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Abstract

Green bonds have gained prominence in China's capital market as tools that help to fuel the transition to a climate-resilient economy. Although the issuance volume in the Chinese green bond market has been growing rapidly in recent years, the impact of the green label on bond pricing has not been adequately studied. Therefore, this paper investigates whether the newly developed financial instrument offers investors in China an attractive yield compared to other equivalent conventional bonds. By matching green bonds with their conventional counterparts and subsequently applying a fixed-effects estimation, our empirical results reveal a significant negative green bond yield premium of -1.8 bps on average in the Chinese secondary market. In addition, the yield premium is found to vary across issuers' business sectors mainly due to the public reputation of bond issuers. Moreover, our empirical results reveal an insignificant relationship between the green certification and the yield premium, possibly reflecting inconsistent green bond standards in the Chinese market. Our results point to some practical implications for policymakers and investors.

Keywords

Green Finance, Green bonds, ESG, China

JEL Classification

G12, Q56

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Estimation of green bond premiums in the Chinese secondary market

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Abstract

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1. Introduction

Given the public interest in climate change over the past decade, green bonds have received increasing attention as one of the key financial instruments to scale up the transition to a lower-carbon and climate-resilient economy (Deschryver and De Mariz, 2020). According to the Green Bond Principles (GBP), green bonds are defined as financial instrument where the use of the proceeds are specifically earmarked to finance climate-friendly projects, such as renewable energy, energy efficiency, pollution control, sustainable management, clean transportation, and eco-efficient products (International Capital Market Association (ICMA), 2018). Being an innovative financial instrument, green bonds offer a well-established sustainable investment avenue to catalyze private capital investment in green projects and thus unlock new investment opportunities for individual and institutional investors (Banga, 2019; Liaw, 2020; Reboredo and Ugolini, 2020; Arif et al., 2020). Thus, within the sustainability-oriented financial community, green bonds have been increasingly popular as one of the main financial instruments to support green projects (Reboredo and Ugolini, 2020).

Since the first green bond was issued by the European Investment Bank (EBI) in 2007, the green bond market has experienced extraordinary growth over the past decade. With an issuance volume of US$500 billion in 2021, the Climate Bonds Initiative (2022) projects that the global green bond issuance may reach US$5 trillion in 2025. The phenomenal growth of green bonds in the capital market reflects the increasing pro-environmental preferences of both bond issuers and investors (Maltais and Nykvist, 2020). Typically, issuing green bonds allows companies to signal to the market their environmental commitment which has been found to have a positive impact on stock prices (Falmmer, 2020; Tang and Zhang, 2020; Baldi and Pandimiglio, 2022). Given the cost of external review, regular reporting, and holding separate accounts for bond proceeds, green bond issuances are expected to be more expensive than those of conventional bonds. In addition to that, green bonds can be misused for greenwashing. In the field of green bonds, the term greenwashing refers to bond issuers deceptively conveying misleading information about their environmental commitment and thus misusing the green label to gain a better public reputation and interest from the side of sustainable-oriented investors (Bachelet et al., 2019, Falmmer, 2020). In this regard, there exists a threat that companies would issue green bonds to position themselves as environmentally responsible while not taking true actions to benefit the environment.

Given its commitments under the Paris Climate Agreement, China has prioritized the environmental and energy transitions in its governance principles for mitigating climate change. In 2015, China's 13th Five Year Plan for Energy Development emphasized the need to establish a green finance system including the development of green bonds to support the transition to a lower-carbon economy. In September 2020, China further announced at the United Nations General Assembly that it will peak its carbon emissions before 2030 and achieve carbon neutrality to attain net-zero emissions by 2060 (known as the dual carbon goals) (Janda et.al, 2022). As facilitated by the government's promise to maintain sustainable economic growth, the Chinese green bond market has experienced extraordinary growth since 2016. With a total volume of US$ 44 billion in green bonds issued in 2020, China remains the second-largest green bond issuing country in the world (Climate Bond Initiative (CBI), 2021).

Given the bullish sentiment on the green bond market, an increased number of empirical research papers studying the existence of a green bond premium have emerged (MacAskill et al., 2021). The term "green bond premium" refers to the yield difference between a green bond and a conventional bond with similar characteristics. With the pro-environmental preferences getting more widespread, an increasing number of investors is willing to accept a lower yield to acquire green investment for their portfolios (Zerbib, 2019; Bachelet et al., 2019; Kortusova, 2020). A green bond premium in the primary market emerges when a green bond is issued at a higher price than its conventional counterpart. Meanwhile, in the secondary market, the green bond premium is subject to price movement as well as realized yield to maturity (MacAskill et al., 2021). As the green bond market has developed, the existence of the green bond premium has been widely studied by academic literature, yet no conclusive results have been drawn. While most of the prior studies reached a general consensus on the presence of green bond premium in the market, the heterogeneity of study designs (e.g., sample selections, matching processes, control variables, empirical methodologies) results in ambiguities regarding the reported significance and magnitude of the green premium in the market. A big majority of existing research on green bonds is based on the European and US bond market. Given the lack of green bond insights in emerging markets, this paper investigates the market reactions to green bond issues in China. Using the most up-to-date data from the Chinese secondary market, we aim to address two specific research questions: (1) Does the green label affect the bond's price? (2) If there exists a significant green premium in China, what are the potential factors that impact the premium?

Our results reveal evidence of a significant green bond premium in the Chinese secondary market, with an average magnitude of 1.8 basis points (bps). This suggests a presence of pro-environmental preference among Chinese investors. In addition, our empirical results suggest that bond duration (years to maturity) has a positive impact on the green premium. Meanwhile, we also find that green bond issuance volume has an insignificant impact on the level of green premium. We additionally find that green premium varies across issuers from different business sectors. Taking the issuers from industrial-related sectors as the reference group, we find that bond issuers from the utility, transportation, financial, and bank-related sectors enjoy a lower cost of capital when it comes to financing environmentally friendly projects. In particular, our empirical results reveal that bond issuers from the utility sector enjoy the highest level of green premium, followed by issuers from the transportation, financial, and bank sectors, respectively. Moreover, our empirical results reveal a mixed conclusion regarding the statistical impact of external audits on the green bond premium. Typically, we find that the Climate Bond Initiative (CBI) climate certification has an insignificant impact on the green premium, while investors are willing to pay a higher price for green bonds issued by environmental, social, and governance (ESG) performance-rated issuers. These findings reflect the fact of inconsistent green bond labeling standards in the Chinese market. Given China's unique characteristics in banking and financial sectors, the bond market is mainly dominated by the interbank and exchange bond markets. The disconnectedness among the sub-markets may restrict investors and policymakers from exploring and understanding the influential factors of green bond pricing. Hence, our analysis contributes to the understanding of investors' preferences in choosing green bonds in the Chinese secondary market.

