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The issuance spread of China's low-carbon transition bonds

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Abstract: Low-carbon transition bonds, as a particular type of sustainable financial instrument, raise funds specifically for the low-carbon transition sector, filling the gap in green finance's support for high-carbon industries. This paper takes low-carbon transition bonds as the research object, studies the current development status of low-carbon transition bonds, and uses the ordinary least squares method to analyze the impact of the transition attribute of these bonds on issuance spreads, showing that they can reduce corporate financing costs. The findings reveal that: (1) There is a significant negative correlation between transition attribute and issuance spreads, and this result holds true after a series of robustness checks. Moreover, the characteristics of the bond itself influence its pricing. (2) Heterogeneity analysis indicates that low-carbon transition bonds can better help non-listed companies and economically underdeveloped regions to finance at lower costs. Finally, this paper provides policy recommendations for the future development and improvement of low-carbon transition bonds.

Keywords: low-carbon transition bonds, issuance spread, transition attribute

JEL classification: G12

1. Introduction

As China's economy enters a new phase of development, shifting from a focus on high-speed growth to one of high-quality growth, the concept of sustainable development has gained increasing prominence. With the continued advancement of the "dual carbon" goals, China urgently needs to transition from a resource-intensive economy to a low-carbon, eco-friendly one, facilitating a low-carbon transformation in production methods. While green technologies and renewable energy projects have become popular investment opportunities, achieving a truly low-carbon economy requires high-emission industries, such as power companies and steel manufacturers, to incur relatively high costs. These costs are primarily associated with shutting down high-carbon projects and transitioning to low-carbon operations. The scale of funding required for this low-carbon transition is substantial, and the complexity of the transition exacerbates the challenges of financing and raises costs for enterprises. Transition finance offers a new solution to these challenges (Tandon, 2021).

In 2019, the OECD pioneered the concept of transition finance, which involves providing financing to economic entities to support their transition activities. While these activities may be "non-green" at the current stage, they are required to gradually become "green" over time. Green finance has already achieved considerable success in promoting environmental projects and industry development. As a powerful complement to green finance, transition finance plays a critical role in facilitating the green and low-carbon transition of carbon-intensive industries and brown assets, contributing to high-quality economic development (Caldecott, 2022). There is an urgent market need for transition finance to provide support. The low-carbon transition bond markets, both domestic and

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international, are still at an early stage. However, it is worth noting that the growth rate of China's domestic market has exceeded that of the international market.

The nature of low-carbon transition bonds falls between green bonds and sustainability-linked bonds. Green bonds typically provide direct financing for pre-defined environmental projects, such as solar power generation or sustainable waste management facilities (Flammer, 2021). Before a company can qualify for financing, its overall environmental performance and commitment to reducing its carbon footprint are assessed. Sustainability-linked bonds are tied to long-term sustainability goals, with funds that can be used for any project as long as it meets specific sustainability improvement criteria, such as reducing a certain amount of carbon emissions within a set timeframe. Like green bonds, low-carbon transition bonds allocate funds to specific projects. However, similar to sustainability-linked bonds, the projects funded by low-carbon transition bonds are not required to be green from the outset; rather, the company must be undergoing a low-carbon transition, with the project's ultimate goal being emission reduction. For example, a fossil fuel project aimed at reducing emissions may qualify. Therefore, compared to green bonds, low-carbon transition bonds offer more flexible financing requirements for high-carbon enterprises, making it easier for them to secure funding. In contrast to sustainability-linked bonds, low-carbon transition bonds specify the use of funds, enabling better oversight and control over the allocation of resources and allowing investors to evaluate the final emissions reduction performance of the company.

Given that low-carbon transition bonds are still in the early stages of development, they are characterized by small issuance volumes and unclear issuance criteria. Many issuers and investors lack the necessary understanding of low-carbon transition bonds and are uncertain about their effectiveness in helping companies achieve a low-carbon transition. This uncertainty may result in issuers being reluctant to issue low-carbon transition bonds or investors being hesitant to purchase them, leading to slow market development. Insufficient financial support for corporate transitions hinders the ability of transition finance products to effectively promote low-carbon transformation, thus impacting the development of transition finance in China.

As a result, the performance of low-carbon transition bonds in financial markets and related research is crucial for the green transition of high-carbon industries. Low-carbon transition bonds must be studied to determine whether they can help high-carbon companies transition, alleviate the difficulties of low-carbon transition financing, and reduce the costs associated with low-carbon transformation. If low-carbon transition bonds can effectively reduce corporate financing costs, what factors influence bond issuance premiums? How can high-carbon enterprises achieve financing at a lower cost? This paper addresses the current issues in China’s low-carbon transition bond market, investigating the issuance costs of low-carbon transition bonds and the factors influencing these costs, and provides reasonable solutions and recommendations for the development of the low-carbon transition bond market.

2. Literature review

If relevant, please include a literature review providing a theoretical background for the study. The literature survey should be brief and focused.

