tax, etc. Green bonds, a bond issued to support projects that positively contribute to the environment, became a significant tool to achieve a climate change goal.

The green bond is a fixed-income security that finances or refinances projects that provides positive impact to the environment or climate. According to the Climate Bond Institution, the first green bond was introduced in 2007 by multilateral institutions European Investment Bank (EIB) and World Bank for an amount of USD 807.2m. Under a decade, cumulative green bond issuance grew more than 560% to over USD 100 billion in 2016. The cumulative green bond issuance then reached USD 1 trillion in 2020 and doubled to over USD 2 trillion within 2 years. The market is dominated by developed countries which accounted for 71% of total green bond issuance. Financial corporates and other corporates are the main players in the green bond market which have issued more than USD 426 billion contributing to 23% and USD 421 billion (22%) of the total green bond market respectively. According to the CBI (1H2022 report), it shows that the United States was the largest player in green bonds with cumulative green bonds issuance of USD 334 billion representing 18% of the total green bond issuance thus far. Green bonds are mostly used to finance energy

projects such as renewable energy accounting for 35% (USD 662 billion) of total green bond issuance. As of the record, green bond issuance is normally a large deal with more than USD 1 billion amount (accounting for 34% of total cumulative bond issuance). In order to reach the net zero goal by 2050, Investment of over USD 275 trillion in sustainable environment projects is required (Rapp, 2022). As such, there is a large potential growth for the green bond market.

As green bonds increase their presence in the bond market, many research studies put interest in the green bond market by studying various aspects including its premium compared to conventional bonds and determinants of the premium on the green bonds, market reaction to the green bond announcement. Referring to (Wu, 2022), green bond premium means the price of green bonds is higher than the comparable conventional bond. In order to test for the green bond premium, the yield difference between the green and conventional bonds is used to test for the premium. The negative green bond premium in the regression model indicated that green bond has a lower yield than conventional bond (lower financial costs), which shows that there is a green bond premium (green bond priced higher than conventional bonds). Studies on the green bond premium were first dated back in 2015 by Preclaw & Bakshi using global green bond data set during 2014-2015 showing the premium of green bonds compared to conventional bonds on the secondary market in different scales. Most of the previous data shows there is a premium in green bonds using various data sets including EU utility provider, EU, US municipal bond, US, China, and global dataset. Most of the studies used a secondary market for the dataset (MacAskill et al., 2021). Recently, there are more research papers focusing on Chinese markets as the growth of green bonds are double digits over the past 2 years or over 100% since 2020 from a cumulative issued amount of USD 120 billion to over USD 332 billion in Jan 2023. The determinants mostly used in the studies to determine green bond premiums are bond characteristics (bond type, tenor, coupon rate), credit rating, the green certificate, industry sector (financial, utility, energy, etc.), and macroeconomic factors (GDP growth and CPI) which the correlation of these factors with green bond premiums are different among countries or dataset used. For example, green certificates provide a negative premium in the EU market but provide a positive premium in the Chinese market. In another aspect study of the green bond market (market reaction to the green bond issuance), there are mixed results of the reaction to green bond issuance. Studies measure cumulative abnormal return (CAR) using CAPM model to determine the reaction to green bond announcements. There was a positive reaction to the announcement both for the first time and seasonal offered in the global bond market at 1.04% (Tang & Zhang, 2020). While a study from Wu, 2022 suggested that there was a negative effect on stock performance, which provides the same result as another research done by (Lebelle et al., 2020) which used CAR as well as Fama French 3 and 4-factor models. The difference in result may be due to the event window and beta used in the model.