The remainder of this paper is organized as follows. Section 2 provides an overview of the existing literature on green bonds and outlines our research questions. Section 3 describes the data on green bonds and presents our matching process. Section 4 reports the empirical methodology used to identify the green bond premium in the Chinese secondary market. Section 5 reports and discusses our main empirical results. Finally, Section 6 summarizes the empirical findings and concludes the paper with policy implications.

2. Literature review and research hypotheses development

As for the flourishing literature on green bonds, existing studies have mainly investigated the differences between the risk and return of green bonds compared to comparable conventional bonds. One of the main research topics concerned is the identification and verification of a green bond premium in the market. Based on the data retrieved from the

Bloomberg Global Bond Index between March 2014 and August 2015, Preclaw and Bakshi (2015) use Option-Adjusted spread (OAS) to quantify credit spreads and report a significant negative green bond premium of 17 bps in the secondary market. Building on the prior work of Preclaw and Bakshi (2015), Nanayakkara and Colombage (2019) develop a hybrid model that consists of a mixture of random and fixed effect approaches to study a sample of 82 green bonds issued between 2016 and 2017. By using the hybrid model, Nanayakkara and Colombage (2019) claim to have simultaneous control of bond-specific characteristics as well as macroeconomic and global factors. Their empirical results find that green bonds are traded at a significant green premium of 63 bps compared to conventional bonds. Zerbib (2019) further quantifies the pro-environmental preferences in the green bond market using a matching procedure consisting of 21 bond-specific characteristics. Using a two-step regression, Zerbib (2019) documents a small significant negative green bond premium of 2 bps in the secondary market across a sample of 110 green bonds issued from 2013 to 2017. In line with Zerbib (2019), Kortusova (2020) confirms a significant negative green bond premium of 1.12 bps using a sample of 94 pairs of matched green bonds. Based on the propensity score matching procedure, Ginafrate and Peri (2019) evaluate the green premium for a sample of 121 European green bonds. Their results reveal significant green premiums of -20 bps and -5 bps in the primary and secondary markets, respectively. MacAskill et al. (2021) conduct a systematic literature review on green bond pricing and highlight that 56% of primary market studies and 70% of secondary market studies show the existence of green bond premium. Moreover, MacAskill et al. (2021) observe that the average green premium reported in the past literature ranges from negative 1 bp to negative 9 bps across different secondary markets.

Except for the use of proceeds, green bonds are almost identical to conventional fixed-income securities. Tolliver et al. (2020) argue that green bonds pricing should be affected by many of the same factors that affect conventional bonds, and investors should not observe any systematic significant pricing differences between the two in both primary and secondary markets. Despite strong fundamental similarities, empirical research often documents a significant yield difference between green and conventional bonds (Bachelet et al., 2019; Zerbib, 2019; Toilliver et al., 2020; MacAskill et al., 2021). Zerbib (2019) discusses that the observed green premium is likely attributable to the impact of investors' pro-environmental preferences. Specifically, Kortusova (2020) indicates that investors with pro-environmental preferences may incorporate social and environmental values into their investment strategy and become more willing to accept a lower yield when including green assets in their portfolios.

In other words, if the green label affects bond prices, it could be observed through the existence of a green premium.

Another strand of literature argues the indifference between green and conventional bonds' pricing by noting the insignificance of the green bond premium in the secondary market (Ostlund, 2015; Petrova, 2016, HSBC, 2016; Larcker and Watts, 2020; Flammer, 2021). Ostlund (2015) defines the green bond premium as the yield differences between green and conventional bonds from the same issuer. Based on a sample of 28 green bonds from the Bloomberg Barclays MSCI Global Green Index, Ostlund (2015) finds no statistical evidence to support the existence of the green bond premium in the market. Using the multi-factor model, Petrova (2016) applies both panel regression and time-series analysis to evaluate the yield return of green bonds relative to their traditional counterparts. Lacking appropriate statistical evidence to support the green bond premium, Petrova (2016) argues that investors are indifferent when investing in green bonds or conventional counterparts. Similarly, HSBC (2016) finds no green bond premium by using a sample of 30 bonds to estimate the yield difference at issuance between green bonds and their comparable conventional counterparts. Larcker and Watts (2020) argue that the mixed results of green premium reported in past literature are mainly due to the methodological misspecifications that produce biased estimates toward finding a green bond premium. Therefore, Larcker and Watts (2020) redefine their matching strategy to get a sample of 640 matched pairs of municipal green and conventional bonds with quasi-identical bond-specific characteristics. Their empirical results show insignificant evidence of green bond premium in the US municipal bonds market, concluding that municipal green and conventional bonds of the same issuer are almost perfect substitutes for investors. In line with Larcker and Watts (2020), Flammer (2021) also reports the absence of the green bond premium in the market. Throughout interviews with the market participants, Larcker and Watts (2020) and Flammer (2021) conclude that the absence of green premium might be caused by green projects being profitable enough to generate competitive returns for investors.

In addition to investigating the possible existence of green bond premium in the market, the past literature has also offered insights into drivers governing the demand for green bonds. Several studies have inspected whether the green premium is affected by information asymmetry among the market participants. Compared to the green bond issuers, the lack of sufficient information may lead investors to find difficulties to identify the true financial and environmental values of underlying green projects. Under the current Chinese regulatory regime, green bond issuers are not required to disclose detailed information about the greenness of underlying projects (Zhang, 2020). Thus, investors tend to take additional independent information (e.g., bond issuer types, credit rating classes, third-party certifications) as key indicators for their risk evaluations (Bachelet et al., 2020; Hyun et al., 2020). As Agliardi and Agliardi (2019) highlighted, the improvement in bond credit rating may allow issuers to benefit from the low cost of debt financing. Based on a sample of US municipal green bonds, Karpf and Mandel (2018) conclude that the yield of a green bond increases with the bond rating classes. On the contrary, Hachenberg and Schiereck (2018) reveal an insignificant relationship between the green premium and bond credit rating classes.