2. Literature review and research hypotheses

In recent years, China’s market for transition bonds has gradually developed. Xia et al. (2023) argue that since June 2022, China’s transition bond market has exhibited characteristics such as rapid growth in financing scale, a focus on brown industries, lower financing costs, and quantifiable "energy-saving and emission-reduction" effects. This indicates that the market for transition bonds in China has not only been launched but is also developing quickly. The introduction of low-carbon transition bonds has also promoted the low-carbon transition of the real economy, providing financing support for

traditional industries, effectively facilitating the transformation of high-carbon enterprises, and enriching the sustainable financial product system (Zhao, 2022). Additionally, Chen (2022) found that issuing green bonds generates positive effects on the market, suggesting that green bonds can inject new vitality into traditional bonds by driving market progress and encouraging investment. However, since China's low-carbon transition bond market is still in its early stages, there are ongoing debates regarding the definition of low-carbon transition bonds, and the related foundational institutional arrangements need further refinement. There is also room for improvement in policy incentives and product innovation (Wei, 2023). Lu et al. (2023) pointed out that although significant progress has been made in the innovation of low-carbon transition bonds in China, there is still a need for improvement in terms of mechanism development.

The main issues currently facing China's low-carbon transition bond market are as follows: First, there is a lack of clear classification for low-carbon transition bonds and precise definitions of low-carbon transition activities, leading to uncertainties regarding the allocation of funds and cases where companies in need of low-carbon transition funding do not receive the necessary financial support. Second, there is a lack of standardized definitions for low-carbon transition bonds, with different entities and markets holding divergent interpretations, resulting in inconsistencies in bond classification. Different databases may even record low-carbon transition bonds differently. Third, the issuance volume of low-carbon transition bonds is small, and there are relatively few types of such bonds, with insufficient support for their development.

Faced with the shortcomings and limitations of China's low-carbon transition bond market, many scholars have proposed their suggestions and perspectives. Zhao (2022) argued that efforts should be made to strengthen the development of a standard system for low-carbon transition bonds, establish a mechanism for evaluating their performance, and improve the planning and disclosure of issuers' transition strategies. Additionally, there is a need to strengthen the management of the use of funds raised through low-carbon transition bonds to ensure that they are genuinely directed toward low-carbon transition projects. Financial institutions should also receive policy incentives to reduce the burden of bond issuance (Qi, 2023).

According to the theories of information asymmetry and debt signaling, the issuance of low-carbon transition bonds can serve as an effective signal, increasing a company's leverage while simultaneously enhancing its social reputation. The issuance of low-carbon transition bonds can effectively reduce a company's financing costs, attract more bond and equity investors, and help promote the adoption of transition bonds. Furthermore, the "transition label" has a positive impact on shareholders. In theory, a company's goal is determined by its owners, namely the maximization of shareholder value. However, if the increase in shareholder value comes at the expense of other stakeholders, sustainable economic development becomes difficult. If a company takes on more social responsibility, such as protecting the environment and maximizing employee welfare during its operations, it will inevitably incur higher costs, which could affect shareholder interests. This creates a conflict between maximizing the interests of other stakeholders and those of shareholders. This study shows that low-carbon transition bonds, as an emerging financial product, can effectively reconcile this conflict. The issuance of low-carbon transition bonds sends a positive signal, promoting the development of the stock market and increasing shareholder value while also protecting the interests of other stakeholders. This provides a new perspective for resolving the conflict between stakeholder interests and shareholder value maximization and enriches the theoretical research on both fronts.

In the study of issuance spreads for low-carbon transition bonds, it is found that, on the one hand, low-carbon transition bonds can reduce the debt financing costs for enterprises (Berrada et al., 2022; Kölbel & Lambillon, 2022). Although companies may not have formal low-carbon commitments at the public governance level, according to the theories of information asymmetry and debt signaling, once a company becomes a

transition bond issuer, it signals that the company is willing and confident in improving its high-carbon production processes and achieving low-carbon operations. The company's progress in low-carbon transition will be monitored by the market. Thus, the issuance of low-carbon transition bonds serves as an effective signal, conveying positive information to the market, improving the company's social reputation, and gaining investor trust. As a result, bond investors are willing to pay a higher price or accept a lower return (low-carbon transition label effect). Furthermore, environmental risks can lead to significant financial costs. From the perspective of risk effects, the issuance of low-carbon transition bonds indicates that the company is actively working toward low-carbon transition. If the market recognizes that low-carbon transition bonds can protect investors from environmental risks and related credit risks (risk effects), the issuance costs of low-carbon transition bonds will decrease.

On the other hand, low-carbon transition bonds may not differ in price from traditional bonds. Currently, most low-carbon transition bond issuers are high-carbon-emission enterprises, and there is no significant difference in the use of funds between low-carbon transition bonds and traditional bonds, except for the requirement that the projects funded by low-carbon transition bonds must ultimately achieve carbon reduction. Therefore, the main difference in issuance is the "transition" label. The credit risk of low-carbon transition bonds remains dependent on the company's core business, meaning that both bond types face the same credit and environmental risks. Moreover, based on the principle of profit maximization, because the low-carbon transition is difficult and subject to technological risks, if a company issues bonds for low-carbon transition purposes, it implies that the company must invest more capital or introduce new technologies, making the project riskier than conventional ones. As a result, investors will demand greater risk compensation.