The previous research papers studied the green bond premium in different markets and find determinants of the green bond premium in those markets. On the other hand, several research papers focused on the market reaction to green bond issuance looking at several event windows. However, no research paper studied the effect of becoming a member of the Paris Agreement on the green bond premium. As of February 2023, 194 countries joined the Paris Agreement. Large green bond issuer countries (EU, China, and US) joined the Paris Agreement in November 2016. The green bond market in 2016 was small with cumulative green bond issuance of less than USD 200bn compared to USD 2tn in 2022. EU and China had never changed their decision on joining the Paris Agreement, unlike the US which changes its decision recently. Originally, the United States signed the Paris Agreement. However, during former President Trump, the United States effectively withdrew from the agreement on 4 November 2020. After President Biden got elected, he put priority on rejoining the agreement which the United States was effectively rejoining on February 19, 2021. So, I will focus on the US market to determine the effect of joining the environmental-related agreement on the green bond premium and observe the determinants of the green bond premium. The paper will compare green bond premiums during the withdrawal period and joining the Paris Agreement. To achieve the purpose of the paper, I will focus on i) identifying green bond premiums in the US market ii) identifying determinants that cause green bond premiums in the US market iii) investigating the effect of joining the Paris Agreement on the green bond premium. The paper contributes to previous literature in several aspects. First, this paper finds green bond premiums in the secondary market (Zerbib, 2019). The paper only focuses on the US market as the country has changed its decision to join the Paris Agreement several times. The paper follows the methodology of (Zerbib 2019) and (Wu 2022) in which they use a two-layer regression model. The model eliminates liquidity premium from the green bond premium. The paper then additionally contributes to previous papers by finding the effect of green bond premium by comparing participation and not participation in the event.

2. Literature Reviews

Green bonds will play a key role in achieving energy transition towards net zero by investing in de-carbonization projects. People are more concerned about climate change as nations are announcing a goal to become net zero, this is a huge potential growth for the green bond market. The green bond was first presented in 2007 by European Investment Bank and World Bank with an amount of USD 649m. At present, there are over 7,800 green bonds issued with issuance amounts exceeding USD 2 trillion with outstanding of over USD 1.86 trillion (Refivnitiv). As green bonds have more presence, there are many research studies on green bonds, The related studies to my paper are topics that studied green bond premium between green

bonds and the comparable conventional bonds and determinants that cause the green bond premiums and market reaction to the green bond announcement.

2.1 Green bond premium and its determinants

The green bond premium is described as the yield difference between conventional bonds and green bonds. Positive green bond premium indicates that green bond is priced higher than conventional bonds and vice versa. Previous studies emphasize the yield difference between conventional bonds and green bonds, the most common method is a matching method. (Zerbib 2019) uses identical conventional bonds for comparison given the same issuer, currency, rating, bond structure, seniority, and coupon type. For matching with maturity, Zerbib allows 2 years of lead and lag of the conventional bonds compared to the green bonds. The paper used a 2-layer model to test for the premium which they separate the liquidity bias by looking at the bid-ask yield. The paper collected global green bonds during 2013-2017 and found that there is a slightly negative green bond premium of 2 bps which means that the green bond provides lower financial cost to the issuer than conventional bonds.

A recent study (Wu 2022) used Zerbib as a baseline for their methodology. Wu was the first person to study green bond premiums in the Chinese market from 2016 to 2019 in particular apart from the global market. The paper found that the green bonds trade at higher ask yield in both worldwide and Chinese markets increasing the financing cost of green bonds. Moreover, green certification leads to higher financing costs by 7.0 to 11.9 bps. As the green bond in the Chinese market significantly increased in its volume, many researchers research the green bond market in China. Another paper (Lin & Su, 2022) studied the issuance choice of bonds in the Chinese market by looking at the yield of issuance and the factors that affect the choice of issuance choice. The paper ran a 2-step procedure i) multiple regressions on binary choices to test for determinants of green bond premium ii) fuzzy set qualitative comparative analysis is used to test significant elements that lead to bond issuance choice with border data from Wu, 2022 covering the period between 2016 to 2021. Unlike previous papers that focused on determinants based on bond characteristics i.e. issue size, maturity, and issue cost, Lin & Su also focused on macro policy (Macro monetary policy, local financial development, and local green finance policy) and issuer characteristics (issuer age, profitability, and size, etc.). If found that firms that want to reduce financing costs would issue green bonds but firms that want large amounts of financing would issue conventional bonds due to additional requirements of green bonds including, getting green certification and validation from a third party. A better profitability firm would be less likely to issue debt financing so green bonds are preferred because of the smaller issuance size. Macro-monetary policy will negatively impact corporate bond selection. Loosen

monetary policy would make green bonds less popular. COVID-19 does not change the firm's preference for financing.