In addition to bond credit ratings, green bonds with third-party green bond certifications and external reviews of corporate environmental, social, and governance (ESG) performance may allow financial investors to reduce suspicions of greenwashing (Bachelet et al., 2019; Wang et al., 2019). From the issuer's point of view, the external green certification may allow asset managers to credibly signal to investors that the proceeds are indeed earmarked for green projects improving the environmental footprint (Ehlers and Packer, 2017). In this sense, investors might be willing to sacrifice part of their returns in exchange for the decreased probability of greenwashing. Since green bonds are a newly developed financial instrument in the Chinese market, the statistical impact of the third-party green certification on the bond premium remains undetermined.

Apart from the bond characteristics, the research conducted by Kapraun and Scheins (2019) and Zerbib (2019) declare that the magnitude of green premium varies across issuer types and business sectors. Given the presence of a significant green premium in the US and European bond markets, Kapraun and Scheins (2019) find out that the magnitude of the yield premium of green bonds issued by governments or supranationals is much larger than those issued by corporates. Meanwhile, Zerbib (2019) reveals that green bonds issued by companies from the consumer products, industrial, and utility business sectors are traded at a higher premium level compared to those issued in the finance and materials sectors.

Based on the above literature review, we test the following null hypotheses to address our research questions:

Hypothesis 1 (H1): *There does not exist a significant price premium on green bonds compared to other equivalent conventional bonds in the Chinese secondary market.*

Under our first hypothesis, we assume that there should be no significant yield difference between green and conventional bonds in the Chinese secondary market. The rejection of the null hypothesis suggests the existence of a statistically significant green bond premium and therefore indicates the presence of pro-environmental preferences among investors in China.

Hypothesis 2 (H2): *The third-party certification in the form of an ESG rating or CBI certification does not affect the magnitude of the green premium in the Chinese secondary market.*

Our second hypothesis assumes that neither bond credit ratings nor external third-party green bond certifications have a statistically significant impact on the green bond premium in the Chinese secondary market. The rationale for the rejection of the null hypothesis can be found in the past literature on green bonds, arguing that investors may be willing to pay a higher price for certified green bonds in exchange for reduction of potential greenwashing behavior of the issuer. The rejection of this hypothesis suggests that issuers' reputation and credibility can generate significant impacts on green bond returns.

Hypothesis 3 (H3): *The magnitude of green bond premium does not differ significantly among business sectors in the market.*

Our third hypothesis assumes that there is no significant difference in the magnitude of green premium across different business sectors. Following the empirical results reported in the past literature, we expect to reject this hypothesis. The rejection of this hypothesis indicates that green bond premium varies across different business sectors, and it is closely related to the public reputation of bond issuers.

3. Data and matching procedure

To empirically study the green premium in the Chinese secondary market, we collect data from Thomson Reuters Refinitiv database and the Chinese iFind database. We start with a dataset covering 179 active corporate green bonds issued in China between 2016 and 2020. Likewise, we also initially consider a conventional bond dataset of 45,175 active conventional bonds issued in China from 2016 to 2020. All selected green and conventional bonds are issued in Chinese Renminbi (CNY). By considering only straight and senior corporate bonds with plain vanilla fixed coupon payments, we reduce our dataset to 113 green bonds and 17,574 conventional bonds available for matching process applied in the next step.

Overall, our green bond study focuses on straight senior corporate green bonds with plain vanilla fixed coupon payments regardless of whether issuers are state-owned or private enterprises. Since we focus only on the secondary market, green bonds are traded freely among individual and institutional investors. Hence, the main investors in the Chinese secondary green bonds are both Chinese retail investors and institutional investors. As discussed by Bachelet et al. (2019), the ideal methodological approach to capture the green premium would be with the use of a one-to-one exact matching method. However, such a one-to-one exact matching can result in a significant level of sample reduction and therefore increase the potential estimation bias. Thus, we adopt a matching procedure consisting of 18 matching criteria to investigate the yield difference between green bonds and their comparable conventional counterparts (Table 1). Within the pool of available candidates in the conventional bonds dataset, we match each green bond with two conventional bonds, one with shorter maturity and the other one with longer maturity. We exclude green bonds from our sample observations in case we find either none or only one matched comparable counterpart. Since it is impossible to find two bonds with identical characteristics, we allow some variations in the following four aspects. As suggested by Zerbib (2019) and Kortusova (2020), we consider a maximum difference of 4 years in issue dates between green and conventional bonds, while the difference in maturity dates must not exceed 2 years. We also use an additional restriction under which the issue amount of a conventional bond is restricted to lie within a range of a minimal 25% and maximal 400% of that of the matched green bond. We do not use the exact bond duration as a condition for our matching process because we would end up with insufficient sample observations for our further empirical analysis.

Table 1: Matching Criteria

	Matching criteria
Issuer	Exact match
Issuer type	Exact match
Bond instrument type	Exact match
Maturity date	$\pm$ 2 years
Issue date	$\pm$ 4 years
Issue Amount	25% to 400% of the green bond
Coupon type	Exact match
Coupon frequency	Exact match
Bond rating	Exact match

Seniority	Exact match
Executable	Exact match
Callable	Exact match
Puttable	Exact match
Extendible	Exact match
Has sinking fund	Exact match
Partly paid	Exact match
Paid in Kind	Exact match
Perpetual	Exact match

The use of the matching process described above leaves us with 56 triplets of matched bonds. Each triplet of matched bonds consists of 1 green bond and 2 conventional bonds. Once the matching is completed, we construct synthetic conventional bonds using the ask yields of matched conventional bonds through a linear interpolation or extrapolation (see Eq.1). For each of the 112 matched bonds, we collect daily ask yields ranging from the issuance date up to November 27th, 2020. Note that 5 green bonds were excluded from our sample due to missing information on ask yields, and 3 green bonds were dropped because of insufficient length of daily pricing data. Overall, our final dataset covers 48 triplets of green bonds and synthetic bonds issued by 33 different bond issuers. Within a total of 14,088 daily ask yields, the number of bond trading days available for each triplet ranges from 41 days to 684 days. Table 2 summarizes the steps we undertook to construct our final dataset.

