Chapter 15
Green Bond Pricing and Its Determinant: Evidence from Chinese Secondary Market

Karel Janda and Binyi Zhang

Abstract This paper investigates whether green bonds offer investors in China an attractive yield compared to other equivalent conventional bonds. By applying a matching method and, subsequently, fixed-effect estimation, our empirical results reveal a significant negative yield premium of green bonds on average—1.8 bps lower than that of their conventional counterparts in the Chinese secondary market. Furthermore, we find that green bond premiums vary across issuers' business sectors, mainly due to the public reputation of bond issuers. We also show that bond credit rating and corporate ESG rating have a significant impact on green bond premiums. Our results point to some practical implications for policymakers and investors.

Key words Green bonds · Green bond premium · ESG trading · China

15.1 Introduction

Climate change has become an increasing global concern, which exacerbates the need for scaling up the transition to a low-carbon and climate-resilient economy. Following this increase in public interest, the market for sustainable finance has grown remarkably in recent years, which opens new investment opportunities for individual and institutional investors (Reboredo & Ugolini, 2020). Within the framework of sustainable investment, green bonds represent a promising tool in fixed-income markets whose proceeds are exclusively earmarked for eligible green

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K. Janda (✉)
Institute of Economic Studies, Faculty of Social Sciences, Charles University, Prague, Czech Republic

Department of Banking and Insurance, Faculty of Finance and Accounting, University of Economics, Prague, Czech Republic

B. Zhang
Institute of Economic Studies, Faculty of Social Sciences, Charles University, Prague, Czech Republic

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projects, such as renewable energy, energy efficiency, carbon mitigation, clean transportation, sustainable waste management and land use, biodiversity conservation, and clean water management (International Capital Market Association (ICMA), 2018). Following the first green bond introduced by the European Investment Bank (EIB) in 2007, the green bond market has experienced remarkable growth over the last decade. According to data published by Climate Bond Initiative (CBI), the global issuance volume of green bonds has grown from $11 billion in 2013 to $258.9 billion in 2019 (CBI, 2020). For the future green bond market expansion, Fatin (2019) estimates that the volume of global green bond issuances may exceed $1 trillion per year in 2030.

As for the flourishing literature on green bond pricing, Maltais and Nykvist (2020) declare that both pecuniary and nonpecuniary motives can attract investors toward green bond investments. In terms of pecuniary motives, green bonds may provide investors opportunities to hedge against environmental financial risks (Elhers & Packer, 2017; Reboredo, 2018; Banga, 2019; Nanyakkara & Colombage, 2019). Alternatively, investors with nonpecuniary motives care less about financial returns and therefore derive proenvironmental preferences by paying a yield premium to acquire a green bond (Zerbib, 2019; Bachelet et al., 2019; Larcker & Watts, 2020; Maltais & Nykvist, 2020).

Previous studies investigating the dynamics of green bond pricing (Preclaw and Baksh 2015; Hachenberg & Schiereck, 2018; Zerbib, 2019; Gianfrate & Peri, 2019; Hyun et al., 2020) have focused on measuring the credit spread between a green bond and its corresponding conventional counterpart, which is known as the green bond premium. However, due to the wide methodological heterogeneity in study designs (e.g., sample selection, matching process, control variables, and empirical analysis), no consensus has been reached on the significance and magnitude of the green premium, and empirical results remain mixed and inconclusive.

Using a sample of bonds from the Bloomberg Global Green Bond Index, Preclaw and Bakshi (2015) perform an ordinary least square regression (OLS) analysis to evaluate the yield difference between green and conventional bonds. Their empirical result suggests a significant negative green bond premium of 17 basis points (bps) on the global secondary market. Nanayakkara and Colombage (2019) use the option-adjusted spread (OAS) to measure the green premium and to document the fact that green bonds are traded at a negative premium of 63 bps compared with other comparable corporate bonds. Based on a matching method that consists of 21 selected bond-specific characteristics, Zerbib (2019) creates 110 triplets of one green bond and two conventional bonds to quantify the magnitude of the effect of proenvironmental risk preferences on the dynamics of green bond pricing. Using a two-step regression analysis, Zerbib (2019) reveals a significant negative green bond premium of −2 bps in the secondary market. Likewise, based on a data set of 121 European green bonds, Gianfrate and Peri (2019) perform a propensity score matching technique and declare the existence of green premiums of −20 bps for the primary market and −5 bps for the secondary market. Moreover, Gianfrate and Peri (2019) point out that a significant negative green premium provides a financial incentive to bond issuers to become more willing to raise funds by issuing green bonds rather than conventional bonds. Reboredo (2018) and Reboredo and Ugolini (2020) conclude that price changes in the green bond market comove with other financial markets, and specifically, the green bond market receives significant spillover effects from price changes in the treasury, USD currency, and the corporate debt market. In a systematic review in the literature of green bond markets, MacAskill et al. (2021) observe an average level of green premium in the range of −1 bp to −9 bps across different secondary markets.