In summary, the following research hypotheses are proposed:

Hypothesis H1: *The transition attribute will impact the issuance spread of low-carbon transition bonds.*

Hypothesis H2: *The transition attribute does not impact the issuance spread of low-carbon transition bonds.*

3. Current development of low-carbon transition bonds

Low-carbon transition bonds refer to debt financing instruments issued to support environmental improvements and address climate change, with funds specifically allocated to low-carbon transition projects. Low-carbon transition bonds serve as a beneficial complement to green finance and are a subcategory of sustainable finance. They are particularly suitable for enterprises in traditional high-carbon emission industries that have low participation in the green bond market. Low-carbon transition bonds primarily support two types of projects and economic activities: (1) projects that are included in the "Green Bond Supported Projects Catalog" but do not yet meet the technical standards, and (2) projects and other related economic activities that align with the goals of carbon peaking and carbon neutrality, with functions that reduce pollution, lower carbon emissions, and improve energy efficiency.

Low-carbon transition bonds primarily fall into two categories: one links the bond terms to the issuer's low-carbon transition targets, and another raises funds to promote a company's green and low-carbon transition. It was launched by the Shanghai Stock Exchange (SSE). Since 2021, the Chinese government, along with enterprises, has actively focused on industrial low-carbon transition and transition finance. On May 31, 2022, NAFMII released the "Notice on the Pilot Program for Low-carbon Transition Bond-Related Innovations," initiating the pilot program for low-carbon transition bonds. On June 2, 2022, the Shanghai Stock Exchange issued the "Shanghai Stock Exchange Guidelines for the Application of the Issuance and Listing Review Rules for Specific Types of Corporate Bonds (2022 Revision)," marking the successful issuance of the first batch of

low-carbon transition corporate bonds in China, which funded the low-carbon transition of five companies.

As shown in Table 1, an analysis was conducted of the annual issuance volume of low-carbon transition bonds in China based on the credit rating of the issuers at the time of issuance. The ratings of low-carbon transition bond issuers were relatively high, with only two bonds rated AA+, while the rest were rated AAA. Table 2 categorizes the issuance of low-carbon transition bonds by maturity, which ranges from 1 to 10 years, with the majority concentrated in four maturities: 2-year, 3-year, 5-year, and 10-year. The 3-year bonds were the most popular among issuers, with the largest issuance volume, totaling 15 bonds, accounting for approximately 42.9% of the total. The second most popular maturities were the 2-year and 5-year bonds.

Table 1: The Statistics of issuance number and the issuance amounts (in 100 million RMB) of low-carbon transition bonds by year and Credit Rating

Year	2021		2022		2023		Total	
	N	Issuance Amount	N	Issuance Amount	N	Issuance Amount	N	Issuance Amount
AA	1	20	2	9.9	0	0	3	29.9
AA+	0	0	1	10	1	2	2	12
AAA	0	0	30	280.3	0	0	30	280.3
Total	1	20	33	300.2	1	2	35	322.2

Source: Derived from Wind database analysis, based on the issuer's credit rating at the time of issuance.

Table 2: The Statistics of issuance number and the issuance amounts (in 100 million RMB) of low-carbon transition bonds by year and maturity

Year	2021		2022		2023		Total	
	N	Issuance Amount	N	Issuance Amount	N	Issuance Amount	N	Issuance Amount
1	0	0	1	10	1	2	2	12
2	1	20	6	35	0	0	7	55
3	0	0	15	141.3	0	0	15	141.3
3	0	0	2	9.9	0	0	2	9.9
5	0	0	7	89	0	0	7	89
10	0	0	2	15	0	0	2	15
Total	1	20	33	300.2	1	2	35	322.2

Source: Derived from Wind database analysis.

Low-carbon transition bonds are financial instruments designed to promote corporate financing for low-carbon transition purposes. According to the classification of industries by the China Securities Regulatory Commission (CSRC), low-carbon transition bond issuers are categorized into eleven industries. The results in Table 3 show that the largest proportion of issuance comes from the "Electric Power, Heat Production and Supply" industry, with a total issuance of 9 billion RMB. This is followed by the "Civil Engineering Construction" industry, with an issuance of 9.49 billion RMB. The "Ferrous Metal Smelting and Rolling" industry, "Coal Mining and Washing" industry, and "Comprehensive" category rank third, tied with each other. They are followed by the "Leasing," "Non-metallic Mineral Products," "Chemical Raw Materials and Chemical Products Manufacturing," "Ecological Protection and Environmental Governance," and "Non-ferrous Metal Smelting and Rolling" industries. Low-carbon transition bond issuers are primarily concentrated in traditional energy and other high-pollution, high-energy-consumption industries.

