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RESEARCH ARTICLE

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Carbon risk, cost of debt financing and the moderation effect of media attention: Evidence from Chinese companies operating in high-carbon industries

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Abstract

The effect of carbon risk on the debt capital market has become increasingly prominent under carbon constraints. We use a panel regression model to examine the relationship between carbon risk and the cost of debt financing and the moderating effect of positive media attention on this relationship. Using a sample of 191 Chinese A-share listed firms operating in high-carbon industries covering the period 2011–15, we conduct an empirical study and find that the relationship between carbon risk and the cost of debt financing in China is a U-shaped one. Thus, carbon risk exerts an "interval effect" on the cost of debt financing, which mainly exists in private firms rather than state-owned firms. This relationship can be mitigated by positive media attention. Compared with private firms that receive low positive media attention, private firms with high positive media attention are more sensitive and less tolerant to environmental regulations. Our findings provide firms with practical advice on carbon risk management, particularly on improving carbon transparency and mitigating the cost of debt financing.

KEYWORDS

carbon risk, cost of debt financing, high-carbon industry, media attention, nonlinear regression analysis

1 | INTRODUCTION

In recent years, public concern over climate change has grown considerably, driven largely by the increasing emission levels of greenhouse gases, and the occurrence of unusual and destructive weather patterns (Thompson, 1998). Global climate change can potentially damage ecological systems and also cause unprecedented negative effects on the global economy and human society (Bebbington & Larrinaga-González, 2008; Labatt & White, 2007). These concerns have prompted governments of many countries to implement regulations and policies for reducing and controlling industrial carbon emissions.

Under the background of economic growth shift and structural adjustment, China, the world's largest carbon emitter, is facing severe climate and environmental problems. At the Copenhagen Climate Conference in 2009, the Chinese Government promised that its carbon footprint in 2020 will be 40–45% less than that in 2005. At the Paris Climate Conference in 2015, the Chinese Government stated that CO_2 emissions are to reach a peak in 2030. To realize these promises,

the Chinese Government has made a series of policies to reduce carbon emissions. In 2011 the Chinese Government launched the carbon trading pilot scheme and in 2017 it introduced a unified carbon emission trading market. China's carbon regulation is moving from a command-and-control one to a market-based one. The market-based carbon regulation will gradually become a "new normal" for the control of carbon emissions. China has become the world's largest potential carbon market. The Chinese Government's "13th Five-Year" plan points out that it is essential to improve the carbon emissions accounting, assessment and accountability system and carbon emission standard system. Firms are not only the main source of carbon emissions, but also the most important participants in the carbon market. Chinese firms are facing increasing carbon risk under the growing intensity of carbon regulation.

With the development of environmental regulations and policies, banks and other financial institutions have recently strengthened efforts to incorporate the risks of climate change into their credit decisions (Busch & Hoffmann, 2007; Coulson & Monks, 1999; Thompson, 1998; Thompson & Cowton, 2004). China is not an exception. On July 12, 2007, the Ministry of Environmental Protection, the China Banking Regulatory Commission and the People's Bank of China issued advice on the implementation of environmental policies and regulations to prevent credit risk. They proposed a green credit mechanism to guide the development of low-carbon green businesses. Therefore, carbon risk under stricter carbon constraints becomes more and more important in the capital market. An increasing number of firms encounter carbon risk-related challenges in debt financing. The relationship between carbon risk and the cost of debt financing in China needs to be determined. In addition, media attention on carbon emissions has intensified globally and plays a crucial role in influencing firm behavior toward reducing carbon emissions (Schmidt, Ivanova, & Schäfer, 2013). In the Chinese context, carbon disclosure of China's listed companies is in its infancy. Many characteristics must be considered in this regard, for example, scattered structure, qualitative information and industry differences. Providing accurate information to creditors entails difficulties. Media attention can effectively help creditors assess the carbon risk of firms. Through carbon-related news, media as an important force in corporate governance influence the relationship between the cost of debt financing and carbon risk, and this moderating effect needs to be determined.

A key to successful lending practices is a lender's ability to rate the factors that influence a borrower's ability to repay debt. A borrower's repayment capacity is theoretically dependent upon liquidity, earnings and capital stock, which are referred to as counterparty credit risks and are a main influence on default risk (Saunders & Allen, 2002; Weber, 2012). We argue that a firm's carbon risk exposure influences default risk because of the resultant uncertainty in current and future cash flows. On balance, a firm with a higher exposure to carbon risk will have a higher default risk. In response, lenders can then mitigate the impact of a borrower's carbon risk through loan contract terms governing collateral, debt maturity and the price of debt. The effect of carbon risk on debt financing is verified by panel data analysis of several capital markets (e.g., Chapple, Clarkson, & Gold, 2013; Chava, 2014; Juhyun, Kathleen, & Peter, 2016; Massari, Gianfrate, & Zanetti, 2016). However, few researchers have conducted studies on the effect of carbon risk on the cost of debt in the Chinese institutional background. China entered the pilot stage of the carbon emissions trading market in 2011. Carbon risk in China's capital market plays an increasingly important role because of intensified carbon constraints. It is significantly important to conduct an empirical study to evaluate the effect of carbon risk on the cost of debt financing in the context of China, which can help firms in carbon risk management.

As an important channel of corporate transparency and information disclosure, the media play an increasingly vital role in the capital market. Consequently, the influence of media attention on the cost of debt financing has drawn research interest (Deboskey & Gillett, 2013; Shi & Zhong, 2016; Tetlock, 2010). Studies have focused on exploring the moderating effect of carbon risk management and corporate carbon disclosure on the relationship between carbon risk and capital cost (Juhyun et al., 2016; Najah, 2012), without considering the incremental informational content of media attention.

We use a sample of 191 A-share listed companies operating in high-carbon industries in China covering the period 2011–15 to test the relationship between carbon risk and the cost of debt financing and the moderating effect of media attention on this relationship. The particular heterogeneity of the property rights of Chinese firms (i.e., state-owned-firms and private firms) has also been considered. Our study contributes to literature in the following ways: (i) it enriches the literature on the influence of carbon risk on the cost of corporate debt financing within China's institutional context and compares the effects of carbon risk on China and other developed debt capital markets; (ii) it analyzes the moderating role of media attention on the relationship between corporate carbon risk and debt financing cost; and (iii) it divides the sample into two subgroups: state-owned-firms and private firms—we test the relationship between carbon risk and the cost of debt financing and the moderating effect of media attention based on the ownership difference. Therefore our study broadens the existing literature and provides a new research perspective in relevant fields.

The paper is organized as follows: the second part reviews the relevant literature and develops the research hypotheses; the third part describes the research design and methods; the fourth part presents the empirical results; the fifth part discusses the results; and the last part concludes the study.