Based on the World Bank's Emerging Market Green Bond Report 2018, East Asia and the Pacific is the largest green bond market among other geographical regions. Among Asian countries, China represents the largest market for the future development of sustainable finance and investment. Given the 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). Since then, green bonds have become a top priority for the Chinese authorities (Wang & Zhang, 2017) with regard to the target of reaching carbon neutrality by 2060. Along with preferential policies and bullish markets for sustainable finance, green bonds have become a crucial financial instrument for China's capital market to finance low-carbon sustainable development. Despite the remarkable growth in issuance volumes over the past few years, the green bond market in China remains relatively nascent and substantially smaller than conventional bond markets.

The examination of previous green bond literature reveals that the evidence of green premium in the green bond market remains mixed and inconclusive. Besides, it is yet to be determined whether this newly developed financial instrument offers investors attractive yields as compared to conventional bonds in the Chinese secondary market. Given that so far only limited attention has been paid to the Chinese green bond market, this paper aims to quantify the magnitude of the yield difference between green bonds and equivalent conventional bonds with the use of the most up-to-date data from the Chinese secondary market. Particularly, this paper aims to address the following two research questions:

- Do bond prices reflect the environmental awareness of financial investors in the Chinese secondary market?
- If there exists a significant green premium in the Chinese bond market, what are the potential factors that have an impact on the premium?

This paper, in investigating the green premium in the Chinese secondary market, contributes to the extant green bond literature in three ways. First, given China's special national conditions in banking and financial sectors, the bond market is mainly dominated by the interbank bond and exchange bond markets. The disconnectedness among the submarkets may restrict investors and policy makers from exploring and understanding the potential influential factors of green bond pricing. Hence, our analysis contributes to the understanding of investors' preference in the choice of green bonds in the Chinese secondary market. Second, in contrast to Wang et al. (2019), who conclude the presence of a positive green bond risk premium in the Chinese market, our empirical analysis provides significant statistical evidence of the existence of a negative green bond premium. Although green bonds are a newly emerging financial instrument in the Chinese market, our results confirm the presence of proenvironmental preferences among the Chinese financial investors that are willing to pay a premium to acquire a green bond in their portfolio management. Third, our empirical results reveal a mixed conclusion regarding the statistical impact of external auditing on the variation in green bond premiums. Typically, CBI climate certification is found to have no significant impact on green premiums, while environmental, social, and governance (ESG)-rated bond issuers are expected to enjoy a lower cost of capital. These findings reflect an inconsistent definition of green bond standards in the Chinese market. Therefore, the ongoing work to improve the consistency of definition standards would be important for the further development of green finance in China.

The remainder of this paper is structured as follows. Section 15.2 outlines the research question and the testable research hypothesis of this paper. Section 15.3 details data sources and the matching process. Section 15.4 reports the empirical methodology we use to identify green bond premiums in the Chinese secondary market. Section 15.5 reports and discusses our main empirical results. Finally, Sect. 15.6 summarizes our empirical findings and concludes the paper with policy implications.

15.2 Research Hypothesis Formulation

Several studies have shown that the green premium is driven by the presence of information asymmetries between investors and bond issuers in the bond market. Thus, investors tend to take independent information enhancers (e.g., bond issuer types, credit rating classes, third-party certifications) as key indicators to minimize the risks associated with information asymmetry (Bachelet et al., 2019; Hyun et al., 2020; Stádník, 2022). In order to address our research questions, we provide the following testable hypotheses:

- **Hypothesis 1** (H1): There does not exist a yield premium on green bonds in comparison with equivalent conventional bonds in the Chinese secondary market.

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. Meanwhile, Stádník (2021) claims that investors should have similar trading strategies and take interest rates sensitivity arbitrage in their green and conventional bond portfolio management.

Hence, like other conventional bonds, the green bond should be traded at its face value, and investors should perceive no price difference between the two. However, the green bond premium has been widely documented in previous studies (Bachelet et al., 2019; Zerbib, 2019; Toilliver et al., 2020; MacAskill et al., 2021). As discussed by Zerbib (2019) and Tolliver et al. (2020), investors with proenvironmental preferences and nonpecuniary motives are encouraged to incorporate—besides financial values—social and environmental values into their portfolio management. Under the condition of similar bond characteristics, the nonpecuniary-motivated investors are willing to accept a lower return on green bond investment, thus causing a negative credit spread between a green bond and a conventional bond and supporting the significance of a negative bond premium in the market. In order to quantify the significance and magnitude of the green bond premium, we hypothesize that there is no difference in the ask yields of green and conventional bonds with identical characteristics in the Chinese secondary market.

- **Hypothesis 2** (H2): A third-party credit rating does not affect the magnitude of the green premium.

Previous literature has documented that the factors affecting the risk premium of green bonds are mainly categorized into macroeconomic conditions, bond characteristics, and the firm-specific characteristics of bond issuers. Moreover, Wang et al. (2019) declare that credit rating, time to maturity, and bond issue size are the three major factors influencing the green premium in the Chinese secondary market. On the basis that bond pricing is closely determined to its credit ratings (Stádník, 2018), Agliardi and Agliardi (2019) conduct a set of numerical computations and their empirical results reveal that credit rating upgrade may lead to a lower cost of capital for green bond issuers. Using the Pearson correlation analysis, MacAskill et al. (2021) demonstrate that bond with credit ratings and investment-grade tend to provide the most predictable existence of a green premium in the range of -2 to -6 bps. Based on the analysis of green bonds in the US municipal bond market, Karpf and Mandel (2018) find that the green premium negatively correlates with bond crediting rating classes. Likewise, Zerbib (2019) finds that the yield premium increases by 2.43 bps for A- and AA-rated bonds in comparison to AAA-rated green bonds. On the other hand, Hachenberg and Schiereck (2018) suggest an insignificant relationship between the green premium and bond credit rating classes. Based on the above examinations, we hypothesize that credit rating classes do not have a statistically significant impact on the green bond premium in the Chinese secondary market.