Another research emphasis on the European market where countries are seriously trickling down on climate change. The study (Sergei & Alesya, 2022) collected data from the first bond issuance in 2007 until 2021 in the EU market to find a green bond premium. The paper used a multiple OLS regression model to analyze the data which showed that there is a premium of approximately 4 bps which gave the same conclusion as other previous studies. Apart from bond characteristics that drive the premium, the paper also tested macroeconomic factors (GDP growth and CPI). It also found that the premium will increase with the presence of an ESG rating. Industry also plays a role in providing premiums given the issuer is in the financial and utility sectors. For the economic factor, GDP growth has a positive effect on the yield, but CPI provides the opposite effect.

2.2 Market reaction to green bond announcement

Another aspect of studying green bonds is the market reaction to the green bond announcement and whether green bond issuance improved the issuer's equity market performance. (Tang & Zhang, 2020) studies the benefit of green bonds to shareholders. The data was collected from the first bond issuance in 2007 until 2017 from Climate Bond Initiative (CBI) and Bloomberg on a global scale. The paper is only limited to financial and industrial public corporations. Event window of 10 before and after the announcement date. The paper used CAPM to identify abnormal returns and the results show that there is a positive reaction to green bond announcements with cumulative abnormal return (CAR) of +1.04%. First-time green bond issuance especially in corporate firms has a stronger market reaction than seasoned-offered and in financial sectors.

Further study was done by (Wu 2022). He compared green bonds with conventional bonds as well as the effect of green bond issuance around the announcement date on the stock price movement. The paper adopted the same event window from Tang which is 10 days before and after the announcement date then added additional windows (-5, 5) and (-5, 10) tested on both first-time issued and seasoned-offered green bonds. Wu also adjusted the beta to be 250 trading data period data and 120 trading days instead of 300 days and 50 days in Tang's model. The result shows a negative effect on the issuer's stock market performance while offering seasoned green bonds does not affect stock price performance. The result contradicts Tang's study.

Another research paper by (Lebelle et al., 2020) studied market reaction to the green bond issuance. The paper used abnormal returns to measure the reaction of the market to the issuance of green bonds. The paper further divided data into developed and emerging markets and excluded any asset-back securities and mortgage-backed securities from the sample as they are not considered green bonds. In Addition to the CAPM model that previous studies used to measure abnormal return, Lebelle also uses the Fama French 3-factor model and 4-factor model for robustness. The beta of 250 days and 50 days before the announcement date is used which is aligned with Wu's study. The paper also provides various event windows (-20,20) (-5,5) (-3,3) (-1,1) and (0, 1). The paper found that the market reacted adversely to the announcement of the green bond issuance by -0.5% and -0.2% depending on the asset pricing model. There are also more negative reactions for developed markets than for emerging markets. Using Fama French, both 3 and 4-factor provided similar results that there is more negative CAR for the first-time green bond issuance and more on advanced markets but no difference between financial and other corporations.

3. Methodology

The paper wants to test two hypotheses.

Hypothesis 1: There is a negative green bond premium in the US market.

Green bond premiums in the US market can be triggered by green certificates, the industry sector, and participating in the Paris Agreement.

Hypothesis 2: There is a larger negative green bond premium during the period when the US joins Paris Agreement

Being promised to follow the GHG emission goal will benefit the bond issuer (lower financial cost).

3.1 Regression models

The paper studies whether the green bond premium exists in the US market, what factors cause green bond premium, and compare the green bond premium between participating and non-participating in the Paris Agreement. Referring to Wu (2022), green bond premium is defined as the price difference between green bonds and comparable conventional bonds. A positive green bond premium means that green bond is priced higher than that of the comparable conventional bonds. However,

in the regression model, I test the green bond premium using the ask-yield spread between green bonds and conventional bonds. The negative green bond premium in the regression model indicates that green bond has a lower yield compared to conventional bonds (lower financial cost) which in turn are priced higher (positive green bond premium). The paper follows Zerbib (2019)'s methodology where the first layer is to determine the green bond premium from the ask-yield spread after eliminating the liquidity spread. Then the second layer is to determine what determinants cause the green bond premium and to what extent.

The first step is to find comparable conventional bonds using a matching method. I follow some Zerbib's (2019) criteria to find the matched conventional bonds which he used 2 comparable conventional bonds to compare with a green bond. The matched bonds should have at least the same issuer, credit rating, currency, and coupon type. Since the maturities cannot be equal, I allow for a two-year lapse (shorter and longer maturity than green bond). Additional restrictions for the matching methods are that the issuance amount of conventional bonds should range between 0.25x to 4x of the green bond, and the issuance date should not be more than a 6-year lapse (shorter and longer maturity) from the green bond issue date.