2 | LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1 | Carbon risk

Environmental risks refer to the actual or potential adverse effects on organisms and the environment of waste discharge and resource consumption resulting from business activities (Romilly, 2007). Environmental risks based on uncertainty may adversely affect a firm, damaging the economic performance of the firm and the economic benefits of its stakeholders (Romilly, 2007). As an integral component of environmental risks, carbon risk mainly refers to the impact of climate change caused by CO_2 emissions from the consumption of fossil fuels (Hoffmann & Busch, 2008). A firm bears the risks related to

carbon emissions and carbon waste disposal, which may lead to the firm's business loss in the process of using various resources to produce and prevent the firm from accessing economic interests. In the context of economic growth and structural adjustments, China's position as the world's largest carbon exporter in dealing with climate change is critical (Tan, Chung, Shi, & Chiu, 2017). Since the 11th Five-Year Plan in 2010, China has strengthened its carbon control policies. With the launch of the carbon trading pilot in 2011, firms that have been identified as the main sources of carbon emissions may be confronted by environmental regulations. Such regulations lead to increased business uncertainty, particularly for firms in high-carbon industries with relatively low carbon performance. Companies used to be able to mitigate carbon risk by externalizing carbon emissions. However, under current carbon regulatory policies, corporate carbon emissions are more likely to be internalized; thus, carbon risk is an important economic consideration (Clarkson, Li, Pinnuck, & Richardson, 2015).

Carbon risk typically consists of three parts: regulatory risk, physical risk and business risk (Dobler, Lajili, & Zéghal, 2014; Massari et al., 2016). Regulatory risk refers to the risk associated with current and future carbon-related policies and regulations that are likely to exert a significant effect on the financial performance and capital cost of a firm through additional compliance costs and/or trading emission credits (Labatt & White, 2007). Physical risk refers to the risk related to the direct effects of climate change, such as drought, floods, storms and rising sea levels, in both the short and the long run (Labatt & White, 2007). Business risk refers to the risk of market competition caused by corporate carbon emissions (Labatt & White, 2007). Carbon is the common element among these risks and may be transformed into financial intermediaries and asset risk for investors. Massari et al. (2016) indicated that carbon risk varies from one industry to another and exists primarily in companies that are directly or indirectly exposed to greenhouse gas emissions.

2.2 | Carbon risk and cost of debt financing

Research on carbon risk is mostly based on agency theory (Armstrong, Guay, & Weber, 2010). As a main corporate stakeholder, the creditor assessing corporate debt financing can focus on the default risk of the borrower (Coulson & Monks, 1999), which depends primarily on liquidity, earnings and capital stock (Saunders & Allen, 2002; Weber, 2012). According to agency theory, in the context of carbon risk, agency problems can arise when the carbon-related goals of lenders and borrowers are misaligned. Through their lending activities, lenders are exposed to carbon risk; thus, they expect borrowers to take measures to mitigate carbon risk, such as complying with carbon regulations and meeting accepted industry standards (Thompson, 1998). By contrast, firms focusing on economic performance may arrive at different decisions, such as investing in more profitable carbon-intensive projects. However, such projects are risky because they usually involve the externalization of pollution, with the corresponding risks being shifted back to the firm because of increasing carbon-related regulations (Goss & Roberts, 2011). If carbon-intensive projects are successful, shareholders are expected to benefit the most; if they fail, creditors tend to bear most of the cost. Even if these projects are successful, creditors may face reputational risks associated with financing unenvironmentally friendly projects. This unequal reward engenders the agency problem. With intensified carbon-related regulations, creditors have incorporated corporate carbon risk into their lending decisions. This study argues that exposure to carbon risk can increase the uncertainty inherent in the future cash flows of firms and, ultimately, the probability of default. Increased default risk can exacerbate agency problems between a lender and a borrower. In the presence of agency problems, creditors can prevent the speculative carbon-related activities of the firm by designing debt contracts, such as raising interest rates (Armstrong et al., 2010). Consequently, firms with increased carbon risk face an increased cost of debt financing.

Regulatory theory also holds the view that carbon risk is positively correlated to the cost of debt financing. The higher the carbon risk, the greater the regulatory pressure on the firm from environmental protection bodies. In addition, additional potential mitigation and compliance costs are more likely to be incurred, decreasing the economic resources of a firm for debt service. Carbon risk can also reduce profitability and cash flow (Barbose, Wiser, Phadke, & Goldman, 2008; Subramaniam, Wahyuni, Cooper, Leung, & Wines, 2015), thus increasing the risk of debt default. In addition, creditors can consider the effects of carbon risk on corporate reputation (Li, Eddie, & Liu, 2014). The environmentally irresponsible behaviors of a firm may harm its image, which may adversely affect its future operations, competitive market position and cash flow. Such an effect can increase the risk of debt default, thus raising the cost of debt financing (Labatt & White, 2007).

There are few studies on the direct effect of carbon risk on debt financing costs in the literature. Thus, we refer to previous studies on the relationship between corporate social responsibility and environmental risk and the cost of debt financing. First, using empirical data on U.S. companies, Lin, Li, He, and Zhou (2014) found that the debt financing cost of firms with increased social responsibility is lower than that of firms with either less or no social responsibility. Chava (2014) demonstrated that corporate environmental risk and cost of debt financing are positively related on the basis of an empirical study using a sample of firms from S&P 500 and Russell 2000. Banks and other financial institutions can charge firms that cause environmental problems a lending rate which is higher than normal. Chen and Gao (2012) used CO_2 emissions data from a U.S. power company and found a positive relationship between carbon emissions and cost of debt financing. Coincidentally, Jung, Herbohn, and Clarkson (2016) reached the same conclusion based on the legislative and regulatory background of Australia. To summarize, the positive relationships between social responsibility, environmental risk, CO_2 emission and so on and cost of debt financing have been reported in the literature. Carbon risk is an inextricable component of environmental risk and is critical to governments and regulators, as well as creditors and other stakeholders. On the basis of the aforementioned theoretical support and previous empirical evidence, we maintain that corporate carbon risk can increase its cost of debt financing and form the following hypothesis:

Hypothesis 1. *Carbon risk is positively related to the cost of debt financing.*

Given the specific circumstances in China, state-owned firms have clear advantages over private firms with respect to property rights protection, government–enterprise relations, financing and other aspects. When private firms apply for loans, banks tend to apply stricter evaluation standards because private firms have weaker relationships with the government and are less able to gain government support. Thus, they tend to pay more attention to the carbon risk of private firms. From the perspective of property rights, the effect of carbon risk on the cost of debt financing of state-owned firms may differ from that of private firms. The preferential policies of the government and possible subsidies to state-owned firms implicitly reassure creditors; differences in the nature of property rights enable creditors to use different risk assessment methods. The following hypothesis is therefore proposed:

> **Hypothesis 1a.** *Carbon risk exerts a stronger positive effect on the cost of debt financing in private firms than in state-owned firms.*

2.3 | Moderating effect of media attention

Media attention refers to news items or reports on a particular entity's behaviors through a variety of traditional or emerging forms (Deboskey & Gillett, 2013). Typically business management research involving media attention distinguishes between two types: positive and negative media attention (see Wang & Ye, 2015). In our study, one interesting fact we identified is that Chinese media coverage of carbon news is rarely negative. According to the descriptive statistics our sample data, 95.2% of carbon-related news items/reports in Chinese media are positive. Therefore, in this research we focus on the positive media attention on carbon information, that is, media coverage of carbon-emission reduction actions taken by public companies to address climate change. It affects the capital market through mechanism of information dissemination and reputation.