- **Hypothesis 3** (H3): The green bond premium does not differ across business sectors in the Chinese secondary bond market.

The research conducted by Kapraun and Scheins (2019) and Zerbib (2019) declares that, apart from bond characteristics, the magnitude of green premium varies across issuer types and business sectors. Given the presence of a negative green premium in the US and European bond markets, Kapraun and Scheins (2019) find that the magnitude of the yield premium of green bonds issued by governments or supranational bodies is much larger than those issued by corporations. Meanwhile, Zerbib (2019) reveals that green bonds issued by business sectors associated with consumer products, industrials, and utilities are traded at a higher premium level compared to those issued by finance and material sectors. Based on this notion, we hypothesize that the green bond premium does not vary across business sectors in the Chinese secondary bond market.

- **Hypothesis 4** (H4): A third green bond certification and an external EGS revision do not affect the magnitude of the green bond premium in the Chinese secondary bond market.

Due to the presence of asymmetric information in the bond market, 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 the suspicion of a greenwashing behavior (Bachelet et al., 2019; Wang et al., 2019). As Ehlers and Packer (2017) stated, from the issuer's point of view, external green certification enables asset managers to prove to investors that the proceeds from green bonds are truly earmarked for environmentally friendly projects. Given the notice of the certification, investors might become more willing to pay a premium for acquiring a green bond. For instance, Larcker and Watts (2019), Bachelet et al. (2019), Wang et al. (2019), and Hyun et al. (2020) conclude that green bonds with third-party certification enjoy a certain amount of pricing benefits. Since green bonds are newly developed financial instruments in the Chinese market, the statistical impact of third-party green certification on the bond premium remains undetermined. Accordingly, our last hypothesis in this research assumes that third-party green bond certification and an external ESG rating do not have a statistical impact on the magnitude of the green bond premium in the Chinese secondary bond market.

15.3 Data

In order to study the green premium in the Chinese secondary market, our first step in data collection is to create a green bond database that contains all bond-specific characteristics. We collect our data from two sources, Thomson Reuters Datastream and the Chinese iFind database, on November 27, 2020. As of that date, there are 179 active green bonds available in the market with issue dates between the years

Table 15.1 Matching Criteria

Bond characteristics	Matching criteria
Issuer	Exact match
Issuer type	Exact match
Bond instrument type	Exact match
Maturity date	±2 years
Issue date	±4 years
Bond issuance volume	25–400% of the green bond
Coupon type	Exact match
Coupon frequency	Exact match
Bond rating	Exact match
Seniority	Exact match
Tenor	±2 years
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

2016 and 2020. Since 2016 was the first year of green bond issuance in China, we do not include any bonds issued before 2016 in our sample observation. By considering only straight and senior green bonds with a plain-vanilla-fixed coupon payment, we exclude 66 bonds from our sample data. Therefore, only 113 green bonds are available in the next step of the matching process.

Following previous literature on green bond pricing, we use econometric specifications to investigate the differences between the yield term structures of green and conventional bonds in the Chinese bond market. As discussed by Bachelet et al. (2019) and Zerbib (2019), the ideal methodological approach to assess the yield premium of green bonds in comparison with that of conventional bonds would be 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 our estimation bias. By considering the above suggestions and in line with previous literature, we adopt a matching method that consists of 19 matching criteria to investigate the yield difference between green bonds and their corresponding conventional bonds (Table 15.1). For each green bond in our matching procedure, we search for two conventional bonds that are the nearest neighbor in terms of the selected bond characteristics. In the case that a green bond is identified to have either none or only one matched conventional bond in our matching process, we would exclude it from our sample data. Since it is impossible to find two bonds with exactly the same characteristics in terms of the issue date, maturity, amount issued, and tenor, we adjust our matching procedure by allowing a reasonable variation in these four bond characteristics. For the issue dates, we consider a maximum of 4-year difference between green and conventional bonds. Besides, we match conventional bonds with a maturity that is neither more than 2 years shorter nor more than 2 years longer than the green bond's maturity. The issue amount of a conventional bond is allowed to lie within the range of 25% as the minimum to four times the matched green bond as the maximum. In terms of tenor, the difference is controlled within 2 years. Based on these principles, we create 64 matched triplets composed of one green bond and two matched conventional bonds.