Table 3 The Statistics of issuance number and the issuance amounts (in 100 million RMB) of low-carbon transition bonds by year and Industry

Year	2021		2022		2023		Total	
	N	Issuance Amount	N	Issuance Amount	N	Issuance Amount	N	Issuance Amount
Electric Power, Heat Production and Supply	0	0	9	90	0	0	9	90
Non-metallic Mineral Products Industry	0	0	2	9	0	0	2	9
Ferrous Metal Smelting and Rolling Industry	0	0	3	17	0	0	3	17
Chemical Raw Materials and Chemical Products Manufacturing	0	0	2	7	0	0	2	7
Coal Mining and Washing Industry	0	0	3	40	0	0	3	40
Ecological Protection and Environmental Governance	0	0	0	0	1	2	1	2
Civil Engineering Construction	0	0	8	94.9	0	0	8	94.9
Non-ferrous Metal Smelting and Rolling Industry	0	0	1	5	0	0	1	5
Comprehensive	0	0	3	17.3	0	0	3	17.3
Leasing Industry	0	0	2	20	0	0	2	20
Hong Kong Issuance	1	20	0	0	0	0	1	20
Total	1	20	33	300.2	1	2	35	322.2

Source: Derived from Wind database analysis, with industry classifications based on the China Securities Regulatory Commission (CSRC) industry categories.

Table 4 provides an analysis of low-carbon transition bond issuances by province. Beijing leads with the highest number of low-carbon transition bonds issued, totaling 11, followed by Hubei Province and Shandong Province, each with 6. Other provinces in descending order include Jiangsu Province, Shanghai, Tianjin, Sichuan Province, and Hong Kong. The number of bonds issued is closely related to the economic and political conditions of each region, with Beijing, as the capital and a major economic and political center, having a significantly higher issuance volume than other provinces.

Table 4: The Statistics of issuance number and the issuance amounts (in 100 million RMB) of low-carbon transition bonds by year and province.

Year	2021		2022		2023		Total	
	N	Issuance Amount	N	Issuance Amount	N	Issuance Amount	N	Issuance Amount
Beijing	0	0	11	105	0	0	11	105
Hebei	0	0	1	10	0	0	1	10
Hubei	0	0	6	69	0	0	6	69
Jiangsu	0	0	3	17.3	1	2	4	19.3
Shandong	0	0	6	62	0	0	6	62
Shanghai	0	0	3	14.9	0	0	3	14.9
Sichuan	0	0	1	2	0	0	1	2
Tianjin	0	0	2	20	0	0	2	20
Hong Kong	1	20	0	0	0	0	1	20
Total	1	20	33	300.2	1	2	35	322.2

Source: Derived from Wind database analysis.

4. Data sources and model specification

4.1 Data sources

This paper uses low-carbon transition bonds classified in the Wind database as the primary sample. The relevant research primarily selects corporate bonds and medium-term notes, resulting in a final sample of 30 low-carbon transition bonds. Following the matching method proposed by Zerbib (2019), two conventional bonds with similar characteristics were matched to each low-carbon transition bond. Specifically, the low-carbon transition bonds were matched with conventional bonds of the same rating and closest maturity. If no conventional bonds met these criteria, bonds from companies in the same Industry were selected with similar ratings, maturity dates, and issuance sizes. The maturity date criterion allowed for bonds with maturity dates up to two years before or after that of the low-carbon transition bond. This process yielded 60 conventional bonds, bringing the total sample to 90 bonds.

4.2 Model Specification

This paper uses the bond issuance spread as the dependent variable to study the impact of the transition attribute on the issuance spread. Based on bond pricing theory and the analysis of influencing factors, the following model is constructed:

$$Yield\ Spread_i = \alpha + \beta * transition + \gamma_i * X_i + \theta_i * Y_i + \phi_i + \varphi_j + \varepsilon_i \quad (1)$$

In this model:

$Yield\ Spread_i$ represents the issuance spread of bond I, defined as the difference between the coupon rate of a bond issued at par and the yield on government bonds of the corresponding maturity on the issuance date.

Transition is a binary variable where low-carbon transition bonds are assigned a value of 1, and the matched conventional bonds are assigned a value of 0.

X_i includes bond-specific variables, such as the credit rating (Rating), issuance size (ISize), maturity (Maturity), whether the bond is callable or puttable (Callable/Puttable), and whether the bond has credit enhancement (Enhancement), and whether it is a corporate bond (Enterprise).

Y_i refers to the financial data of the issuing company for bond i, using data from the year prior to issuance, including the leverage ratio (Leverage), return on assets (ROA), company size (Size), the proportion of tangible assets (Tangibility), whether the company is publicly listed (Listed), and whether the company is state-owned (SOE).

ϕ_i represents year-fixed effects, and φ_j represents industry-fixed effects, with industry classifications based on the China Securities Regulatory Commission (CSRC) industry categories.

4.3 Selection and definition of variables

In this paper, the bond issuance spread ($Yield\ Spread_i$) is used as the dependent variable, defined as the difference between the coupon rate of a low-carbon transition bond issued at par and the yield on a government bond of the same maturity on the issuance date, measured in basis points (bp), where 1bp = 0.0001. For example, if Bond A is issued on January 1, 2022, with a maturity of one year and an issuance rate of R_z, the issuance spread would be the difference between R_z and the yield on a one-year government bond, R_g on January 1, 2022. Specifically:

$$YieldSpread_i = R_z - R_g \quad (2)$$

The explanatory variable is the binary variable for the transition attribute (Transition), where low-carbon transition bonds are assigned a value of 1, and conventional bonds are assigned a value of 0. If the coefficient of the explanatory variable is significant, it indicates a significant difference between low-carbon transition bonds and

the matched conventional bonds. Otherwise, it suggests that the transition attribute has no significant impact on the issuance spread of low-carbon transition bonds.