On the one hand, banks and other financial institutions cannot fully obtain firms' carbon information due to information asymmetry. Fang and Peress (2009) argued that media coverage can reduce information friction. Tetlock (2010) also found that the media played a crucial role in mitigating information asymmetry between firms and stakeholders. The media collect relevant information about carbon-emission reduction through professional channels and disseminate carbon-related news to the public. Meanwhile, firms may release carbon-related news to the public through the media, which can meet the information needs of stakeholders. It helps banks and other financial institutions to better understand public companies' efforts in reducing carbon emissions, improving firms' carbon transparency. An increase in carbon transparency mitigates information asymmetry between firms and lenders, which directly results in a decrease in the cost of debt financing.

By contrast, positive carbon-related news helps a firm to publicize its environmental responsibility and build a good image of being environmentally friendly. It can influence financial institutions on their decisions related to corporate loan approval. This is because it is generally perceived that organizations with environmental reputations are less risky borrowers because they are less likely to engage in risky environmental behavior (such as pollution). In other words, a good reputation will bring implicit guarantee to the firm, reducing its default risk. As a consequence, banks and other financial institutions are more inclined to approve loans applied for by reputable firms than those with a poor reputation (Dyck, Volchkova, & Zingales, 2008).

Many studies have asserted that media attention moderates the relationship between corporate social responsibility or environmental performance and corporate performance, firm value and capital costs (Bushee, Core, Guay, W., & Hamm, 2010; Dyck et al., 2008), thereby reducing the information asymmetry between firms and stakeholders (Bushee, Core, Guay, & Hamm, 2010). These findings imply that firms can reduce the negative capital market responses to their carbon risk through positive media attention. Frequent or periodic releases of carbon-related news about their efforts to address global warming can be an effective means for carbon communication. Firms with more positive media attention are likely to be able to communicate effectively with lenders during the lending process about their carbon management strategies. This, in turn, may lead to lenders having a greater understanding of the issues and incorporating them in a systematic way in deciding a firm's carbon risk premium. Reduced information asymmetry can also directly result in a lower cost of debt. Based on the above analysis, we put forward the hypothesis:

> **Hypothesis 2.** *Positive media attention can negatively moderate the effect of carbon risk on cost of debt financing.*

The moderating effect of positive media attention can also vary depending on the nature of ownership. For state-owned firms, creditors are more reassured by the government support and protection behind the company. Thus, the nature of state property rights can weaken media concern regarding the external governance factors in reducing the benefits of the cost of debt financing. Compared with state-owned firms, private enterprises have less cohesive connections with the government and depend less on the government for additional subsidies and preferential policies. Creditors can be more dependent on external positive media attention brought about by the effect of governance. Thus, media governance in mitigating the cost of debt financing is more obvious. Shi and Zhong (2016) argue that the media exert a stronger effect on nonstate-owned companies than on state-owned companies; that is, the state-owned nature of state-owned companies can inhibit the moderating effect of media on the relationship between carbon risk and the cost of debt financing. We therefore propose the following hypothesis:

> **Hypothesis 2a.** *The moderating effect of positive media attention is more significant in private firms than in state-owned firms.*

3 | RESEARCH DESIGN

3.1 | Sample and data

The literature suggests that creditors are highly sensitive to carbon-related issues in high-carbon emission industries (Juhyun et al., 2016). In the Chinese context, in 2011 the State Council promulgated

The Notice on Carrying out Carbon Trading Pilot and proposed the gradual establishment of a carbon emissions trading market. The eight high-energy consumption industries—petrochemical, chemical, building materials, steel, nonferrous metals, papermaking, electric power and aviation—were gradually included. The national carbon emission trading market is expected to be completed in 2017. Considering such regulations and the environmental sensitivity of excavating industries with high carbon emissions, we selected the data from 2011 to 2015 of Shanghai and Shenzhen A-share high-carbon industries (including the eight pilot industries and excavating industries).

The financial data required were obtained from the RESSET http://www.resset.cn/ database. Data for companies that were penalized for carbon violations come from the Green Securities section of the Institute of Public and Environmental Affairs (IPE) database. IPE is a public environmental research institute registered in Beijing. Since its inception in June 2006, IPE has been committed to collecting, collating and analyzing environmental information published by government and enterprises. Through its green securities database, we can query the listed company's environmental violations records and specific punitive measures information according to the classification of pollutants. In this way, we can search violation information due to carbon emissions in detail. Following the method developed by Li and Shen (2010), we selected data on media attention from CNKI, "China's important newspaper full-text database". Names of listed companies are searched as key words. Finally, we screened the annual positive media coverage on the carbon emissions of the listed companies.

The samples are further processed according to the following steps after a preliminary analysis: (i) companies with missing financial data are excluded; (ii) specially treated (ST) companies are excluded; and (iii) all continuous variables are winsorized at 1 and 99% for the year. Table 1 presents the final sample distribution after these treatments.

3.2 | Variables

3.2.1 | Dependent variable

Previous studies often use debt ratings and debt average yield to measure the cost of debt financing (Boubakri & Ghouma, 2010; Minton & Schrand, 1999). China has no authoritative debt ratings or provisions for different types of debt interest (such as bank loans, bonds, notes payable and other nonbank loans); thus, we use the method developed by Pittman and Fortin (2004) to measure the cost of debt financing by the following equation: total interest expense/average of interest-bearing debt. The interest-bearing debt mainly includes short-term borrowings, noncurrent liabilities due within 1 year, long-term loans, bonds payable and long-term payables reported in the balance sheet.

TABLE 1 Final sample distribution

Industries	Number of firms	Number of state-owned-firms	Number of private firms
Petrochemical	5	5	0
Chemical	61	38	23
Building materials	19	14	5
Steel	15	13	2
Nonferrous metals	17	11	6
Papermaking	7	4	3
Electric power	43	38	5
Aviation	8	8	0
Extraction	16	14	2
Total	191	145	46

3.2.2 | Independent variables

Most scholars measure carbon risk via the following formula: carbon emissions/operating income (Juhyun et al., 2016; Kim, An, & Kim, 2015). However, the current report from the Carbon Disclosure Project China fails to provide complete data on carbon emissions. In addition, only a small number of China's listed companies provide quantitative data on carbon emissions through annual reports, social responsibility reports, environmental reports or sustainability reports. Previous research indicates that the regulatory risk of firms due to carbon emissions can significantly affect the debt capital market. To measure carbon risk, we use data on the carbon pollution violations of firms and the corresponding type of punishment, as reported by Lorraine, Collison, and Power (2004) and Dobler et al. (2014). We define *Carbon Risk* as an ordinal variable. The scores we assigned are as follows: 0, if the company does not receive any punishment due to carbon emission; 1, if the company is ordered to make rectification due to excessive carbon emissions; 2, if the company is subject to a fine or complaint because of a carbon emission violation; and 3, if the company has been suspended operation pending consolidation because of carbon emissions. The higher the *Carbon Risk* value, the more carbon risk the firm has. If one firm is subject to more than two different kinds of punishment in the same year, we assign the value according to the most serious punishment. For example, if a company was ordered to make rectification and was fined as well in 2013 but in other years it did not receive any punishment, its *Carbon Risk* in 2013 is 2 and in other years is 0.

To determine how positive media attention can moderate the relationship between carbon risk and the cost of debt financing, we use the number of carbon-related news items and reports each year referring to a company as a measure of positive media attention. We collect the positive media coverage from the CNKI database. Using the method developed by Lee, Park, and Klassen (2015), we filter the total number of media reports by topic search and then analyze the contents of each report to determine the total number of reports related to carbon emissions. Specifically, when the report includes content on carbon management, energy saving, low carbon production, low carbon innovation, low carbon investment and other similar contents, this is defined as carbon news.