Once the matching is completed, we use linear interpolation and extrapolation to combine the ask yields of matched conventional bonds into a synthetic bond. In doing so, we retrieve the ask yields of each triplet of bonds (the green bond and the corresponding conventional bonds) from Thomson Reuters Datastream, from the issue date of the matched green bond up to October 22, 2020. For any missing values on each of the three matched bonds, we remove the entire line out of our panel. The ask yield of the synthetic conventional bond is estimated by a linear function between the two conventional bonds at the time of maturity of the green bond. For each triplet of matched bonds, with α as the intercept and β as the slope coefficient of a linear function passing through $\left(\text{Maturity}_{i,t}^{\text{CB1}}, Y_{i,t}^{\text{CB1}}\right)$ and $\left(\text{Maturity}_{i,t}^{\text{CB2}}, Y_{i,t}^{\text{CB2}}\right)$, the daily ask yield of a synthetic conventional bond is estimated through the following equation:

$$Y_{i,t}^{\text{SB}} = \alpha + \beta \cdot M_{i,t}^{\text{GB}} \tag{15.1}$$

where $Y_{i,t}^{\text{SB}}$ represents the daily ask yield of the synthetic bond and $M_{i,t}^{\text{GB}}$ refers to the number of days to maturity with respect to the green bond maturity date. In addition to that, we take the difference in the ask yield of a green bond and a corresponding synthetic bond to measure the yield spread among matched green bonds and the corresponding synthetic bonds (See Eq. 15.2)

$$\Delta Y_{i,t} = Y_{i,t}^{\text{GB}} - Y_{i,t}^{\text{SB}} \tag{15.2}$$

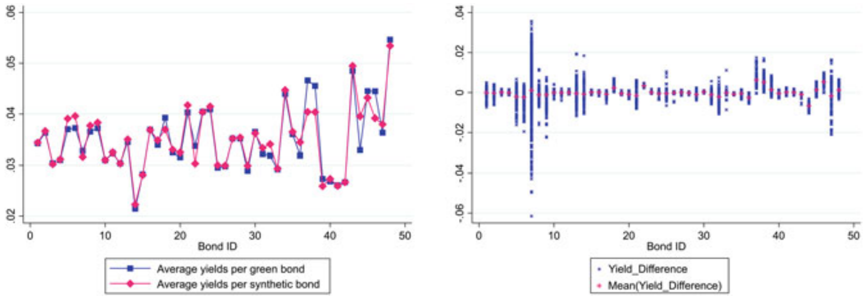
In order to ensure the robustness of our matching result, we keep the estimated yield spread within the interval from the 2.5th to the 97.5th percentile based on the general distribution of the average of $\Delta Y_{i,\ t}$, which we obtained from Eq. 15.2. This approach allows us to avoid unwanted high or low unrealistic values of the ask yield difference in our data sample and therefore to minimize the impact of outliers on our estimation.

Based on the matching criteria presented in Table 15.1, 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 bond differs from the conventional bonds. The test results reported in Table 15.2 reveal that, at the median level, the coupon rate, time to maturity, and the issue price between the two sample groups are not statistically different. Figure 15.1 shows how the ask yields and the yield differences

Table 15.2 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
Issue price	100	100	0.000	1.00
Amount issue	4.246	9.054	−4.806	0.0198

Note: The null hypothesis suggests an identical distribution between two pairs of observations



(a) (b)

Fig. 15.1 Distribution of the yield differences and the ask yields between green and synthetic bonds. (**a**) Average daily yields of green and synthetic bonds. (**b**) Yield difference between green and synthetic bonds

Table 15.3 Steps for sample construction

Search criteria	Number of bonds
Number of active bonds labeled as "green" on Thomson Reuters Eikon/ Datastream and the Chinese iFind database	179
Straight and senior green bonds with plain-vanilla-fixed coupon payment	113
Green bonds available for the matching process	64
Matched green with sufficient time-series length	48

Note: We removed three green bonds from our sample observation due to the limited time series available for the matching. Additionally, three matched triplets were excluded from the sample to avoid unwanted high and low synthetic ask yields. The number of bond trading days available for each pair of group ranges from a minimum of 41 days to a maximum of 684 days.

vary across matched pairs of green and synthetic bonds, and it indicates a good quality control of our matching process.

Table 15.3 summarizes the steps we undertake to construct our final database for empirical analysis. Our sample data constitute an unbalanced panel of 48 triplets of green bonds and synthetic bonds from 33 bond issuers with a total number of 14088 daily observations. The number of bond trading days available for each pair of group ranges from a minimum of 41 days to a maximum of 684 days. The earliest observation of yield difference ($\Delta Y_{i,\ t}$) is available from May 17, 2017; the latest is dated October 22, 2020.

15.4 Methodology

We take the ask yield spreads of green bonds and their corresponding synthetic bonds to determine if there exists a green premium in the Chinese secondary market. Since the matched bond pairs are designed to be consistent as far as possible, the green premium is defined by controlling the residual differences in liquidity between matched conventional bonds and their corresponding green counterparts (Zerbib, 2019; Hyun et al., 2020). Hence, we apply a one-way individual fixed-effect panel regression model to estimate $\Delta Y_{i,\ t}$ on $\Delta \text{Liquidity}_{i,\ t}$:

$$\Delta Y_{i,t} = \alpha_i + \beta\,\Delta\,\text{Liquidity}_{i,t} + \varepsilon_{i,t} \tag{15.3}$$