The second step is to form a synthetic conventional bond. Since there are 2 comparable conventional bonds with different yields and maturities that will be used to compare with green bonds, I then form a synthetic conventional bond using an equation (1). Ask-yield and bid-ask spread of synthetic bonds is the distance-weighted average of the two conventional bonds' yields.

$$i_{SCB} = \frac{t_s}{t_l + t_s} i_s + \frac{t_l}{t_l + t_s} i_t \quad (1)$$

$i_{SCB}, i_s, i_l$is the yield of a synthetic conventional bond, a shorter maturity conventional bond, and a longer maturity conventional bond respectively.

t_s, t_l is maturity difference in months from the green bond to the shorter maturity conventional bond and the longer maturity conventional bond respectively.

The paper uses ask-yield spread following the methodology of (Tang and Zhang 2019) and (Wu, 2022) because it is universally available, unlike i-spread and OAS. The ask yield of the synthetic bond is calculated from the equation (1) and referred to as $y_{i,t}^{SCB}$ in the equation (2). The ask-yield spread is then defined as

$$\Delta y_{i,t} = y_{i,t}^{GB} - y_{i,t}^{SCB} \quad (2)$$

$y_{i,t}^{GB}$, $y_{i,t}^{SCB}$is the daily ask-yield of green bond and synthetic conventional bond respectively.

The paper refers to Zerbib's (2019) method that uses two-layer model regression. The first regression is to employ a panel fixed effect model to examine green-synthetic conventional yield spread affected by liquidity spread and green bond premium. The first layer tried to control the residual difference in liquidity between the green bond and comparable conventional bonds. The bid-ask spread is used as a proxy for liquidity. $\Delta Liquidity_{i,t}$ captures the liquidity difference between the green bond and synthetic the conventional bond. Since the synthetic conventional bond consists of 2 bonds, equation (1) is used to find the bid-ask spread of the synthetic conventional bond. The first layer regression model used the ask yield spread derived from equation (2) as a dependent variable and liquidity spread from equation (3) as an independent variable. The green bond premium (GP_i) in equation (4) is then defined as an unobserved effect which is the ask-yield difference between the green bond and the synthetic bond after eliminating the liquidity spread.

$$\Delta Liquidity_{i,t} = Liquidity_{i,t}^{GB} - Liquidity_{i,t}^{SCB} \quad (3)$$

Where

$\Delta Liquidity_{i,t}$ is the daily bid-ask spread difference between the green bond and the conventional bond;

$Liquidity_{i,t}^{GB}$ *and* $Liquidity_{i,t}^{SCB}$ is the daily bid-ask spread of green bond and synthetic bond respectively.

$$\Delta y_{i,t} = GP_i + \beta_1 \Delta Liqspread_{i,t} + \varepsilon_{i,t} \quad (4)$$

$\Delta y_{i,t}$ is an ask-yield difference as derived from equation (2)

GP_i is green bond premium;

$\Delta Liqspread_{i,t}$ is liquidity spread difference as derived from equation (3)

$\varepsilon_{i,t}$ is the error term

The second layer is to determine factors and to what extent that cause green bond premiums. The GP_i from the first layer-equation (4) is used as a dependent variable in the equation (5). The variables tested in the model are green bond certificate, industry sector, and participation in Paris Agreement.

$$GP_i = \alpha + \beta_1 Cer_i + \beta_2 Paris_i + \beta_3 Sector_i + \varepsilon \quad (5)$$

Cer is a dummy variable where 1 means green bond has CBI certificate;
Paris is a dummy variable where 1 means bond that was issued when the US joined the Paris Agreement; and
Sector is a dummy variable where 1 means industry sector that heavy emit GHG namely Utility or Industrial;
α is the intercept; and
ε= error term

4. Data

The paper employs daily data of ask yield and bid-ask spread from Bloomberg for green bonds and conventional bonds in order to test for the green bond premium. The data is collected from 1 January 2017 until 28 April 2023. Data is collected from 2017 which was the first full year that the US participated in the Paris Agreement until the most recent data. Bond characteristics that are used to test for factors affecting green bond premium are also collected from Bloomberg and Refinitiv.