Table 2: Steps for sample construction

Search criteria	Number of bonds
Active green bonds from Thomson Reuters Eikon and iFind database	179
Straight and senior green bonds with plain vanilla fixed coupon payment	113
Green bonds available for the matching process	56
Green bonds with sufficient time length of daily ask yields	48

Note: The number of bond trading days available for each pair ranges from 41 days to 684 days. 8 green bonds were dropped due to either insufficient time length or missing information on ask yields.

For each triplet of matched bonds, with α as the intercept and β as the slope coefficient of a linear function passing through $(\mathrm{Maturity}_{i,t}^{CB1}, Y_{i,t}^{CB1})$ and $(\mathrm{Maturity}_{i,t}^{CB2}, Y_{i,t}^{CB2})$, the daily ask yield of a synthetic conventional bond is estimated through the following linear equation:

$$Y_{i,t}^{SB} = \alpha + \beta \cdot M_{i,t}^{GB}, \quad (1)$$

where $Y_{i,t}^{SB}$ represents the daily ask yield of the synthetic conventional bond and $M_{i,t}^{GB}$ refers to the number of days to maturity for a green bond *i*. In addition, we take the yield difference between each matched green bond and its corresponding synthetic conventional counterparts (see Eq.2).

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

To ensure the robustness of our matching result, we trim the estimated yield spread at 2.5% and 97.5% percentile based on the distribution of the average $\Delta Y_{i,t}$ obtained from Eq.2. This approach allows us to avoid any unrealistically low or high values of the ask yield spread in our sample and therefore to minimize the impact of outliers on our estimation. Based on the matching criteria presented in Table 1, we apply the Wilcoxon signed rank test to assess the quality of our matching result by testing whether the sample distribution of the matched green bonds differs significantly from that of their conventional counterparts. The test results reported in Table 3 reveal that neither the coupon rate nor the time to maturity between the two sample groups statistically differ between the two groups. Figure 1 shows how the ask yields and the yield difference vary across matched pairs of green and synthetic bonds, and thus indicates a good quality control of our matching process.

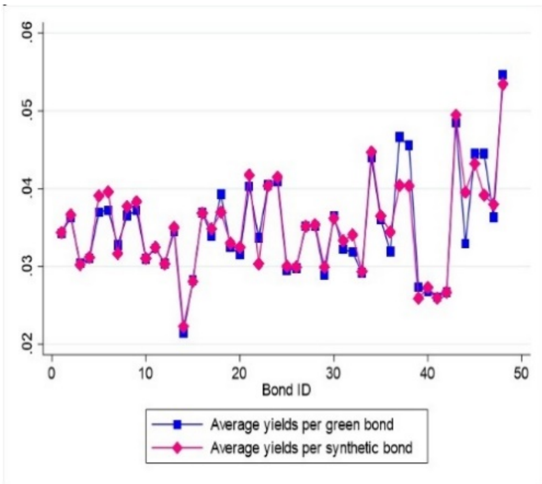
Table 3: Comparison of bond characteristics using Wilcoxon Signed Rank Test

Bond characteristics	GB	CBs	Mean Difference	P-value
Coupon (%)	4.263	4.202	0.06	0.556
Time to maturity (Year)	3.875	4.094	-0.218	0.459
Amount issue	4.246	9.054	-4.806	0.0198

Note: The Wilcoxon signed rank test is applied with the null hypothesis of identical distributions between two groups.

Figure 1: The average ask yields of green and conventional bonds and respective yield

differences, per bond pair.



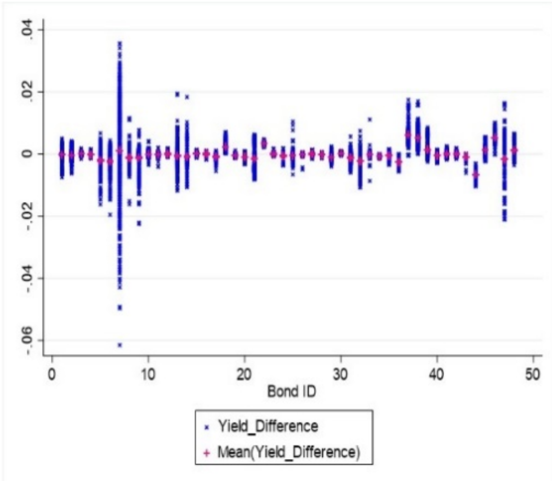


Table 4: Descriptive statistics of matched green and conventional bonds

A: Summary statistics of matched green bonds (GB)								
	Min	1st Quart	Mean	Median	3rd Quart	Max	SD	Obs
Ask Yield GB (%)	0.74	3.04	3.47	3.54	3.98	6.39	0.82	14088
Coupon (%)	2.93	3.68	4.18	4.36	4.74	6.80	0.92	48
Issue Amount (Billion RMB)	0.20	0.58	1.25	4.05	3.00	30.00	6.79	48
Time to Maturity (Years)	3.00	3.00	3.00	3.88	5.00	5.00	1.00	48
B: Summary statistics of matched conventional bonds (CB)								
	Min	1st Quart	Mean	Median	3rd Quart	Max	SD	Obs
Ask Yields CB (%)	1.00	2.98	3.36	3.44	3.84	6.31	0.82	28176
Coupon (%)	2.08	3.52	4.03	4.23	4.99	7.50	1.08	96
Issue Amount (Billion RMB)	0.20	0.84	1.50	8.67	4.00	200.0	24.75	96
Time to Maturity (Years)	3.00	3.00	3.00	4.09	5.00	10.0	1.45	96

Note: The sample consists of 48 green bonds and 96 conventional bonds, respectively. All data were retrieved and collected from Thomson Reuters Eikon and China iFind database on November 28th, 2020. The ask yields of synthetic conventional bonds (SB) are computed through linear interpolation and extrapolation.