From the parameters in Eq. 15.3, $\Delta Y_{i,\ t}$ refers to the daily yield difference for the ith bond pair on the day t, which is computed using Eq. 15.2. The main parameter of our interest, which captures a time-invariant green premium, is α_i. The significant negative α_i indicates the presence of a green premium, revealing that investors are willing to accept a lower yield for acquiring green bonds in the Chinese market. The parameter $\varepsilon_{i,\ t}$ denotes the idiosyncratic error term. $\Delta \text{Liquidity}_{i,\ t}$ represents the liquidity difference between a green bond and its synthetic counterpart, which is defined as

$$\Delta\,\text{Liquidity}_{i,t} = \text{Liquidity}_{i,t}^{\text{GB}} - \text{Liquidity}_{i,t}^{\text{CB}} \tag{15.4}$$

Since the intraday transactional quote data are not available for infrequently traded bonds, we cannot apply conventional liquidity benchmarks, such as the intraday effective bid-ask spreads, to estimate the liquidity of the Chinese green bond market. Among the existing low-frequency proxies for the measurement of liquidity, one strand of previous literature based on global research has suggested that the daily version of the closing percent quoted spread (CPQS) is superior to all other low-frequency percent-cost proxies (Chuang & Zhang, 2014; Fong et al., 2017; Zerbib, 2019; Będowska-Sójka & Echaust, 2020). In this paper, we comply with previous research and use the closing percent quoted spread (CPQS) as our liquidity proxy, which is expressed as follows:

$$\text{Liquidity}_{i,t} = \text{CPQS}_{i,t} = \frac{(P_{A,t} - P_{B,t})}{M_{i,t}} \tag{15.5}$$

where $P_{A,\ t}$ and $P_{B,\ t}$ are the closing ask and bid price, respectively, observed at the end of each available trading day t. $M_{i,\ t}$ refers to the average of $P_{A,\ t}$ and $P_{B,\ t}$. For the purpose of computing liquidity difference, a liquidity proxy for the matched synthetic bonds is also estimated using the distance-weighted average of the CPQS based on the maturity of conventional bonds in relation to the maturity of green bonds:

Table 15.4 Descriptive statistics of the estimated bond liquidity

	Min	1st quartile	Mean	Median	3rd quartile	Max	SD	*N*
$CPQS_{GB}$(%)	0.00	0.16	0.23	0.25	0.33	0.98	0.13	14088
$CPQS_{CB}$(%)	0.000	0.001	0.002	0.002	0.003	0.007	0.001	28176
ΔCPQS (%)	−0.53	−0.05	0.03	0.00	0.09	0.92	0.12	14088

Note: This table reports the descriptive statistics of the difference in bond liquidity between green bonds and their synthetic conventional counterparts using the closing percent quoted spread (CPQS). GB and CB refer to green bond and conventional bond, respectively

$$\mathrm{CPQS}_{i,t}^{\mathrm{SB}} = \frac{d_2}{d_1 + d_2}\mathrm{CPQS}_{i,t}^{\mathrm{CB}_1} + \frac{\mathrm{d}_1}{\mathrm{d}_1 + \mathrm{d}_2}\mathrm{CPQS}_{i,t}^{\mathrm{CB}_2} \tag{15.6}$$

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

Table 15.4 provides the descriptive statistics of the estimated CPQS of green bonds and their synthetic bond counterparts. Given that $\Delta\mathrm{CPQS}_{i,\,t}$ is centered around zero with a low level of standard deviation, our matching process has well managed to have control of the liquidity differentials between the matched green and conventional bonds.

15.5 Determinants of the Green Premium

Besides green premium identification, we investigate the potential determinants of the green premium as our second research question. Based on both theoretical and empirical evidence from previous literature on green bond pricing, we consider third-party credit rating, external verification, and bond issuers' sector as the potential factors influencing the green premium in the Chinese bond market. Table 15.5 reports detailed descriptions of the variables we used for our investigation.

It is worth noting that our second step in the analysis is based on a strict assumption that all time-invariant green effects are fully captured by estimating Eq. 15.3. Based on that prior assumption, we perform OLS model specifications with robust standard errors to test our hypotheses 2–4. Consistent with other research, we take the variables issue amount and maturity as our control variables for the purpose of robustness control. 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 (Stádník, 2014). 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. The variable Maturity is calculated as the number of years to green bond maturity. To test our second hypothesis (H2), the possible impact of credit rating on the green bond premium, we include a categorical variable representing the third-party credit rating into our model specification based on information retrieved from Chinese domestic rating agencies. Based on the Thomson Reuters Business Classification (TRBC), we create a

Table 15.5 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 Eq. 15.1.
Green premium ($\widehat{\alpha}$)	Green premium is calculated using the one-way individual fixed-effect estimation, Eq. 15.3.
Time to maturity (years)	The time to maturity of each green bond, measured in number of years.
Credit rating	The bond credit rating of our matched green bond (AAA, AA+, AA), set as a categorical variable, with a corresponding value from 1 to 3, respectively. The rating is issued by Chinese domestic rating agencies, and we retrieved 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 is equal to 1 if the bond is certified by CBI and 0 otherwise.
ESG rating	The ESG rating of our green bonds (B, C, C−, D, D+, and not rated), set as a categorical variable, with a corresponding value from 1 to 6, respectively. Data source from Thomson Reuters Eikon/Datastream.
Sector	We use the Thomson Reuters Business Classification (TRBC) to determine the bond issuers' business sector, which leaves us, in the case of the present sample, with eight categories: (i) agency; (ii) bank; (iii) financials, which encompass nonpublic banks and financial services; (iv) chemicals; (v) consumer; (vi) industrials; (vii) transportation; and (viii) utility-electricity. The base value in our case is agency.
Issues amount	The total amount of green bond issuance. We take the natural logarithm to avoid unwanted heteroscedasticity.