Data Overview

I examine 525 US green bonds on Bloomberg on 30 April 2023. To find the synthetic conventional bond to the green bonds by following Zerbib's 2019 method for the matching step. First, I find conventional bonds that are 2 years lapse to the green bonds with the same rating as the green bond, then I further find bonds that have the same currency, same coupon type, 6 years lapse of issuance date, and 0.25x-4x of the green bond's issuance amount. If there are more than 2 matching bonds, then I choose the bond with the closest maturity to the green bond. After the matching method, there are 54 green bonds used to run the regression. While there are 85 conventional bonds used to match with the green bonds. The numbers of conventional bonds are less than 2 times that of the green bonds because some of the conventional bonds can be matched with more than 1 green bond. The first green bond issued in the data set was in 2015 while the first issued conventional bond was issued in year 2014. Both green bonds and comparable conventional bonds were mostly issued in the recent years (2020 onwards). The amount of green bonds issued was USD 19m while conventional bonds issuance amount is USD 39m (Table 1). Green bonds are mainly AAA rated which are all from the supranational institutions namely International Bank for Reconstruction & Development (IBRD) and International Finance Corporation (IFC) while corporate bonds are mostly BBB+ rated (Table 2). Supranational institutions are also the main players in the US green bond market in the dataset (Table 3) while the largest issuance size is from the financial sector. The green bond has the shortest tenor of 4 years and the longest tenor of 30 years with an

average of 11 years similar to comparable conventional bonds. The largest green bond issuance is USD 1.25bn from PepsiCo Inc while Visa Inc issued the largest bond amount of USD 1.5bn. The average issuance amount of comparable conventional bonds is slightly higher than green bond with an average amount of USD 433m (Table 4).

Table 1: Numbers of bonds issuance across years

The table presents the number of green bonds (GB) and Synthetic Conventional Bonds (CB) issued in a year and the amount issuance.

	GB		**CB**	
Year	No.	Amount	No.	Amount
2014	0		1	400,000,000
2015	2	64,986,000	6	2,005,432,021
2016	2	675,000,000	3	1,950,000,000
2017	0	-	7	3,736,159,814
2018	7	3,209,219,051	9	2,804,703,442
2019	6	1,832,047,442	9	3,353,669,700
2020	11	4,460,940,000	16	8,782,604,114
2021	17	4,854,441,611	17	6,058,984,945
2022	8	4,067,690,829	15	7,253,485,340
2023	1	100,000,000	2	531,453,794
Total	**54**	**19,264,324,933**	**85**	**36,876,493,170**

Table 2: Bond ratings

The table presents the number of green bonds (GB) and Synthetic Conventional Bonds (CB) in terms of their rating. The rating is the best rating among Moody's, Fitch, and S&P.

	GB		**CB**	
Rating	No.	Amount	No.	Amount
AAA	27	4,170,390,194	34	4,420,067,128
AA+	1	138,734,739	2	279,392,042
AA-	4	2,080,625,000	7	4,612,415,000
A+	2	2,000,000,000	4	3,895,600,000
A	1	350,000,000	2	550,000,000
A-	6	3,049,575,000	12	7,594,019,000
BBB+	9	4,975,000,000	18	11,825,000,000
BBB	1	400,000,000	2	900,000,000
BBB-	3	2,100,000,000	4	2,800,000,000
Total	**54**	**19,264,324,933**	**85**	**36,876,493,170**

Table 3: Industry sectors of bond issued.
This table shows the number of GB and CB and the amount issuance in terms of their industry sector.

	GB		CB	
Industry	No.	Amount	No.	Amount
Supra-national	28	4,309,124,933	36	4,699,459,170
Financial	14	7,499,575,000	28	17,869,019,000
Industrial	4	2,580,625,000	8	5,708,015,000
Utility - electricity	4	2,275,000,000	6	3,150,000,000
Special purpose	2	1,500,000,000	3	2,250,000,000
Trans - rail	2	1,100,000,000	4	3,200,000,000
Total	**54**	**19,264,324,933**	**85**	**36,876,493,170**

Table 4: Bond Characteristics
This table represents the statistics including minimum, maximum, average, and standard deviation of tenor (years), and issuance amount (USD) for GB and CB.