Panel A and B of Table 4 report the summary statistics of green and conventional bonds obtained from the matching process. On average, the matched green bonds have a coupon rate of 4.18%, maturity of 3 years, and issuance amount of RMB 1.25 billion. Similarly, the matched conventional bonds have an average coupon rate of 4.03%, 3 years to maturity, and issuance amount of RMB1.5 billion. Notice that the issuance amount for green bonds in our sample is significantly smaller in comparison to their conventional counterparts. At the median level (50% percentile), the issuance volume of a green bond is approximately one-half of the volume of a conventional bond. This finding is not surprising, since green bonds are a relatively nascent financial instrument compared to the conventional bond. Also, the green projects were limited in the past. Therefore, the volume of money needed for their financing was not as large in comparison to financing traditional projects.

4. Methodology

4.1. The estimation of the green premium

To determine whether there exists a green premium in the Chinese secondary market, we take the yield spread between green bonds and equivalent synthetic conventional correspondents. Following the method introduced by Zerbib (2019), we consider the liquidity differential between green and conventional bonds as a control variable in our analysis. In doing so, we apply a one-way individual fixed effect panel regression model to estimate $\Delta \mathrm{Y}_{\mathrm{i,t}}$ on $\Delta \mathrm{Liquidity}_{\mathrm{i,t}}$:

$$\Delta \mathrm{Y}_{\mathrm{i,t}} = \alpha_{\mathrm{i}} + \beta \Delta \mathrm{Liquidity}_{\mathrm{i,t}} + \varepsilon_{\mathrm{i,t}}. \quad (3)$$

$\Delta \mathrm{Y}_{\mathrm{i,t}}$ is computed using Eq.2 and refers to the daily yield difference for the ith bond pair on the day t. α_i captures the time-invariant green premium and is thus the main parameter of our interest. A significant negative α_{i} would indicate the presence of a green premium in the market. $\varepsilon_{i,t}$ denotes the idiosyncratic error term. $\Delta \mathrm{Liquidity}_{\mathrm{i,t}}$ represents the liquidity difference between a green bond and its synthetic counterpart and is defined as:

$$\Delta \mathrm{Liquidity}_{\mathrm{i,t}} = \mathrm{Liquidity}_{\mathrm{i,t}}^{\mathrm{GB}} - \mathrm{Liquidity}_{\mathrm{i,t}}^{\mathrm{CB}}. \quad (4)$$

Although China has one of the largest green bond markets in the world, this market is still relatively young and small compared to conventional bond and stock markets. Given that green bonds are not traded as frequently as conventional bonds and common stocks, intraday quote data are not available for us to measure the liquidity. Due to limited data accessibility, we do not have any specific indicators to reflect liquidity of the Chinese green bond market. To quantify the degree of liquidity of the bond market, previous literature based on global research has shown that the Closing Percent Quoted Spread (CPQS) is the best among all other low-frequency liquidity proxies (Chung and Zhang, 2014; Będowska-Sójka and Echaust, 2020). Hence, we comply with the previous literature by taking the CPQS as our liquidity proxy for our green premium analysis.

$$\mathrm{Liquidity_{i,t}} = \mathrm{CPQS_{i,t}} = \frac{\left(\mathrm{P_{A,t}} - \mathrm{P_{B,t}}\right)}{\mathrm{M_{i,t}}} \tag{5}$$

Eq.5 defines our estimation of the $\mathrm{CPQS_{i,t}}$, where $P_{A,t}$ and $P_{B,t}$ are closing ask and bid price observed at day t, respectively. $M_{i,t}$ refers to the average of $P_{A,t}$ and $P_{B,t}$. For synthetic bonds, the $\mathrm{CPQS_{i,t}^{SB}}$ is approximated through the distance-weighted average based on the differences in the maturities of matched green and conventional bonds:

$$\mathrm{CPQS_{i,t}^{SB}} = \frac{\mathrm{d2}}{\mathrm{d1+d2}}\mathrm{CPQS_{i,t}^{CB1}} + \frac{\mathrm{d1}}{\mathrm{d1+d2}}\mathrm{CPQS_{i,t}^{CB2}}\,, \tag{6}$$

where $\mathrm{d_1} = |\mathrm{Maturity_{GB}} - \mathrm{Maturity_{CB1}}|$ and $\mathrm{d_2} = |\mathrm{Maturity_{GB}} - \mathrm{Maturity_{CB2}}|$.

4.2.Determinants of the green premium

Based on theoretical and empirical evidence from the previous literature on green bond pricing, we consider the third-party credit rating, external verification, and issuer's sector as the influential factors of green premium in the Chinese bond market. Table 5 reports detailed descriptions of variables that we consider in our investigation. Our analysis of green premium influential characteristics is strictly based on the assumption that all time-invariant green premium is fully captured by estimating Eq.3. Based on that assumption, we perform OLS model specifications using robust standard errors to test Hypothesis 2 and Hypothesis 3. Bond issuance amount is expected to influence the attractiveness of green bonds to investors (Shi and Jurevica, 2021). Given that small bond issuance may result in a small investor base in the market, the trading activities and bond liquidities are expected to be relatively low. In contrast, bonds with higher issue amounts are more likely to experience price volatility by having a higher volume of trading activities in the market. In this paper, we take the natural logarithm of the issuance amount to avoid any unwanted heteroskedasticity. In addition to the bond issuance amount, bond duration (measured by years to maturity) is another factor that might have a significant impact on the green bond pricing dynamics. Bonds with longer durations incorporate larger market risks and therefore investors might require an additional yield premium to compensate for taking on such a risk. In this paper, maturity is calculated as the number of years to the green bond maturity. To quantify the impact of the green bond qualification on the green bond premium (H2), we include a categorical variable representing the third-party credit rating into our model specification based on the information retrieved from the Chinese bond rating agencies. In addition, we introduce dummy variables "CBI certificate" and "EGS rating" to evaluate the impact of third-party green bond certification and sustainability rating on the green premium in the Chinese secondary market. Based on the Thomson Reuters Business Classification (TRBC) codes, we create a categorical variable "Sector" to investigate whether green premium varies across different business sectors (H3). Overall, our analysis of green premium influential factors is formulated in the following model specification:

$$\hat{\alpha}_i = \beta_0 + \beta_1 \text{Maturity}_i + \beta_2 \log(\text{Issue amount}) + \beta_3 (\text{CBI certified}) + \beta_4 (\text{ESG rating}) + \beta_5 \ (\text{Sector}) \ + \beta_7 (\text{Credit rating}) + \varepsilon_{i\,.} \tag{7}$$