Control variables include bond issuance characteristics X_i and the basic information of the issuing company Y_i. At the bond level, the control variables X_i include the bond's credit rating (Rating), total issuance amount (ISize), bond maturity (Maturity), whether the bond is callable or puttable (Callable/Puttable), and whether the bond has credit enhancement (Enhancement). At the company level, Y_i refers to the financial data of the bond-issuing company from the year prior to issuance, including the leverage ratio, return on assets, company size, proportion of tangible assets, whether the company is publicly listed, and whether it is a state-owned enterprise. ϕ_i and φ_j represent the fixed effects, controlling for year and industry fixed effects, with industries classified according to the China Securities Regulatory Commission (CSRC) industry classification. Below is an introduction to all the control variables used in this paper:

(1) Bond Rating (Rating). The credit ratings for low-carbon transition bonds are generally high, concentrated in the categories of AA, AA+, and AAA, corresponding to numerical values 1-3, where a higher rating is represented by a larger numerical value. According to previous studies, the higher the bond rating, the lower the issuance spread.

(2) Issuance Amount (ISize). The issuance amount refers to the total funds raised at the time of bond issuance, measured in 100 million RMB.

(3) Callable/Puttable. A callable bond allows the issuer to repurchase the bond from the bondholder at a specified price before maturity, functioning similarly to a bond with a call option. Callable is a binary variable (0-1), where 1 indicates a callable bond and 0 otherwise. A puttable bond allows the bondholder to sell the bond back to the issuer at a specified price before the bond's maturity date, functioning similarly to a bond with a put option. Puttable is a binary variable (0-1), where 1 indicates a puttable bond and 0 otherwise.

(4) Credit Enhancement (Enhancement). Credit enhancement is a binary variable (0-1), indicating whether the bond has a credit guarantee. If the bond has credit enhancement, the value is 1; otherwise, it is 0. Bonds with higher credit quality are often issued at lower prices.

(5) Enterprise Bond (Enterprise). This is a binary variable (0-1), where 1 represents enterprise bonds, which are approved by the National Development and Reform Commission (NDRC), and 0 represents corporate bonds, which are approved by the China Securities Regulatory Commission (CSRC).

(6) Leverage. This variable reflects the issuer's financial data and is calculated as the ratio of total liabilities to total assets, indicating the company's debt structure. A lower leverage ratio means a lower debt level, allowing the company to issue bonds at lower costs, thus reducing the issuance spread. Therefore, leverage is positively correlated with the bond's issuance spread.

(7) Return on Assets (ROA). ROA is a financial metric calculated as net income divided by total assets. A higher ROA indicates better financial performance, making the company's bonds more attractive to investors and enabling the company to raise funds at lower costs. Generally, the higher the ROA, the lower the bond issuance spread.

(8) Size. The natural logarithm of the company's total assets. Typically, larger companies tend to have lower bond issuance spreads.

(9) Tangibility. Tangibility is calculated as the ratio of tangible assets to total assets. A higher proportion of tangible assets lowers the company's default risk, reducing the bond's issuance spread.

(10) Listed Company (Listed). This is a binary variable (0-1), where 1 indicates the bond issuer is a publicly listed company and 0 otherwise. Listed companies typically have higher levels of information disclosure compared to non-listed companies, reducing information asymmetry for investors and consequently lowering the issuance spread.

(11) State-Owned Enterprise (SOE). This is a binary variable (0-1), where 1 represents state-owned enterprises (SOEs) and 0 represents non-state-owned enterprises. SOEs

generally enjoy higher credibility compared to non-SOEs and can issue bonds at lower interest rates.

All variables are detailed in Table 5.

Table 5: Definition of Variables

Variable Classification	Full Name of Variable	Variable	Definition
Dependent Variable	Issuance Spread	YieldSpread	The difference between the bond yield and the government bond yield of the same maturity
Explanatory Variable	Transition Attribute	Transition	Low-carbon Transition bond = 1, conventional bond = 0
Control Variable	Bond Rating	Rating	AA = 1, AA+ = 2, AAA = 3
	Issuance Amount	ISize	The total amount of funds raised by the bond
	Callable/Puttable	Callable/Puttable	Callable/Puttable = 1, otherwise = 0
	Credit Enhancement	Enhancement	With guarantee = 1, without guarantee = 0
	Enterprise Bond	Enterprise	Enterprise bond = 1, otherwise = 0
	Leverage Ratio	Leverage	The ratio of total liabilities to total assets
	Return on Assets	ROA	Net income divided by total assets
	Size	Size	Natural logarithm of total assets
	Tangibility	Tangibility	Tangible assets divided by total assets
	Listed Company	Listed	Listed company = 1, otherwise = 0
	State-Owned Enterprise	SOE	State-owned enterprise = 1, otherwise = 0