	GB		CB	
	Tenor (Years)	Amount (USD)	Tenor (Years)	Amount (USD)
Min	4	15,000,000	2	4,700,000
Max	30	1,250,000,000	31	1,500,000,000
Mean	11	356,746,758	11	433,841,096
S.D.	9	318,258,259	8	395,826,106

5. Result

5.1 Green bond premium

The first layer regression model is to find the green bond premium by using panel fixed effect model regression. I ran the regression model using the following equation. The first layer regression is to exclude the effect of liquidity premium from the green bond premium.

$$\Delta y_{i,t} = GP_i + \beta_1 \Delta Liqspread_{i,t} + \varepsilon_{i,t}$$

Where,

- $\Delta y_{i,t}$ is ask yield spread which is the ask yield of the green bond minus the synthetic conventional bond;
- GP_i is green bond premium;
- $\Delta Liqspread_{i,t}$ is bid-ask spread which is the bid-ask spread of the green bond minus the synthetic conventional bond

I expect to see a negative green bond premium in the regression model which indicates that green bond has lower financial cost than comparable conventional bonds (green bonds are priced higher than conventional bonds). The statistics for the first layer regression model can be found in Table 5 and the regression result are shown in Table 6.

Table 5 shows statistics of ask yield spread and liquidity spread. On average green bonds and conventional bonds have similar yields (similar financial cost) but green bonds' yield is slightly lower by 0.5 bps. Green bonds are slightly more liquid than conventional bonds by 0.7 bps. The variable can significantly explain the ask yield difference which liquidity premium increases the ask yield difference (Table 6). The result shows that green bonds and conventional bonds have similar yield with slight positive green bond premium of 8 bps but the premium is not significant in the regression result, so it cannot be used to explain the ask yield spread. The green bond premium for each individual green bond in the dataset is shown in Table 7 which shows that there is a negative green bond premium of 17.7 bps. There is an extremely negative green bond premium which is from International Bank for Reconstruction & Development rated AAA in Mexican Peso. While the maximum green bond premium is 0.79% from PepsiCo Inc. for clean Transportation in USD currency rated A+.

Table 5: Descriptive statistics of the variables in the first layer regression model that finds the green bond premium eliminating the liquidity premium effect. The table shows the mean, standard error, minimum, and maximum of the dependent variable (ΔY is ask yield spread between the green bond and the synthetic conventional bond) and independent variable (ΔLiqSpread is the liquidity spread between the green bond and synthetic conventional bond).

	Obs.	Mean	Std. Dev	Min	Max
ΔY	24,743	-0.005	0.930	-11.440	6.839
ΔLiqSpread	24,743	-0.007	0.122	-2.295	0.648

Table 6: Regression result of the first layer. This table gives the result of the first layer ($\Delta y_{i,t} = GP_i + \beta_1 \Delta Liqspread_{i,t} + \varepsilon_{i,t}$) using the fixed effect model.

Variable	B
GP	0.008
	(0.006)
Δ*LiqSpread*	2.076*
	(0.047)
R^2	0.072

Standard errors in parentheses
**p<0.01*

Table 7: Distribution of the green bond premium from the first layer regression model in the data set.

Variable	Mean	Std. Dev	Min	25% percentile	50% percentile	75% percentile	Max
GP	-0.177	0.929	-6.483	-0.219	-0.029	0.082	0.791

5.2 Determinants of green bond premium

In the second layer regression model, I want to find determinants that cause the green bond premium and its effect. I use green bond premium as a dependent variable and use bond characteristics namely green bond certificate, industry sector, and joining the Paris Agreement as independent variables. I ran the multiple linear regression using equation (5).

$$GP_i = \alpha + \beta_1 Cer_i + \beta_2 Paris_i + \beta_3 Sector_i + \varepsilon \quad (5)$$

Cer	is a dummy variable where 1 means green bond has CBI certificate;
Paris	is a dummy variable where 1 means bond that was issued when the US joined the Paris Agreement;
Sector	is a dummy variable where 1 means industry sector that heavily emits GHG namely Utility or Industrial;
α	is the intercept; and
ε	error term

Table 8 shows the minimum, mean, and maximum of each variable used in the second-layer regression model. It shows that 78% of the green bonds have a CBI certificate, and nearly all the green bonds in the dataset were issued when the US joined Paris Agreement as the timeframe covered since the US initially participated in the Paris Agreement in Nov 2016 while the withdrawal period was less than a year. Furthermore, only 15% of the issuers come from the utilities and industrial sectors as previously discussed majority of the green bonds are from supranational institutions and the financial sector.