Table 5: Descriptions of variables

Variable	Description
Yield difference $\Delta \text{Yield}_{i,t}$	Calculated as the yield difference between a green bond and the corresponding synthetic bond. The ask yield of synthetic is calculated using the Eq.1.
Green premium ($\hat{\alpha}$):	Green premium is estimated using the one-way individual fixed effect estimation. Eq.3
Time to maturity (years)	The time to maturity of each of green bonds included in our sample, measured in number of years.
Issues amount	The total amount of the green bond issuance. We take the nature logarithm to avoid unwanted heteroskedasticity.
Credit rating	The green bond credit rating (AAA, AA+, AA), set as a categorical variable, with value assigned from 1 to 3, respectively. We retrieve the credit rating data from the Chinese iFind database.
CBI certificate	A dummy variable indicating whether a green bond is certified by the Climate Bond Initiative. The variable equals 1 if the bond is certified by CBI and 0 otherwise.
ESG rating	A dummy variable indicating whether a green bond has ESG rating. The variable equals 1 if the bond has ESG rating and 0 otherwise. We source the ESG date from Thomson Reuters Refinitiv database.
Sector	Based on Thomson Reuters Business Classification (TRBC) code, we subset green bond issuers into following five categories: (i) Bank; (ii) Financials, which encompasses non-

	public banks and financial services; (iii) Industrials; (iv) Transportation; and (v) Utility.

5. Empirical results and discussion

The individual effect is confirmed in our sample data through the Breusch-Pagan Lagrange Multiplier (LM) test. Given the Hausman test result, we find that the fixed effects estimator is more efficient than the random effect estimator. Therefore, we specify a within-fixed effect regression model to inspect the sign, significance, and magnitude of the green premium in the Chinese secondary market. Table 6 reports the within-fixed effect estimation of Eq.3 based on an unbalanced panel of 14,088 daily observations. The negative coefficient of the ΔLiquidity is highly significant at least at 5% level, implying that an increase of 1 bp in ΔLiquidity leads to a decrease in green bond premium of 1.009 bps in the Chinese secondary market. This finding is consistent with the findings of Zerbib (2019), Kortusova (2020), and Gianfrate and Peri (2019), who declare a significant negative relationship between the liquidity differentials and the yield spread in the green bond market.

Table 6: Within fixed effects estimation result

	Dependent variable: $\Delta Y_{i,t}$			
	Fixed effects	Fixed effects with Robust Standard error	Fixed effects with One-way Cluster Standard Errors	Fixed effects with Two-way Cluster Standard Errors
$\Delta \text{Liquidity}_{i,t}$	-1.009***	-1.009**	-1.009**	-1.009***
	(0.0965)	(0.390)	(0.390)	(0.339)
Constant	0.000436***	0.000436***	0.000436***	0.000436***
	(4.54e-05)	(0.000127)	(0.000127)	(0.000108)
No.Obs	14,088	14,088	14,088	14,088
R^2	0.008	0.008	0.008	0.008
F-Statistic	109.16***	6.67***	6.67***	8.85***

Note: ***, **, * refer to statistical significance at 1%, 5% and 10% level, respectively. Number in parentheses represents standard error.

Table 7: Diagnostic tests

Tests	Test statistic	P-value	Conclusion
Breusch and Pagan LM test	63944.55	0.000	Presence of individual effects
Hausman Test	10.05	0.001	Fixed estimator is better than random effect
Modified Wald test	1.0e+07	0.000	Presence of heteroskedasticity
Wooldridge serial correlation	2.448	0.124	Absence of serial correlation
Pesaran cross-sectional dependence test	35.954	0.000	Presence of cross-sectional dependence

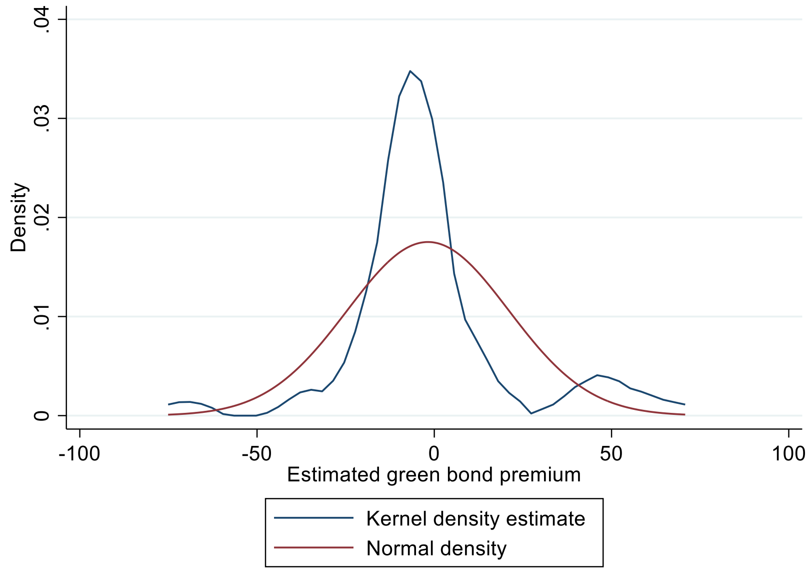
Although Woolridge test suggests the absence of serial correlation, the diagnostic test results from Pesaran and Modified Wald tests reveal the presence of cross-sectional dependence and heteroscedasticity in the model's residual (Table 7). To account for heteroskedasticity and cross-sectional dependence, we specify the robust standard errors, one-way and two-way cluster standard errors in our model estimations. Note that our estimation evidences a weak R^2 of approximately 1% indicating a low level of explanatory power. Since the setup of the fixed effects model discards the individual effects in the estimation procedure, having a low R^2 is somehow acceptable in our case. The highly significant estimated coefficient of $\Delta \mathrm{Liquidity}_{i,t}$ reveals a meaningful explanatory power of the control variable and therefore suggests that we should not discard it from our model specification.