3.2.3 | Control variables

Referring to previous studies on the relationship between environmental (carbon) risk and the cost of debt financing, that is, Chava (2014), Chen and Gao (2012), Goss and Roberts (2011), Juhyun et al. (2016) and Li et al. (2014), we select the following control variables: the benchmark lending rate, firm size, asset–liability ratio, proportion of fixed assets, net profit margin of assets, growth rate of the operating income, multiple interest rates, cash flow and time of listing, and the annual dummy variable.

Loan benchmark interest rate: To control the average annual interest rate, we use the 1–3-year bank loan interest rate set by the People's Bank of China as the benchmark for the corresponding year. The higher the benchmark interest rate on central bank loans, the higher the cost of debt.

Firm size: Larger companies generally have a longer history and more collateralized assets. Their cash flows are also less likely to be affected by negative shocks and have a lower default risk. In addition, the effect of reputation increases with the size of the company. Consequently, larger firms have a greater ability to withstand risks. Their default risk is lower, as is the cost of debt.

Leverage ratio: The higher the leverage ratio, the higher the default required by the debtor, and the higher the cost of debt financing for these companies.

Proportion of fixed assets: Firms with more fixed assets can provide more guarantees for debt repayment and this reduces the losses borne by creditors at the time of default. The proportion of fixed assets to total assets is expected to be negatively correlated with the cost of debt.

Return on assets: Higher return on assets coincides with higher profitability and a lower likelihood of default. It can provide increased security for the capital of the creditor, which helps reduce the cost of debt financing.

Operating income growth rate: A high growth rate of the operating income represents great growth potential. However, growing firms face greater uncertainty for the future. Therefore, cost of debt financing is relatively high.

Interest coverage: Firms with a higher interest coverage have ample cash repayments to return due debts and a lower financial risk, which leads to a lower cost of debt.

Cash flow: The cash flow of firms directly affects the debt default risk. Firms with more cash can better guarantee their debt repayment, resulting in a lower cost of debt financing.

Time of listing: Firms with a shorter time-to-market are subject to greater risks and are more likely to suffer from difficulties. A longer listing time implies less information asymmetry between firms and creditors, and the time of listing is negatively related to the cost of debt.

We also include industry and year dummy variables (fixed effects) into our regressions. The variables in the analysis model are presented in Table 2.

3.3 | Models

We use the panel data model to handle the sequence correlation and heteroscedasticity in cross-sectional data or time series data. The panel data model can simultaneously reduce the endogeneity problem arising from missing variables to improve the validity of parameter estimation.

The study sample, which consist of data for 191 firms covering the period 2011–15, belongs to the "big N, small T" type. Through the *F*-test and the Hausman test, we determine that the fixed-effects model should be adopted (with industry fixed effect and time fixed effect). We use Stata 13.0 to conduct panel data analysis.

Our study is divided into two parts: Model (1) to test H1 and Model (2) to test H2.

$$COD_{i,t} = \beta_0 + \beta_1 RISK_{i,t} + \sum \beta CONTROL_{i,t} + \beta_j \sum YR + \beta_k \sum IND + \varepsilon \quad (1)$$

$$COD_{i,t} = \beta_0 + \beta_1 RISK_{i,t} + \beta_2 PMA_{i,t} + \beta_3 RISK_{i,t} \times PMA_{i,t} + \sum \beta CONTROL_{i,t} + \beta_j \sum YR + \beta_k \sum IND + \varepsilon \quad (2)$$

In Model (1), *RISK* is the main test variable, and its β_1 coefficient represents the effect of carbon risk on the cost of debt financing. On the basis of *H1*, we predict that β_1 is positive.

In Model (2), the interaction between carbon risk and positive media attention is introduced, and the coefficient β_3 denotes the moderating effect of positive media attention. According to *H2*, β_3 is expected to be negative.

4 | EMPIRICAL RESULTS

4.1 | Descriptive statistics

Table 3 lists the descriptive statistical results for the main variables of the overall sample. The mean value of the carbon risk variable is 1.123, and the median is 1; these results indicate that the carbon risk of most firms is high. Comparative analysis of the mean and median of positive media attention indicates that the media attention received by most firms in the sample is lower than the average, which suggests that positive media coverage of the enterprise carbon news is insufficient. The reason for this may be that the media pay more attention to the financial information of the firms rather than their carbon information. To improve its role in corporate governance in capital markets, media coverage on corporate carbon news needs to be strengthened.

4.2 | Correlation analysis

The Spearman rank coefficient analysis of the main variables in the model is presented in Table 4. As shown, a significant positive correlation is exhibited between *COD* and *RISK* at the 5% level, suggesting that carbon risk can be positively correlated with the cost of debt financing. However, variable dependency is affected by several factors, such as sample size; thus, *H1* is assumed to require further analysis. *PMA* is significantly correlated with *COD* and *RISK*, suggesting that positive media attention can affect the relationship between carbon risk and the cost of debt financing.

We also carry out a variance inflation factor (VIF) test. Our test shows that VIF values of all independent variables are less than 2, indicating that there is no multicollinearity between the independent variables.

TABLE 2 Definitions of variables

Variable type	Variable name	Variable symbol	Variable definitions
Explained variable	Cost of debt financing	*COD*	Total interest expense/average interest at the beginning of the period
Explanatory variables	Carbon risk	*RISK*	Not being punished for carbon emissions = 0; Ordered for rectification because of excessive carbon emissions = 1; Fined or complaint was filed because of carbon emissions = 2; Suspended operation pending consolidation because of carbon emissions = 3
	Positive media attention	*PMA*	ln (Total number of positive carbon news reports +1)
Control variables	Loan benchmark interest rate	*PRIME*	Central bank loan benchmark interest rate
	Enterprise scale	*SIZE*	ln (Total assets at the end of the period)
	Leverage ratio	*LEV*	Total liabilities at the end of the period/total assets at the end of the period
	Proportion of fixed assets	*FIX*	Fixed assets/total assets
	Return on assets	*ROA*	Net profit/total assets
	Operating income growth rate	*GROWTH*	(Current operating income − Previous period operating income)/Previous period operating income
	Interest coverage	*IC*	EBIT/interest expense
	Cash flow situation	*CFO*	Operating net cash flow/total assets at the end of the period
	Time of listing	*AGE*	ln (Years of being listed)
	Year	*YR*	Dummy variable
	Industry	*IND*	Dummy variable

TABLE 3 Descriptive statistics of major variables

Variables	N	Mean	Median	Minimum	Maximum	SD
COD	955	0.065	0.061	0.018	0.224	2.887
RISK	955	1.123	1	0	3	0.870
PMA	955	0.487	0.693	0	2.197	0.530
PRIME	955	0.058	0.059	0.050	0.063	0.445
SIZE	955	22.730	22.685	19.973	25.874	1.249
LEV	955	0.593	0.600	0.210	1.100	0.176
FIX	955	0.406	0.399	0.063	0.842	0.181
ROA	955	0.025	0.022	−0.168	0.174	4.866
GROWTH	955	0.041	0.019	−0.418	0.849	0.219
IC	955	5.173	2.053	−8.432	0.717	11.465
CFO	955	0.049	0.048	−0.125	0.206	6.164
AGE	955	2.927	2.890	2.485	4.249	0.267

4.3 | Regression analysis

4.3.1 | Main effect

Table 5 presents the regression results of Model (1). As shown, the *RISK* coefficients in the general sample, state-owned-firm subsample and private-firm subsample regression are 0.043, 0.108, and − 0.277, respectively. Positive and negative coefficients exist, and the results are not exactly the same as stated in Hypothesis 1. None of the regression coefficients passed the 10% significance test. In addition, the model has a low overall fit, suggesting that although carbon risk is significantly related to the cost of debt financing, the assumed linear relationship between carbon risk and the cost of debt financing is not verified. That is, the effect of carbon risk on the cost of debt financing may not be linear, which is unexpected. Under China's particular institutional background, the effect may be nonlinear. We are very interested in this. Given that Barnett and Salomon (2012) and Huang, Duan, and Zhu (2017) undertook similar studies using a nonlinear regression model, we also use a nonlinear regression model to further explore the relationship between carbon risk and the cost of debt financing in the Chinese context.