5. Empirical results and analysis

5.1 Descriptive statistical analysis

Based on the aforementioned bond-matching method, 30 low-carbon transition bonds were matched with 60 corresponding conventional bonds, forming a final research sample of 90 bonds in total. Table 6 provides the descriptive statistics for the 90 bonds in the sample, including the number of observations (N), mean, 25th percentile (25%), median, 75th percentile, and standard deviation (STD). The average maturity of the bonds is 3.84 years. In terms of issuer characteristics, approximately 90% of the bonds were issued by state-owned enterprises (SOEs), with a relatively small proportion issued by non-state-owned enterprises. Additionally, around 42% of the bonds were issued by publicly listed companies, while the majority were issued by non-listed companies.

5.2 Correlation and heteroscedasticity analysis

The correlation analysis shows that the issuance spread of the bonds is negatively correlated with the transition attribute. Additionally, the bond rating, issuance amount, whether the bond is an enterprise bond, the company's ROA, company size, and whether the company is listed are also negatively correlated with the issuance spread. The p-value for the correlation between issuance spread and transition attribute is 0.002, indicating a highly significant negative correlation between these two variables. However, the significance of the other variables is weaker.

Since heteroscedasticity in the data can affect the accuracy of the results and reduce the precision of estimates and forecasts, the overall data was tested for heteroscedasticity. The White test yielded a p-value of 0.1829, indicating that heteroscedasticity is not present in the data. Furthermore, the VIF (Variance Inflation Factor) test produced a p-value of

1.90, suggesting that the data does not suffer from multicollinearity. Thus, subsequent econometric analysis can proceed.

Table 6: Descriptive Statistics

	N	Mean	25%	Median	75%	STD
Yield Spread(bps)	90	97.374	52.630	80.755	124.750	67.303
Transition	90	0.333	0.000	0.000	1.000	0.474
Rating	90	2.978	3.000	3.000	3.000	0.148
ISize	90	9.559	5.000	10.000	13.000	6.065
Maturity	90	3.844	3.000	3.000	5.000	2.077
Callable	90	0.400	0.000	0.000	1.000	0.493
Puttable	90	0.100	0.000	0.000	0.000	0.302
Enhancement	90	0.022	0.000	0.000	0.000	0.148
Enterprise	90	0.300	0.000	0.000	1.000	0.461
Leverage	90	0.664	0.623	0.680	0.727	0.107
ROA	90	0.045	0.019	0.035	0.062	0.047
Size	90	26.101	25.396	26.146	26.557	0.927
Tangibility	90	0.151	0.030	0.161	0.275	0.163
Listed	90	0.422	0.000	0.000	1.000	0.497
SOE	90	0.900	1.000	1.000	1.000	0.302

5.3 Analysis of Matching Effectiveness

Table 7 compares low-carbon transition bonds with their matched conventional bonds, analyzing the number of bonds (N) and the mean values of bond characteristics. The last column reports the t-test p-values for differences in bond characteristics and issuing company characteristics between low-carbon transition bonds and matched conventional bonds in the sample. The symbols ***, **, and * represent significance levels of 1%, 5%, and 10%, respectively. First, descriptive statistics were conducted on the bond characteristics and basic issuer characteristics for 30 low-carbon transition bonds and 60 conventional bonds. Then, a t-test was performed. The null hypothesis is that there are no differences between the characteristics of low-carbon transition bonds and their matched conventional bonds. If the t-value is large and the p-value is less than 0.05, the null hypothesis can be rejected, indicating significant differences between the variables, which would suggest that the matching was not effective. Conversely, if the null hypothesis cannot be rejected, it indicates that the matching is effective, allowing for further research.

As shown in the table, all bond characteristics, including credit rating (Rating), issuance amount (ISize), bond maturity (Maturity), whether the bond is callable or puttable (Callable/Puttable), whether the bond has credit enhancement (Enhancement), and whether the bond is an enterprise bond (Enterprise), show no statistical difference between low-carbon transition bonds and matched conventional bonds. The table also compares issuer characteristics, showing no significant differences between the issuers of low-carbon transition bonds and their matched conventional bond counterparts in terms of leverage (Leverage), return on assets (ROA), company size (Size), proportion of tangible assets (Tangibility), whether the company is listed (Listed), and whether the company is a state-owned enterprise (SOE). These observations confirm the effectiveness of the matching method used in this chapter.