Table 8: Distribution of the green bond premium estimates

$\hat{\alpha}_i$ (bps)					
Min	1st Quart	Median	Mean	3rd Quart	Max
-70.1	-11.9	-5.2***	-1.8***	2.4	65.8

Note: The green bond premium α_i is defined as the fixed effects model of Eq.3. We apply a Student's t test, and a Wilcoxon matched-pairs signed-ranks test to determine whether mean and median value of the estimated green premium are statistically different from zero. ***, **, * represents the significance at 1%, 5% and 10% level of significance, respectively.

Figure 2: Kernel density of the estimated green bond premium



The distribution of the green bond premium ranges from -70 bps to 65 bps with the median and mean value of -5.2 bps and -1.8 bps, respectively (Table 8). As presented by the kernel density plot in Figure 3, a total of 71% of the estimated green premium is negative. To test our first hypothesis (H1) about the significance of a green premium in the Chinese secondary market, we apply a Student's T-test and a non-parametric Wilcoxon signed ranks test with continuity correction to assess whether the mean and median values of the estimated green premium differ significantly from zero. Based on the P-values of these two tests, we have enough statistical evidence to reject the null hypothesis, revealing that the green premium is present in the Chinese secondary market.

The finding of a negative green bond premium in the Chinese market is consistent with previous green bond literature, which documents the presence of pro-environmental preferences among investors (Gianfrate and Peri, 2019; Zerbib, 2019; MacAskill et al., 2021). Although the estimated magnitude of the green premium in our empirical analysis is relatively small, it does significantly reflect the Chinese investors' willingness to incorporate pro-environmental considerations into their portfolio and risk management.

However, our result contradicts a study of Wang et al. (2019) who reports a positive risk premium of 1.73% on average in the Chinese market. Wang et al. (2019) neither adopted a matching process nor used liquidity differential as the control variable in their analysis.

Alternatively, Wang et al. (2019) perform their empirical analysis on green bond premium based on an extended version of the capital asset pricing model (CPAM) and compute the premium by taking the difference between the yield to maturity of green bonds' risk-free interest rates. By contradicting the results of previous studies, our result adds to the green bond literature by providing significant evidence to argue for the existence of the negative green bond premium in the Chinese secondary market.

Regarding the analysis of green premium influential factors, we apply a cross-section linear regression of $\widehat{\alpha_i}$ on the bond-specific characteristics. Table 9 presents four model specifications that we undertake to address Hypotheses 2 and 3 accordingly. Following Kortusova (2020), we take the year to maturity and issue amount as two control variables for our second step regression analysis. By choosing the maturity and the log(issue amount) as the control variables, the model specification (a) represents our baseline model. Model specification (b) captures the premium variation across different business sectors, and model specification (c) evaluates the impact of bond rating on the magnitude of the premium. Likewise, model specification (d) incorporates all variables of interest together.

Table 9: Determinants of green bond premium in the Chinese secondary market

Variable	(a)	(b)	(c)	(d)
Maturity	4.506	4.829	5.404*	7.719**
	(3.28)	(3.53)	(3.57)	(3.64)
Log (Issue Amount)	-2.698	-0.626	1.489	0.545
	(2.55)	(2.75)	(3.19)	(3.27)
Sectors				
Bank		-18.288*	-23.104*	-19.250*
		(10.14)	(11.84)	(10.92)
Financials		-25.668**	-28.774***	-25.816***
		(10.05)	(10.35)	(9.51)
Transportation		-21.753*	-22.214*	-31.955***
		(12.07)	(12.42)	(11.80)
Utility		-31.964***	-29.350**	-36.734***
		(11.60)	(12.02)	(11.30)
Bond credit rating				
AA			-16.080	-30.206
			(23.26)	(22.15)

AA+			0.299	0.689
			(14.59)	(13.44)
AAA			-14.686**	-14.688**
			(7.87)	(7.62)
CBI certificate				19.528**
				(8.24)
ESG rating				-14.799**
				(7.59)
Constant	38.163	11.351	-23.717	-21.798
	(55.94)	(56.39)	(64.11)	(62.21)
R^2	0.064	0.234	0.328	0.511
No. Obs	48	48	48	48
VIF	1.00	1.70	1.86	1.96

Note: This table summaries empirical results of step 2 regression based on a sample of 48 green bonds using robust standard errors. ***, **, * represents the individual test significance at 1%, 5% and 10%, respectively. VIF tests are applied to test the presence of multicollinearity. The sector refers to a categorical variable based on the Thomson Reuters Business Classifications (TBRC), and we take the sector "Industrials" as the reference group for our analysis. Bond credit rating also refers to a categorical variable which is retrieved from the Chinese People's Bank of China (PBOC). In our analysis, we take green bonds with no PBOC credit rating as our reference group. CBI certificate and ESG rating are dummy variables.

Table 9 summarise our OLS estimation results of Eq.7. Regarding the control variables, we do not have enough statistical evidence to confirm that the bond issue amount significantly impacts the magnitude of the green premium. Hence, the green premium does not seem to be determined by the bond issue amount in the Chinese market. A positive maturity-premium nexus is found, suggesting that the green bond premium increases along with the number of years to maturity. However, the estimated coefficient on maturity is significant only in model specifications (c) and (d). Concerning Hypothesis 2, our empirical results suggest that the third-party credit rating significantly impacts the magnitude of the green bond premium in the Chinese secondary market. Specifically, the premium of the AAA rated green bonds is found to be 14.69 bps lower than the reference group of unrated green bonds. In contrast, the premium of AA and AA+ rated green bonds are found to be statistically indifferent from the reference group. The significant rating effect on the green premium reveals that investors would sacrifice their returns to mitigate information asymmetry by obtaining additional information from rating agencies. Contradictory to previous studies (e.g., Bachelet et al., 2019; Li et al., 2020), we do not observe a significant impact of green certification on the premium. However, our result is in line with the finding of Larcker and Watts (2020), who document that CBI climate certification does not have an economically significant impact on the green premium in the global secondary market. Given the significant coefficient on ESG rating, our results suggest that corporate ESG policies can benefit bond issuers to gain a lower cost of capital since investors are willing to pay a premium of -14.8 bps for the bond acquisition.