We introduce the quadratic in Model (3) to test the relationship between carbon risk and cost of debt financing.

$$COD_{i,t} = \beta_0 + \beta_1 RISK_{i,t} + \beta_2 RISK^2{}_{i,t} + \sum \beta CONTROL_{i,t} + \beta_j \sum YR + \beta_k \sum IND + \varepsilon \quad (3)$$

Table 6 presents the regression results for Model (3). As shown, the goodness of fit of Model (3) is larger than that of Model (1), regardless of

TABLE 4 Spearman rank correlation coefficients

Variables	COD	RISK	PMA	PRIME	SIZE	LEV	FIX	ROA	GROWTH	IPM	CFO	AGE
COD	1											
RISK	0.159**	1										
PMA	−0.137*	0.126***	1									
PRIME	0.046	−0.132***	0.058**	1								
SIZE	−0.353***	0.275***	0.246***	−0.077**	1							
LEV	0.214***	0.054**	0.079**	0.029	0.167***	1						
FIX	−0.085**	0.086**	0.011	−0.033**	0.346***	0.229	1					
ROA	−0.158***	0.004	0.028	0.028**	0.208***	−0.334	−0.053	1				
GROWTH	0.029	−0.031	0.054***	0.190**	−0.039***	0.002*	−0.020	0.176***	1			
IC	−0.086***	−0.092**	−0.081*	0.118***	−0.105***	−0.238***	−0.185***	0.229***	0.172***	1		
CFO	−0.051*	0.038*	0.036	−0.015	0.186***	−0.113**	0.250***	0.298***	−0.019	0.132***	1	
AGE	−0.034	−0.069**	0.025	−0.126**	0.057	0.062***	0.016	−0.135***	−0.079**	−0.098***	−0.011	1

Asterisks indicate that the correlation is significant at the *10, **5, and ***1% levels, respectively.

TABLE 5 Main effect regression analysis results (1)

Variables	Full samples	State-owned-firm subsample	Private-firm subsample
RISK	0.043 (0.40)	0.108 (1.05)	−0.277 (−0.94)
PRIME	0.204 (0.85)	0.027 (0.11)	0.458 (0.77)
SIZE	−0.796 (−10.14)	−0.546*** (−6.77)	−0.967*** (−4.49)
LEV	0.020*** (3.47)	0.011 (1.61)	0.044*** (3.73)
FIX	−0.010* (−1.90)	−0.004 (−0.78)	−0.004 (−0.32)
ROA	−0.050** (−2.28)	−0.016 (−0.62)	−0.089** (−2.17)
GROWTH	0.006 (1.43)	0.002 (0.39)	0.016 (1.50)
IC	−0.027*** (−3.24)	−0.013 (−1.54)	−0.112*** (−4.29)
CFO	−0.050*** (3.07)	−0.029* (−1.69)	−0.073* (−1.86)
AGE	−0.087 (−0.25)	−0.296 (−0.91)	0.989 (0.97)
Constant	0.223*** (8.57)	0.189*** (7.38)	0.215*** (3.00)
YR	Yes	Yes	Yes
IND	Yes	Yes	Yes
N	955	725	230
Adjusted R^2	0.360	0.203	0.448

Asterisks indicate that the correlation is significant at the *10, **5, and ***1% levels, respectively. Standard error is clustered by firm.

TABLE 6 Main effect regression analysis results (2)

Variables	General sample	State-owned-firm subsample	Private-firm subsample
RISK	−0.715 (−2.03)	−0.376 (−1.09)	−1.222** (−2.36)
$RISK^2$	0.337** (2.26)	0.216 (1.47)	0.658** (2.17)
PRIME	0.200 (0.83)	0.025 (0.10)	0.389 (0.66)
SIZE	−0.789*** (−10.06)	−0.539*** (−6.68)	−0.984*** (−4.61)
LEV	0.020*** (3.50)	0.011* (1.75)	0.044*** (3.79)
FIX	−0.010* (−1.78)	−0.004 (−0.72)	−0.001 (−0.06)
ROA	−0.049** (−2.22)	−0.014 (−1.54)	−0.089** (−2.18)
GROWTH	0.007 (1.48)	0.002 (0.36)	0.017 (1.56)
IC	−0.027*** (−3.27)	−0.013* (−1.94)	−0.109*** (−4.20)
CFO	−0.051*** (−3.10)	−0.029* (−1.70)	−0.076* (−1.94)
AGE	−0.080 (−0.24)	−0.291 (−0.89)	0.873 (0.86)
Constant	0.222*** (8.54)	0.188*** (7.31)	0.225*** (3.16)
YR	Yes	Yes	Yes
IND	Yes	Yes	Yes
N	955	725	230
Adjusted R^2	0.364	0.205	0.453

Asterisks indicate that the correlation is significant at the *10, **5, and ***1% levels, respectively. Standard error is clustered by firm.

the sample: the general sample, the state-owned-firm subsample or the private-firm subsample. Compared with Model (1), Model (3), which introduces the square of carbon risk, can elucidate the relationship between carbon risk and the cost of debt financing in the Chinese context. In addition, the coefficient of *RISK* (−0.715) in the full sample regression was significantly negative at the 5% level, whereas the coefficient of $RISK^2$ (0.337) was significantly positive at the 5% level. These results indicate that the effect of corporate carbon risk on the cost of debt financing has a threshold (1.061). Below this threshold, the cost of debt financing declines nonmonotonically as a firm's carbon risk increases, but then increases continuously until carbon risk reaches a maximum at 3. Figure 1 graphically depicts the U-shaped relationship between carbon risk and cost of debt financing.

The significance test at 10% shows that the nature of state-owned ownership undermines the relationship between carbon risk and the cost of debt financing. In the private-firm subsample, the regression coefficient of *RISK* is −1.222, and that of $RISK^2$ is 0.658, both of which are significant at the 5% level. This finding indicates that carbon risk exhibits a significant positive "U" relationship with the cost of debt financing in the private-firm subsample.