Table 7: Comparison Between Low-carbon Transition Bonds and Matched Conventional Bonds

Classification	Low-carbon Transition bonds		Matched Conventional Bonds		t-test
	N	Mean	N	Mean	(p-value)
Rating	30	3.000	60	2.967	0.033
					(0.317)
ISize	30	9.343	60	9.667	-0.324
					(0.813)
Maturity	30	3.733	60	3.900	-0.167
					(0.722)
Callable	30	0.367	60	0.417	-0.050
					(0.652)
Puttable	30	0.067	60	0.117	-0.050
					(0.462)
Enhancement	30	0.033	60	0.017	0.016
					(0.618)
Enterprise	30	0.300	60	0.300	0.000
					(1.000)
Leverage	30	0.664	60	0.663	0.001
					(0.968)
ROA	30	0.048	60	0.043	0.005
					(0.698)
Size	30	26.266	60	26.019	0.247
					(0.237)
Tangibility	30	0.116	60	0.168	-0.052
					(0.158)
Listed	30	0.333	60	0.467	-0.134
					(0.232)
SOE	30	0.933	60	0.883	0.911
					(0.462)

Note: The definitions of variables in the table can be found in Chapter 4. The last column reports the differences between low-carbon transition bonds and conventional bonds, with the p-values of the t-test shown in parentheses.

5.4 Univariate analysis

First, univariate analysis is conducted between low-carbon transition bonds and matched conventional bonds, using the bond issuance spread to measure the bond market's response to the issuance of low-carbon transition bonds. The bond spread is defined as the difference between the coupon rate of a bond issued at par and the yield on government bonds of the corresponding maturity on the day of issuance. If bond investors prefer holding low-carbon transition bonds over conventional bonds with similar characteristics, this transition preference would lead to a premium on low-carbon transition bonds, resulting in higher prices and lower spreads.

Table 8 reports the results of the univariate analysis of the spreads between low-carbon transition bonds and matched conventional bonds. It presents the number of low-carbon transition bonds and matched conventional bonds (N), as well as the average spread grouped by state ownership (SOEs and Non-SOEs). The last column shows the spread premium of low-carbon transition bonds over their conventional counterparts, along with the p-values from the t-test for the difference. As shown in the first row, the average issuance spread for low-carbon transition bonds is 61.345 bps, while for conventional bonds, it is 115.389 bps. Statistical tests indicate that the spread for low-carbon transition bonds is significantly lower than that of comparable conventional bonds

by an average of about 54 basis points. As of March 2023, the total issuance of low-carbon transition bonds in China amounted to 32.22 billion RMB, and compared to conventional bonds, low-carbon transition bonds are estimated to save approximately 174 million RMB per year in financing costs for projects. Further division of the sample by state ownership and bond type reveals that the spread differences are mainly concentrated among issuers. State-owned enterprises (SOEs) issue a significantly higher number of bonds than non-SOEs, and non-SOEs tend to have significantly lower issuance spreads.

Table 8: Univariate Analysis

Classification	Low-carbon Transition Bonds		Matched Conventional Bonds		t-test
	N	Yield spreads(bps)	N	Yield spreads(bps)	(p-value)
Total	30	61.345***	60	115.389***	-54.044***
		(0.000)		(0.000)	(0.000)
SOEs	28	60.739***	53	109.882***	-49.143***
		(0.000)		(0.000)	(0.000)
Non-SOEs	2	69.830***	7	157.089***	-87.259**
		(0.000)		(0.000)	(0.047)

Note: The p-values from the t-tests are reported in parentheses. * indicates significance levels at 10%, ** at 5%, and *** at 1%. "Yield spreads" refer to issuance spreads.

5.5 Multivariate Analysis

Table 9 presents the OLS regression results of the model (Equation 1). First, only year and Industry-fixed effects are controlled, as shown in Column 1. Next, bond characteristics are added as control variables in Column 2, and the coefficient of the variable "Transition" remains significantly negative. Finally, all control variables from the model (1) are included, as shown in Column 3, and the coefficient of "Transition" is still significantly negative, confirming hypothesis H1. The average spread of low-carbon transition bonds is 45.544 bps lower than that of conventional bonds. The average spread in the sample is 97.374 bps, meaning the reduction of 45.544 bps constitutes about 46.8% of the sample's average spread.

The control variables in the study indicate that bond callability is significantly positively correlated with issuance spreads. Additionally, return on assets (ROA), being publicly listed (Listed), and state ownership (SOE) are negatively correlated with bond spreads (Wang & Zhang, 2013; Chen & Guo, 2022), consistent with findings in some of the literature.

6. Robustness tests

Since the bond spreads in the sample are generally positive, and the distribution of bond spreads is truncated at zero, the OLS regression assumption of normally distributed dependent variables may lead to biased estimates. To address this issue, a Tobit regression with a truncated distribution is employed in this section. As shown in Column 1 of Table 10, the coefficient of the 0-1 variable "Transition" is -48.344, and it is significantly negative at the 1% level, further supporting the validity of hypothesis H1, which indicates a significant negative correlation between transition attribute and the issuance spreads of low-carbon transition bonds.