The regression result displayed in Table 9 depicts the effect of variables on the green bond premium. Surprisingly, bonds with a CBI certificate increase the green bond premium by 0.57%. The certificate assures that bonds follow green bond principles. The result contradicts (Hyun et al., 2020) finding suggested that investors are willing to pay a premium (resulted in a higher price, and lower yield) for investments that offer clear ESG-related reporting fund proceeds. The increase in green bond premium due to having a green certificate could be attributed to low

demand in green bond market. The green bond market has experienced significant growth in recent years, with a more than 100% increase in less than 2 years, reaching USD 2 trillion in 2022. As such, green bonds with certificates that were issued in prior years when the demand for green bonds was lower may exhibit higher yields compared to comparable conventional bonds. Other variables cannot be used to explain the green bond premium as the result is not significant.

Table 8: Descriptive statistics of variables used in the second layer regression model that find the causes of green bond premium ($GP_i = \alpha + \beta_1 Cer_i + \beta_2 Paris_i + \beta_3 Sector_i + \varepsilon$). The table shows the minimum, mean, maximum, and standard deviation of each variable.

Variable	Mean	Std. Dev	Min	Max
Cer	0.778	0.420	0	1
Paris	0.944	0.231	0	1
Sector	0.148	0.359	0	1

Table 9: Regression result of the second layer model that finds the variables that affect the green bond premium. Variables used are dummy variables of Cer (the green bond that has a green bond certificate), Paris (the green bond that was issued during the period when the US joined the Paris Agreement), and Sector (heavy GHG emission industry sector namely utility and industrial)).

Variable	
	B
α	-0.644
	(0.568)
Cer	0.565***
	(0.302)
Paris	-0.009
	(0.551)
Sector	0.248
	(0.355)
R^2	0.073
Obs	54
Sig	0.282

Standard errors in parentheses
**p<0.01, **p<0.05, ***p<0.1*

6. Conclusion

The paper investigates whether green bonds are priced at a premium compared to conventional bonds by analyzing the yield spread between green bonds and comparable conventional bonds (where a negative yield spread indicates a premium). The study also examines the factors influencing the yield difference including the effect of participating in Paris Agreement to the green bond premium. Initially, the paper expected to find a negative green bond premium, indicating that green bonds have lower yields than comparable conventional bonds, as investors are willing to accept lower yields for the ESG benefits associated with green projects. However, the paper obtained contradictory results. Specifically, the paper found that green bonds and comparable conventional bonds have similar yields, with a slight difference of only 8 basis points (green bonds yield higher than comparable conventional bonds). This result contradicts Zerbib's 2019 paper but aligns with Wu's 2022 paper. The certificate factor was identified as an explanation for the yield difference, as having a certificate increases the green bond premium. This could be attributed to green bonds being issued in previous years when the demand for green bonds was lower relative to the conventional bond market. Participating in the Paris Agreement cannot be used to explain the green bond premium in US markets.

To enhance transparency in the green bond market, policymakers should establish standardized procedures for green bond issuance and provide guidelines for reporting on the environmental impact of green bond projects. Policymakers should also define the scope of use of proceeds to support a net-zero emissions goal. Additionally, regulatory frameworks should be implemented to monitor green bond issuance and ensure compliance with established standards. This could involve periodic audits, third-party verification, and penalties for non-compliance or misleading claims. Increased transparency in the green bond market improves its reputation and leads to higher demand, thereby enhancing market efficiency. Furthermore, as the green bond market is relatively small compared to conventional bonds, governments should encourage green bond issuance by subsidizing some issuance costs, providing tax benefits to green bond issuers, or allowing green bond issuers to use carbon credits generated from green projects financed by green bonds to offset carbon footprints. Since the paper found no significant yield difference between green bonds and conventional bonds, issuers should consider issuing green bonds to promote the efficiency of the green bond market. Additionally, investors with a preference for positive ESG factors should consider investing in green bonds as they offer similar returns compared to conventional bonds.

However, the current research has some limitations. The green bond market is small compared to the conventional bond market, resulting in a limited sample size. In

the United States, there have only been 525 green bond issuances since 2008, and the regression analysis was conducted using data from only 54 green bonds, which may not fully represent the overall green bond market. The data collection period extends back to 2017, but the effectiveness of the Paris Agreement has improved in recent years with the establishment of the Paris Rulebook. Therefore, the results may not fully capture the current state of the green bond market.

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