4.3.2 | Moderating effect

To evaluate the moderating effect of positive media attention, we use Model (4) to test:

$$\begin{aligned} COD_{i,t} = {} & \beta_0 + \beta_1 RISK_{i,t} + \beta_2 RISK^2{}_{i,t} + \beta_3 PMA_{i,t} \\ & + \beta_4 RISK_{i,t} \times PMA_{i,t} + \beta_5 RISK^2{}_{i,t} \times PMA_{i,t} \\ & + \sum \beta CONTROL_{i,t} + \beta_j \sum YR + \beta_k \sum IND + \varepsilon \end{aligned} \quad (4)$$

In Table 7, the regression results of Model (4) show that the coefficient on $RISK^2 \times PMA$ is negative and significant at 10% level, which indicates that positive media attention mitigates the U-shaped relationship between carbon risk and the cost of debt financing. As an important dimension of carbon information transparency, media coverage of firms' efforts in carbon risk management can weaken the U-shaped relationship between carbon risk and the cost of debt financing through information dissemination and reputation effects.

In addition, the estimated coefficient of $RISK^2 \times PMA$ in the private-firm subsample is significant at the 5% level, whereas that of $RISK^2 \times PMA$ in the state-owned-firm subsample is not significant at the 10% level. These results show that compared with the state-owned-firms, private firms are typically more susceptible to the moderating effect of positive media attention.

4.3.3 | Further analysis

Our prior regression analysis results indicate that the main and the moderating effects are more significant in the private-firm subsample.

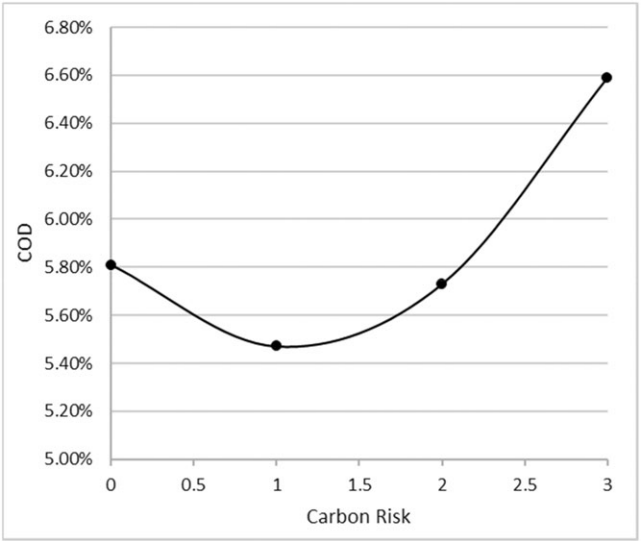

FIGURE 1 Relationship between carbon risk and cost of debt financing

TABLE 7 Regression analysis results

Variable	Full sample	State-owned-firm subsample	Private-firm subsample
RISK	−0.697** (−1.97)	−0.355 (−1.03)	−1.448** (−2.51)
$RISK^2$	0.327** (2.17)	0.204 (1.38)	0.562** (2.34)
PMA	−0.076* (−1.75)	−0.110 (−1.42)	−0.077** (−2.10)
RISK×PMA	0.098** (2.15)	0.079* (1.84)	0.133** (2.52)
$RISK^2$×*PMA*	−0.296* (−1.84)	−0.093 (−1.22)	−0.484** (−2.24)
PRIME	0.210 (0.87)	0.005 (0.35)	0.404 (0.68)
SIZE	−0.784*** (−9.85)	−0.533*** (−6.48)	−0.980*** (−4.57)
LEV	0.020*** (3.52)	0.011* (1.69)	0.043*** (3.66)
FIX	−0.010* (−1.82)	−0.004 (−0.76)	−0.001 (−0.05)
ROA	−0.049** (−2.23)	−0.015* (−1.87)	−0.090** (−2.20)
GROWTH	0.007 (1.47)	0.002 (0.75)	0.017 (1.60)
IC	−0.027*** (−3.29)	−0.013* (−1.70)	−0.109*** (−4.19)
CFO	−0.051*** (−3.10)	−0.028* (−1.68)	−0.075* (−1.89)
AGE	−0.074 (−0.22)	−0.308 (−0.94)	0.828 (0.81)
Constant	0.221*** (8.36)	0.196*** (7.11)	0.226*** (3.14)
YR	Yes	Yes	Yes
IND	Yes	Yes	Yes
N	955	725	230
Adjusted R^2	0.373	0.206	0.481

Asterisks indicate that the correlation is significant at the *10, **5, and ***1% levels, respectively. Standard error is clustered by firm.

Therefore, to interference of avoid state-owned firms in the analysis of the moderating effect of positive media attention, we focus on private firms to further evaluate the moderating effect of positive media attention from two aspects: sensitivity and tolerance. We rerun the analysis for the sample divided into high and low positive media attention. The regression results are presented in Table 8. For private firms with high positive media attention, the $RISK^2$ regression coefficient is 0.526, and the *RISK* regression coefficient is −0.804. For private firms with low positive media attention, the $RISK^2$ regression coefficient is 0.767, and the *RISK* regression coefficient is −1.493. All these regression coefficients are significant at the 10% level.

TABLE 8 Partitioned regression results

Variable	Private firms with high positive media attention	Private firms with low positive media attention
RISK	−0.804* (−1.72)	−1.493** (−2.05)
$RISK^2$	0.526* (1.80)	0.767* (1.95)
PRIME	0.184 (0.19)	0.511 (0.73)
SIZE	−1.396*** (−3.27)	−0.936*** (−3.67)
LEV	0.064* (1.80)	0.042*** (3.17)
FIX	0.021 (0.95)	−0.006 (−0.37)
ROA	−0.039* (−1.67)	−0.098** (−2.14)
GROWTH	0.026 (1.04)	0.015 (1.27)
IC	−0.116* (−1.78)	−0.105*** (−3.55)
CFO	−0.045 (−0.63)	−0.078 (−1.62)
AGE	0.678 (0.47)	0.929 (0.74)
Constant	0.312** (2.47)	0.210** (2.48)
YR	Yes	Yes
IND	Yes	Yes
N	65	165
Adjusted R^2	0.542	0.431

Asterisks indicate that the correlation is significant at the *10, **5, and ***1% levels, respectively. Standard error is clustered by firm.

As is clearly shown in Figure 2, private firms with high positive media attention have a $RISK^2$ coefficient of 0.526 (absolute value), which is less than that of the private firms with low positive media attention (i.e., 0.767). The quadratic term coefficient of the quadratic curve indicates the sensitivity of the dependent variable to the independent variable; that is, the relationship between carbon risk and the cost of debt financing is weaker in private firms with high positive media attention. In addition, in private firms with high positive media attention, carbon risk and the cost of debt financing exhibit a U-shaped relationship with an inflection point of 0.973; meanwhile, in private firms with low positive media attention, the U-shaped relationship between carbon risk and the cost of debt financing has an inflection point of 0.762. Tolerance refers to the state when the inflection point of the U-shaped curve appears; that is, the degree of carbon risk when the curve reverses. This shows that the cost of debt financing of private firms with high positive media attention is less tolerant of carbon risk than that of private firms with low positive media attention.

4.4 | Robustness test

First, according to the method by Li et al. (2014), other alternative indicators are used to measure the cost of debt financing. An alternative formula, "interest expense + fee + other financial expenses)/ average liability with interest" (*COD*), is used to calculate the proxy of the cost of debt financing. In Table 9, the regression results show that the main and moderating effects hold in the robust test. The relationship between carbon risk and the cost of debt financing remains significant (β_1 = −0.681, t = −1.95; β_2 = 0.336, t = 2.24). The relationship between $RISK^2$×*P MA* and the cost of debt financing is also significant (β_4 = −0.293, t = −1.82). Therefore, our study is robust.