Table 9: Baseline Regression Results

	(1)	(2)	(3)
Transition	-53.337***	-49.582***	-33.714**
	(15.163)	(18.115)	(15.475)
Rating		-134.395**	-126.605*
		(52.423)	(55.947)
ISize		-1.113	-0.308
		(1.068)	(1.086)
Maturity		4.937	4.721
		(5.183)	(5.328)
Callable		14.590	33.367**
		(23.725)	(16.444)
Puttable		3.348	2.950
		(32.619)	(32.350)
Enhancement		-9.959	-25.843
		(11.704)	(26.848)
Enterprise		18.833	15.661
		(16.572)	(18.345)
Leverage			-10.307
			(147.692)
ROA			-452.996*
			(260.126)
Size			15.545
			(11.145)
Tangibility			174.108*
			(101.946)
Listed			-45.472**
			(21.024)
SOE			-15.386
			(28.117)
Constant	88.383***	467.153***	54.592
	(13.723)	(157.178)	(342.499)
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
N	90	90	90
Adj. R-squared	0.405	0.495	0.596

Note: A fixed effects panel regression model is used, controlling for industry and year fixed effects, with robust standard errors reported in parentheses. * indicates significance levels at 10%, ** at 5%, and *** at 1%.

Drawing from the framework of Xu and Yang (2013) on bond spreads, this study redefines the issuance spread as the difference between the bond's yield to maturity and the 1-year fixed deposit rate set by the People's Bank of China (PBOC), using 1.5% as the benchmark rate. The issuance spread is recalculated as the new dependent variable, forming a panel dataset for repeating the OLS regression analysis. As shown in Table 10, only year and industry fixed effects are controlled in Column 2. Subsequently, bond characteristics are added as control variables in Column 3, and the coefficient of "Transition" remains significantly negative. Finally, all control variables from the model (1) are included, as shown in Column 4, and the coefficient of "Transition" is still

significantly negative, confirming hypothesis H1 and indicating the robustness of the earlier results.

Table 10: Robustness Tests

	(1)	(2)	(3)	(4)
Transition	-48.344***	-48.681***	-47.869***	-31.370**
	(12.338)	(16.131)	(18.015)	(15.166)
Bond level Controls	Yes	No	Yes	Yes
Firm-level Controls	Yes	No	No	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
N	90	90	90	90
Adj. R-squared		0.472	0.570	0.657

Note: A fixed effects panel regression model is used, controlling for industry and year fixed effects, with robust standard errors reported in parentheses. * indicates significance levels at 10%, ** at 5%, and *** at 1%.

7. Heterogeneity analysis

As shown in Table 11, considering that the bond issuance spread may be influenced by various factors such as the type of enterprise or Industry, heterogeneity tests were conducted across different classifications. The first classification divides bond issuers by ownership type into listed and non-listed companies. As shown in columns 1 and 2, the Transition coefficient for bonds issued by listed companies is -2.217, while for non-listed companies, it is -44.348, with significance at the 10% level. The chi-square test results indicate significant differences between groups, suggesting a more pronounced impact on non-publicly listed companies.

The second classification separates bonds based on the Geographical Region. Given China's vast territory, there are significant differences in economic development levels across eastern, central, and western regions. With relatively advanced low-carbon transition technologies and higher market recognition for low-carbon transition bonds, enterprises in the eastern region tend to have more favorable conditions. To test this observation, this study categorizes the sample bonds based on the issuers' regional location, as presented in columns 3 and 4. The results show that significant issuance premiums exist across all groups. Low-carbon transition bonds issued in the central and western-eastern regions exhibit a more pronounced premium. The chi-square test reveals a statistically significant distinction.

Table 11: Heterogeneity Results

	Listed	Non-listed	Eastern Region	Central & Western regions
	(1)	(2)	(3)	(4)
Transition	-2.217	-44.348*	-31.689**	-76.876***
	(22.529)	(24.552)	(16.332)	(36.178)
Bond level Controls	Yes	Yes	Yes	Yes
Firm-level Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
N	38	52	72	18
Adj. R-squared	0.926	0.570	0.665	0.996
χ2 test（p-value）	0.001***		0.000***	

Note: Robust standard errors are reported in parentheses. * indicates significance levels at 10%, ** at 5%, and *** at 1%.

8. Research conclusions and policy implications

This paper studies low-carbon transition bonds using the Ordinary Least Squares (OLS) method to investigate the impact of the transition attribute on bond issuance spreads. The findings show, first, that the transition attribute of low-carbon transition bonds significantly reduces their issuance spreads. The study further validates the robustness of the conclusion that the transition attribute of low-carbon transition bonds reduces the issuance spread through robustness tests. Additionally, through heterogeneity analysis, the study reveals that low-carbon transition bonds can better help non-listed companies and economically underdeveloped regions to finance at lower costs.

These findings provide valuable insights into the issuance and pricing of low-carbon transition bonds:

1. As a novel financial instrument, low-carbon transition bonds benefit from a negative transition premium, effectively reducing corporate financing costs. Companies should actively engage in research on low-carbon transition bonds, align with green transition policies, and issue low-carbon transition bonds to raise funds at lower costs.

2. Governments should enhance guidance, broaden the scope of support for low-carbon transition bonds to serve more industries, and attract investors through mechanisms such as interest subsidies or government credit enhancements.

3. Macroeconomic regulation of low-carbon transition bonds should be strengthened, expanding the geographic reach of eligible issuers and providing assistance to companies that lack the capacity to issue low-carbon transition bonds, thereby easing the financing difficulties of small and medium-sized enterprises and those in less-developed regions.

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