categorical variable, "Sector," to investigate whether green premiums can vary across bond issuers' sectors (H3). In addition to that, we use dummy variables "CBI certified" and "EGS rating" to investigate the impact of third-party certification on the green premium in the Chinese secondary market. Overall, we perform our second step of the analysis using the following model specification:

$$\widehat{\alpha}_i = \beta_0 + \beta_1 \text{Maturity}_i + \beta_2 \log\left(\text{Issue amount}\right) + \beta_3 (\text{CBI certified}) + \beta_4 (\text{ESG rating}) + \sum_{i=1}^{N\ \text{Sector}} \beta_{\text{sector}}(i) \times \text{Sector}_i + \sum_{i=1}^{N\ \text{rating}} \beta_{\text{rating}}(j) \times (\text{rating})_j + \varepsilon_i \tag{15.7}$$

15.6 Empirical Results and Discussion

We identify the presence of individual effects in our sample observation through the Breusch-Pagan Lagrange multiplier (LM) test. Furthermore, based on the result of the Hausman test (Table 15.7), we expect the fixed-effect estimator to be more efficient than the random-effect estimator. Therefore, we specify a within-fixed-

Table 15.6 Within-fixed-effect estimation results

	Dependent variable: $\Delta Y_{i,t}$			
	Fixed effects	Fixed effects with robust standard errors	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
No. pair	48	48	48	48
R^2	0.008	0.008	0.008	0.008
F-statistic	109.16***	6.67***	6.67***	8.85***

Note: ***, **, and * refer to statistical significance at 1%, 5%, and 10% levels, respectively. The number in parentheses represents standard errors

Table 15.7 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 heteroscedasticity
Wooldridge serial correlation	2.448	0.1243	Absence serial correlation
Pesaran cross-sectional dependence test	35.954	0.000	Presence of cross-sectional dependence

effect regression model to estimate the sign, significance, and magnitude of the green bond premium in the Chinese secondary market. Table 15.6 reports the results of the within-fixed-effect estimation of Eq. 15.3 based on an unbalanced panel of 14088 daily observations. The negative coefficient of ΔLiquidity is highly significant at the 5% level. Specifically, the estimated coefficient implies 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, controlling green-bond-specific time-invariant characteristics. This finding is consistent with the findings of Zerbib (2019) and Gianfrate and Peri (2019), who declare a significant negative relationship between liquidity differentials and yield spread in the green bond market.

Although the Woolridge test suggests the absence of a 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 15.7). In order to account for heteroscedasticity and cross-sectional dependence, we specify robust standard errors and one-way and two-way cluster standard errors in our model estimations to combat the presence of these effects. The model estimations in Table 15.6 report a low level of R^2, which is around 1%, indicating a low explanatory power of our model specification. The low level of R^2 is

Table 15.8 Distribution of the green bond premium estimates

$\widehat{\alpha}_i$(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-effect model of Eq. 15.3. We apply the Student t-test and the Wilcoxon matched-pair signed-rank test to determine whether the mean and median values of the estimated green premium are statistically different from 0. ***, **, and * represent the significance at 1%, 5%, and 10% levels of significance, respectively

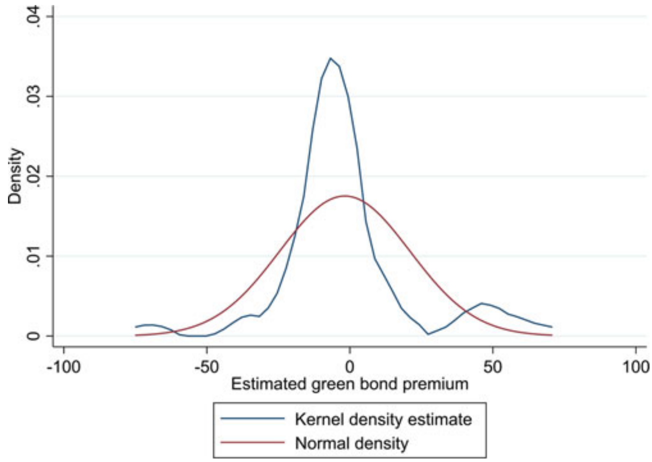


Fig. 15.2 Distribution of estimated green bond premiums in the Chinese secondary market

acceptable for within-fixed-effect estimation since the model setup discards individual effects in the estimation procedure (Bachelet et al., 2019). Moreover, the highly significant estimated coefficient of $\Delta \text{Liquidity}_{i,\ t}$ suggests the importance of using CPQS as the proxy for liquidity control in our model specification.

The distribution of the green bond premium ranges from –70 bps to 65 bps, and the average and median values of the premium are –5.2 bps and –1.8 bps, respectively (Table 15.8). Especially, a total of 71% of the premium are negative, as presented by the kernel density plot of the estimated green bond yield premium in Fig. 15.2. To test our first hypothesis (H1) on the presence of a green premium in the Chinese secondary market, we apply the Student t-test and the nonparametric Wilcoxon signed-rank test with continuity correction to access whether the mean and median values of the estimated green premium are statistically different from 0. Based on the P-values of these two tests, we do have enough statistical evidence to reject the null hypotheses, revealing that the green premium does exist in the Chinese secondary market.