Second, we use lagged *positive media attention*. Considering that delay may affect the carbon news of listed firms and that a certain degree of endogeneity exists between positive media attention and the cost of debt financing, we use the "lagged one period" model to test for robustness. As shown in Table 10, the moderating effect of positive media attention is shown to be robust (β_4 = −0.301, t = −1.87).

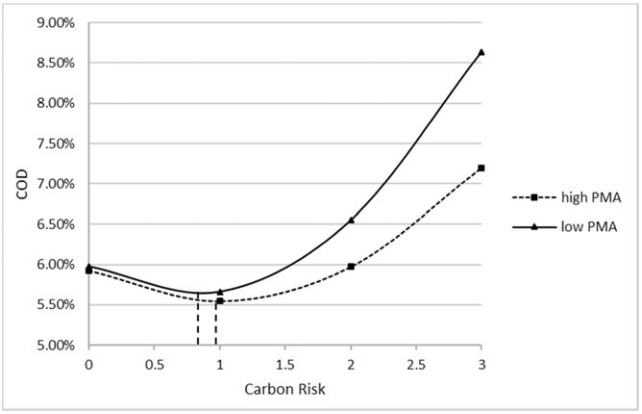

FIGURE 2 Moderating effect of positive media attention

TABLE 9 Robustness test results (1)

	Full sample		State-owned firm subsample		Private-firm subsample	
Variables	(3)	(4)	(3)	(4)	(3)	(4)
RISK	−0.708** (−2.00)	−0.681* (−1.95)	−0.458 (−1.20)	−0.434 (−1.12)	−1.153** (−2.19)	−1.361** (−2.34)
$RISK^2$	0.339** (2.30)	0.336** (2.24)	0.229 (1.41)	0.217 (1.31)	0.625** (2.00)	0.530** (2.17)
PMA		−0.107* (−1.79)		−0.136* (−1.74)		−0.078** (−2.13)
RISK×PMA		0.092** (2.07)		0.071* (1.78)		0.125** (2.39)
$RISK^2$×*PMA*		−0.293* (−1.82)		−0.101 (−1.33)		−0.488** (−2.25)
PRIME	0.161 (0.62)	0.181 (0.69)	0.089 (0.34)	0.060 (0.22)	0.429 (0.70)	0.457 (0.74)
SIZE	−0.776*** (−9.17)	−0.767*** (−8.94)	−0.510*** (−5.71)	−0.499*** (−5.48)	−1.000*** (−4.51)	−1.006*** (−4.52)
LEV	0.020*** (3.29)	0.021*** (3.30)	0.011* (1.93)	0.010* (1.69)	0.045*** (3.76)	0.044*** (3.64)
FIX	−0.009 (−1.54)	−0.009 (−1.57)	−0.003 (−0.56)	−0.004 (−0.59)	−0.001 (−0.06)	−0.001 (−0.05)
ROA	−0.046* (−1.94)	−0.046* (−1.95)	−0.007* (−1.73)	−0.008* (−1.83)	−0.091** (−2.14)	−0.091** (−2.15)
GROWTH	0.007 (1.51)	0.007 (1.49)	0.001 (0.27)	0.001 (0.27)	0.017 (1.58)	0.018 (1.61)
IC	−0.023** (−2.54)	−0.023*** (−2.57)	−0.008 (−0.88)	−0.009 (−0.94)	−0.111*** (−4.09)	−0.110*** (−4.06)
CFO	−0.050*** (−2.84)	−0.050*** (−2.86)	−0.027* (−1.73)	−0.028* (−1.78)	−0.075* (−1.85)	−0.075* (−1.83)
AGE	−0.189 (−0.55)	−0.192 (−0.56)	−0.533 (−1.60)	−0.544 (−1.63)	0.790 (0.75)	0.777 (0.73)
Constant	0.230*** (8.37)	0.227*** (8.15)	0.192*** (6.94)	0.189*** (6.69)	0.230*** (3.09)	0.229*** (3.07)
YR	Yes	Yes	Yes	Yes	Yes	Yes
IND	Yes	Yes	Yes	Yes	Yes	Yes
N	955	955	725	725	230	230
Adjusted R^2	0.361	0.368	0.202	0.204	0.455	0.479

Asterisks indicate that the correlation is significant at the *10, **5, and ***1% levels, respectively. Standard error is clustered by firm.

Finally, we alter the control variables (see Table 11). For the full sample, we use the market-to-book ratio as an alternative proxy for growth opportunities and rerun the regression analysis. The results show the robustness of the findings of our main analysis.

TABLE 10 Robustness test results (2)

Variable	Full sample	State-owned firm subsample	Private-firm subsample
RISK	−0.712** (−2.08)	−0.358 (−1.05)	−2.450** (−2.52)
$RISK^2$	0.334** (2.22)	0.206 (1.39)	0.958** (2.31)
PMA	−0.074* (−1.74)	−0.114 (−1.43)	−0.079** (−2.13)
RISK×PMA	0.102** (2.16)	0.083* (1.86)	0.139** (2.55)
$RISK^2$×*PMA*	−0.301* (−1.87)	−0.097 (−1.24)	−0.485** (−2.24)
PRIME	0.207 (0.86)	0.005 (0.35)	0.397 (0.66)
SIZE	−0.779*** (−9.76)	−0.529*** (−6.41)	−0.977*** (−4.53)
LEV	0.024*** (3.54)	0.014* (1.72)	0.048*** (3.69)
FIX	−0.009* (−1.82)	−0.005 (−0.78)	−0.001 (−0.08)
ROA	−0.052** (−2.24)	−0.018* (−1.89)	−0.095** (−2.24)
GROWTH	0.008 (1.48)	0.002 (0.73)	0.017 (1.60)
IC	−0.031*** (−3.32)	−0.016* (−1.72)	−0.114*** (−4.29)
CFO	−0.047*** (−3.05)	−0.030* (−1.69)	−0.076* (−1.89)
AGE	−0.079 (−0.26)	−0.311 (−0.97)	0.830 (0.82)
Constant	0.230*** (8.41)	0.192*** (7.01)	0.224*** (3.12)
YR	Yes	Yes	Yes
IND	Yes	Yes	Yes
N	955	725	230
Adjusted R^2	0.371	0.211	0.478

Asterisks indicate that the correlation is significant at the *10, **5, and ***1% levels, respectively. Standard error is clustered by firm.

5 | DISCUSSION

Carbon risk is widely recognized as an important factor of debt contracts in the context of tightening carbon regulation (Busch &

TABLE 11 Robustness test results (3)

	Full sample	
Variables	(3)	(4)
RISK	−0.732** (−1.98)	−0.721* (−1.95)
$RISK^2$	0.329** (2.07)	0.324** (2.11)
PMA		−0.082* (−1.76)
RISK×PMA		0.095** (2.10)
$RISK^2$×*PMA*		−0.289* (−1.79)
PRIME	0.176 (0.64)	0.171 (0.62)
SIZE	−0.791*** (−9.19)	−0.773*** (−9.01)
LEV	0.022*** (3.30)	0.019*** (3.28)
FIX	−0.013 (−1.58)	−0.012 (−1.85)
ROA	−0.052* (−1.94)	−0.050* (−1.92)
GROWTH	−0.004* (−1.77)	−0.003* (−1.68)
IC	−0.028** (−2.57)	−0.025*** (−2.54)
CFO	−0.044*** (−2.81)	−0.042*** (−2.80)
AGE	−0.169 (−0.52)	−0.162 (−0.48)
Constant	0.246*** (8.40)	0.237*** (8.38)
YR	Yes	Yes
IND	Yes	Yes
N	955	955
Adjusted R^2	0.364	0.370

Asterisks indicate that the correlation is significant at the *10, **5, and ***1% levels, respectively. Standard error is clustered by firm.