Our empirical results also provide enough statistical evidence to reject Hypothesis 3 suggesting that the green premium varies across different business sectors in the Chinese secondary market. Taking the issuers from industry-related sectors as the reference group, we find that bond issuers from the financial, transportation, and utility-related sectors enjoy a lower cost of capital. In particular, bond issuers from the utility sector enjoy the highest level of green premium followed by issuers from the transportation, financial and bank sectors, respectively. This finding is consistent with our expectation as well as the previous literature, which suggests that the green bond premium varies among business sectors and it is closely related to the public reputation of bond issuers (e.g., Hanenberg and Schiereck, 2018; Bachelet et al., 2019; Gianfrate and Peri, 2019; Kapraun and Scheins, 2019; Zerbib, 2019; Fatica et al., 2021).

The insignificant effect of the green label on the green premium reflects a fact of inconsistent green bond labeling standards in the Chinese market. Under a general consistent framework of green bond definition, the eligibility of green projects in China differs from the international standards on the use of proceeds. Given the Green Bond Endorsed Project Catalogue introduced by the People Bank of China (PBOC) in 2015, investments in clean coal are defined as eligible green projects. Clean coal refers to a set of coal utilization technologies such as conversion, combustion, and pollution control, aimed at reducing emissions and improving energy efficiency (Xie, 2021). For example, coal gasification represents one of the most crucial conversion technologies for China aiming to achieve optimal coal utilization towards cleanliness in the future. However, given deficiencies in technologies, coal utilization in China remains relatively low. Taking clean coal as a green project implies a further encouragement of coal-fired power generation and contributes to the increasing carbon emissions in China, even though some of the emissions can be alleviated by using clean technologies (Zhang, 2020). Xie (2021) highlights that environmental pollution caused by gaseous, liquid, solid waste, and wastewater is still prominent in China. Under the international standards, the eligibility of clean coal is not supported according to the Green Bond Principles. Since there is no global definition of green bonds, various organizations have customized their green labeling standards and have gained popularity and acceptance among investors and regulators in China. Having definitional divergence in green bond eligibility between the Chinese and international standards, the impact of CBI green certification on the green premium remains limited and questionable in the Chinese market. Based on this view, the regulatory development on labeling standards for green bonds is crucial for the future expansion of the green bond market in China.

6. Conclusion

Green bonds, as a nascent fixed-income financial instrument, represent a promising channel for scaling up the transition to a carbon-neutral economy. Along with supporting policies and bullish market development, the green bond market has experienced remarkable growth in China in recent years. In this paper, we study the green bond premium in the Chinese secondary market by addressing the following research questions: firstly, whether there exists a green bond premium in the Chinese market; secondly, if so, what factors influence the magnitude of the green premium. To do so, we apply a matching method consisting of 18 bond-specific characteristics to create a dataset of 48 matched pairs of green and conventional bonds. Using the CPQS as a proxy variable for the liquidity control, we perform a fixed-effects panel regression on our unbalanced panel of 14,088 bond-day observations to estimate the sign, magnitude, and significance of the green premium in the Chinese secondary market.

Overall, our empirical results reveal a significant negative green bond premium of -1.8 bps in the Chinese secondary market, suggesting that non-pecuniary motivated investors are willing to accept lower financial returns for green bond investments in comparison to conventional bonds. Besides the presence of pro-environmental preferences among investors, our paper adds to the green bond literature by examining how the estimated green bond premium varies with bond-specific characteristics in the Chinese secondary market. Based on a two-step regression analysis, our findings suggest that green bond premium varies across issuers' business sectors, where green bonds issued in utility, transportation, financial, and bank-related sectors are traded at higher green bond premiums than green bonds issued in the industrial-related sector. Our empirical results reveal that bond issuers from the utility sector enjoy the highest level of the green premium, followed by issuers from the transportation, financial, and bank sectors, respectively. Given the presence of information asymmetry, investors are willing to pay a higher price for green bonds with AAA credit ratings compared to green bonds with lower credit ratings. Our findings show that bond issuers with ESG ratings enjoy a 17.6 bps discount at green bond issuance, compared to bond issuers who do not have a sustainability rating. With the global trend of integrating ESG considerations in the corporate policies, Tang and Zhang (2018) show that ESG policy and green bond issuance could raise up company's public reputation and hence improve stock valuation and liquidity. Slimane et al. (2020) argue that the ESG rating has become an important part of determining the yield premium in bond pricing.

Consistent with Larcker and Watts (2020), our estimates conclude that the CBI climate certification has no significant impact on the green premium, which leads us to question the credibility of CBI green certification in the Chinese markets. The insignificant effect on the green premium reflects the inconsistent green bond labeling standards in the Chinese market. Although ICMA's Green Bond Principles and CBI Climate Bond Standards are being widely applied as one of the main reference standards for defining green bonds in China (Wang and Zhang, 2017), many other customized certification mechanisms are also available for bond issuers in the market. The lack of consistent green bond standards in China might restrict investors' willingness to invest in green bonds, induced by information asymmetry, as well as the suspicions of greenwashing behavior (Hyun et.al, 2020).

Our empirical results have the following policy implications with respect to the future development of sustainable finance market in China. Under the current regulatory regime in China, the transparency requirement for disclosure of information on green bond is relatively loose compared to the international standards. Investors are not capable to fully process all information from the market and therefore lack objective evaluation of underlying financial and environmental values of green projects. Greater information transparency is needed to remove information asymmetry among the market participants. While having a large domestic market, the green bond market in China is also progressively promoted to attract more international investors (Zhang, 2020). Prevailing inconsistencies between the local and international green bond standards present a significant barrier for the Chinese green bond market when it comes to its attractiveness to international investors. Hence, a regulatory development that would minimize the gap between the Chinese and international green bond standards is critical for China to attract investors from the international market.

7. References

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