The negative green bond premium in the Chinese market is consistent with the findings from previous green bond literature, which also documents that financial investors are willing to accept a lower financial return for a green bond investment (Gianfrate & Peri, 2019; Zerbib, 2019; MacAskill et al., 2021). The presence of the green premium confirms the intention of the Chinese financial investors to be driven by nonpecuniary motives and thereby be willing to pay for a premium to green their investment portfolio. Although the estimated magnitude of the green premium in our empirical analysis is relatively small, it does significantly reflect Chinese investors' willingness to incorporate proenvironmental preferences into their portfolio design and risk management.

However, our finding is in contrast with that of Wang et al. (2019), who reveal a positive risk premium on an average of 1.73% in the Chinese green bond market. Notice that Wang et al. (2019) have not adopted a matching process; neither have they included liquidity as the control variable in their model specifications. 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 and risk-free interest rates. Thus, our result adds to the green bond literature by providing significant evidence to argue for the presence of a negative green bond premium in the Chinese secondary market.

Besides green bond premium identification, we further explore premium variation in several subsamples according to the main characteristics of the selected green bond sample: its rating, business sector, CBI certificate, and ESG rating. By doing this, we calculate the average and median premiums of each subsample and test whether they are significantly different from 0. Table 15.10 reports the average and median green premiums per subsample. The −8.194 bps average yield premium on the green bonds issued by financials is significantly different from 0 at a 99% confidence level. AAA-rated green bonds show an average level of −5.445 bps premium with the same degree of significance. Additionally, ESG-rated green bonds show a significant negative green premium of −12.583 bps at a 95% confidence level. Although the average and median values of CBI-certificated green bonds are negative, they are not statistically significantly different from 0 (Table 15.9).

Regarding the determinants of the green premium, we apply a cross-section linear regression of $\widehat{\alpha_i}$ on the bond-specific characteristics. Table 15.10 represents four model specifications, which we undertake to address hypotheses 2–4. The variance inflation factor (VIF) test results indicate the absence of multicollinearity of underlying variables in each of these model specifications. By choosing maturity and log (issue amount) as the control variables, the model specification (a) evaluates the impact of bond crediting on the green bond premium, and model specification (b) captures green bond premium variation across different business sectors. Likewise, model specifications (c) and (d) assess the impacts of external green certification and verification on the green bond premium. In terms of robustness control, we perform our OLS specifications with the use of robust standard errors.

Table 15.10 summarizes our OLS estimation results of Eq. 15.7. With regard to control variables, we do not find that bond issue amount has a significant impact on the magnitude of green premiums. Hence, the green bond premium does not seem to be determined by the bond issue amount in the Chinese market. In terms of maturity

Table 15.9 Green bond premium in several market segments

		Median	Mean	No. Green bond
Total		−1.775***	−5.235***	48
Sector	Agency	−5.859	−5.859	1
	Bank	−6.142**	−3.765	16
	Financials	−5.364**	−8.194**	10
	Chemicals	−6.340	−6.340	2
	Consumer	22.622	22.622	2
	Industrials	17.058	24.984*	5
	Transportation	2.350	0.4356	6
	Utility	−7.759	−16.190	6
Credit rating	AAA	−5.445***	−5.887***	41
	AA+	22.891	23.183*	6
	AA	17.059	17.059	1
CBI bond	Certificated green bond	−3.778	−1.120	35
	Self-labelled green bond	−5.798**	−3.537	13
ESG rating	ESG rated	−12.136***	−12.583**	15
	Not rated	−3.340	3.138	33

Note: We apply the paired Student *t*-test and Wilcoxon signed-rank test to determine whether the mean and median values are statistically different from 0. ***, **, and * refer to statistical significance at 1%, 5%, and 10% levels, respectively

between different green bonds, a generally positive relationship is found, suggesting that the green bond premium increases with the number of years to bond maturity. However, the estimated coefficient on maturity is only significant in model specifications (a) and (d). To test our Hypothesis 2, the model specification (a) indicates that the third-party credit rating has a significant impact on the magnitude of the green bond premium in the Chinese secondary market. Specifically, the statistical impact of a credit rating is significant for AAA-rated green bonds with a magnitude of −16.76 bps with respect to the reference group of AA-rated bonds. In terms of the AA+-rated green bond, we do not find a significant difference in comparison to the reference group. Based on the model specification (b), we find out that the green premium varies between different business sectors, and we thus have enough statistical evidence to reject Hypothesis 3. Furthermore, our estimated results suggest that the green bonds issued by agencies, financials, and transportation- and utility-related sectors have a negative effect of 27.88 bps, 25.84 bps, 22.39 bps, and 32.02 bps, respectively, on the green premium in comparison with industrial-related sectors. In terms of the green bonds issued by banks, we do not find any statistical significance to support the negative effect on green bond premiums. This finding is consistent with previous literature, which suggests that the green bond premium varies among business sectors and it is closely related to the public reputation of the bond issuers (e.g., Hanenberg & Schiereck, 2018; Bachelet et al., 2019; Fatica et al., 2019; Gianfrate & Peri, 2019; Kapraun & Scheins, 2019; Zerbib, 2019).

Surprisingly, contrary to previous studies (e.g., Bachelet et al., 2019; Flammer, 2020), we do not observe any statistical evidence to support a significant relationship

Table 15.10 Determinants of green bond premium in the Chinese secondary market

	Variable	(a)	(b)	(c)	(d)
Control variables	Maturity	4.940*	5.232	3.071	5.394*
		(2.805)	(4.054)	(2.999)	(2.810)
	Log (issue amount)	−0.460	−0.471	−0.469	−3.961
		(2.065)	(2.275)	(2.126)	(2.672)
TRBC sector	Agency		−27.88**		
			(12.53)		
	Bank		−17.78		
			(13.33)		
	Financials		−25.84**		
			(11.50)		
	Transportation		−22.39*		
			(11.26)		
	Utility		−32.02*		
			(16.79)		
Credit rating	AA+	12.91			
		(13.16)			
	AAA	−16.76***			
		(4.953)			
External verification	ESG rating			−13.62*	
				(7.492)	
Green bond certification	CBI certificate				9.465
					(6.387)
	Constant	1.546	6.633	0.554	54.72
		(39.79)	(46.21)	(47.13)	(56.92)
	Observations	48	48	48	48
	R-squared	0.243	0.248	0.122	0.091
	VIF	3.37	1.65	1.23	1.16

Note: This table summarizes the empirical results of step 2 regression based on a sample of 48 green bonds. Robust standard errors are reported in parentheses; ***, **, and * represent the individual test significance at 1%, 5%, and 10%, respectively. VIF tests are applied to examine the presence of multicollinearity. The sector refers to a categorical variable based on the Thomson Reuters Business Classifications (TRBC), and we use the industrials as the reference group in our regression analysis. Credit ratings are retrieved by Chinese domestic credit rating agencies, where AA is equal to 1 and AAA is equal to 3 in the common credit rating scale, and we use AA credit rating as the reference variable in our analysis. CBI certificate and ESG rating represent the third-party certificate and external certification, respectively

between green certification and the yield 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. The insignificant label effect on the green premium may be due to the inconsistent definition of green bond standards in the Chinese market. Since there is no global definition of green bond, Ehlers and Packer (2017) point out that various organizations have developed their own customized measuring standard green bond definition. Given the country-specific characteristics, agencies may modify the measuring standards accordingly to develop their own customized taxonomies. Hence, practitioners have raised concerns that green bonds could be merely a form of greenwashing (Flammer, 2020) and the credibility of the CBI green certificate remains questionable in the Chinese market. Since there is no global definition of green bonds, various organizations have customized their green labelling 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. Therefore, the regulatory development on labelling standards for green bonds is crucial for the future expansion of the green bond market in China. The estimated coeffcient on variable is negative and significant at a 10% level, suggesting that ESG policies can benefit green bond issuers from lower cost of capital. Thus, as long as external ESG auditing is concerned with green bond pricing, our results support a partial rejection of Hypothesis 4.

15.7 Conclusion

Green bonds, as an innovative fixed-income financial instrument, represent a promising channel for mobilizing financial resources to scale 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 two research questions: first, is there a green bond premium in the Chinese market? Second, what factors influence the magnitude of the green premium? To do so, we apply a matching method that consists of 19 bond-specific characteristics to create a data set of 48 matched pairs of green and conventional bonds. Using CPQS as a proxy variable for liquidity control, we perform fixed-effect panel regression on our unbalanced panel of 14088 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 nonpecuniary-motivated investors are willing to accept lower financial returns for green bond investments rather than those for conventional bonds. Besides the presence of pro-environmental preferences among investors, our paper adds to the extant green bond literature by examining how the estimated negative green bond premium varies with bond-specific characteristics in the Chinese secondary market.

Based on a two-step regression analysis, our findings suggest that the green bond premium varies across issuers' business sectors, where green bonds issued by agencies, financials, and transportation- and utility-related sectors are traded at lower yields compared to the green bonds issued by industrials. According to our estimates, investors are willing to pay a higher price for green bonds with AAA credit ratings in comparison with other lower-rated green bonds. 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 the CBI green certificate in the Chinese markets. Although ICMA's Green Bond Principles and CBI Climate Bond Standards are being applied as the main reference standards for defining green bond in China (Wang & Zhang, 2017), many other customized certification mechanisms are available to any bond issuers on the market. Given the lack of consistent green bond standards, investors' willingness to venture into green bond investments is limited because of information asymmetry and suspicions of greenwashing behaviors (Hyun et al., 2020). For policy makers, as highlighted by Ehlers and Packer (2017), the ongoing legal improvement to the consistency of green bond standards would be especially important for the future development of sustainable green finance in the Chinese secondary market.

Lastly, we find that external bond issuers with ESG ratings enjoy a 13.62-bps discount at green bond issuance, as compared with bond issuers that do not have such verification. With the global trend of integrating ESG considerations into corporate policies, Tang and Zhang (2020) show that the ESG policy and green bond issuance could raise a company's public reputation and hence improve stock valuation and liquidity. Furthermore, Slimane et al. (2020) argue that ESG rating has had a larger and increasing part in determining the yield premium in bond pricing. 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. 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.

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