Hoffmann, 2007; Chapple et al., 2013; Juhyun et al., 2016). China's carbon regulations and policies are mainly aimed at high-carbon industries. To explore the relationship between carbon risk and the cost of debt financing, we select the listed companies operating in high-carbon industries as our study sample. Our sample is highly representative. In our empirical study, there is an unexpected discovery—the relationship between carbon risk and the cost of debt financing is not positive linear; instead it is U-shaped. The underlying mechanism behind the unexpected U-shaped relationship deserves further exploration.

The main effect result shows a U-shaped relationship between carbon risk and the cost of debt financing. The result is not consistent with our positive linear hypothesis. As we note, a positive linear relationship between carbon risk and the cost of debt financing is developed from empirical evidence of advanced capital markets. As mentioned earlier, compared with the relatively more mature foreign capital markets, China's debt capital market has its own institutional background and characteristics. The integrity and effectiveness of China's carbon policies are still insufficient at the present stage. Only when carbon risk reaches a certain level (e.g., firms are ordered to make adjustments/changes due to excessive carbon emissions) do lenders pay attention. The traditional agent theory is mainly applied to the firms on the right side of the U-shaped curve. Firms with increased carbon risk can be urged to reduce carbon emissions. Lenders can also charge higher interest to firms with a greater environmental liability. However, there are as yet no systematic theories or hypotheses to explain the firms on the left side of the curve. We hold the view that the "interval effect" may be attributed to the imperfect carbon risk assessment mechanism of China's debt capital market during our research period. It is noteworthy that China launched the unified carbon emission trading market in 2017 to control carbon emissions strictly. However, our study is based on the period 2011–15 when the carbon trading system was only piloted in a few areas. The intensity of carbon regulation was low at that time. Correspondingly, banks and other financial institutions perceived low carbon risks of firms, especially those on the left side of the U-shaped curve. As a result, lenders did not acknowledge the carbon risk management efforts of the firms on the left side of the U-shaped curve. Instead, their green credit mechanism is mainly aimed at firms on the right side of U-shaped curve, that is, firms with higher levels of carbon risk. For firms with very low levels of carbon risk (i.e., those on the left side of the curve), with the same level of carbon regulation intensity in the capital market, their level of carbon risk management is relatively high, indicating that they need to allocate a substantial part of the funds to carbon reductions and green innovations and other environmental projects (Dobler et al., 2014). If their investment in carbon risk management exceeds the strategic investment necessary for compliance, their economic benefits of carbon reductions would be less than their investment costs. Thus, lenders will punish their carbon risk management measures that are less likely to increase their firm values (Fujii, Iwata, Kaneko, & Managi, 2013; Jasch, 2006). Lenders are less interested in carbon risk management activities of firms with low carbon risk or do not believe that such activities can effectively improve these firms' corporate reputation, create their competitive advantages or reduce their risk. That is, for these low-risk firms, excessive investment in carbon risk management is inefficient and unnecessary from the perspective of lenders (Najah, 2012). In addition, even if carbon reduction investment can economically benefit these low-risk firms, the main benefits belong to their shareholders. Lenders can only share very limited benefits of the improvement of carbon performance. Therefore, lenders can require additional compensation in the debt contract for this unfair benefit transfer (Li et al., 2014).

As an important dimension of carbon transparency, positive media attention is introduced into our analytical framework based on the information dissemination mechanism and reputation mechanism. Our empirical results indicate that positive media attention can mitigate the effect of carbon risk on the cost of debt financing. Furthermore, we research the moderating effect of positive media attention from two dimensions: sensitivity and tolerance. We hold the view that sensitivity weakens because positive media coverage of carbon news involving private firms improves the perception of corporate environmental management by creditors. Thus, positive media attention can weaken the perception of corporate carbon risk by the debt capital market, thereby relaxing credit restrictions on private firms. This effect can decrease the unit of change of the cost of debt financing in response to carbon risk. Tolerance is increased because positive media attention can reduce the negative effect of corporate carbon risk on its environmental reputation; thus, the real reputation of private firms with different levels of positive media attention varies (Karpoff & Lott, 2005; Komarek, Lupi, Kaplowitz, & Thorp, 2013). Himme and Fischer (2014) found that corporate reputation affects the credit decision of the debt capital market to a certain extent. Positive media reporting on the carbon reductions of private firms protects their environmental reputation and reduces their environmental pressure. Thus, positive media attention can postpone the interval of the agency effect, which later reverses the response of the cost of debt financing to carbon risk.

We also consider the influence of ownership based on the Chinese context. A mixed ownership (e.g., state-owned and private) is the unique feature of the Chinese economy. In the process of debt financing, state-owned-firms are more likely to receive loans at low interest rates due to their good political connections with the government and financial bodies. Banks and other financial institutions will pay more attention to the carbon risk and carbon information of private firms. Therefore, for private firms, positive media coverage of carbon news is more helpful to mitigate a lender's perception of a firm's carbon risk. This directly results in a decrease in the cost of debt financing. Our regression results also show that both the main effect and the moderating effect are more significant in private firms, which is consistent with our theoretical analysis.

6 | CONCLUSIONS

Based on empirical data from China's Shanghai and Shenzhen A-share listed firms operating in high-carbon industries from 2011 to 2015, we use the double fixed effects model to evaluate the relationship between carbon risk and the cost of debt financing and the moderating effect of positive media attention on this relationship. The results indicate that: (i) there is a U-shaped relationship between carbon risk and the cost of debt financing, and this relationship is mainly embodied in

private firms; (ii) as an important external corporate governance mechanism, positive media attention can negatively moderate the relationship between carbon risk and the cost of debt financing; and (iii) the moderating effect of positive media attention varies with the ownership of the firms. The cost of debt financing is more sensitive to carbon risk and more tolerant in private firms with high positive media attention than in general private firms.

Our study has several contributions:

1. We investigate the effect of carbon risk on the cost of corporate debt financing in the context of China's carbon regulatory policies. The empirical settings of previous studies mainly focused on advanced capital markets. We, for the first time, study this relationship in the Chinese context. Meanwhile, considering our particular institutional environment, we evaluate the effect of carbon risk on the cost of debt financing and analyze the mechanism underlying the different ranges of the U-shaped curve.
2. Our study complements the literature on the effect of carbon transparency on the cost of debt financing. Carbon transparency mainly includes two dimensions: corporate reporting and information dissemination (Gupta & Mason, 2016). Company reporting mainly refers to the disclosure of carbon information through annual reports, social responsibility reports, environmental reports and sustainability reports (Depoers, Jeanjean, & Jérôme, 2016; Matisoff, 2013), and information dissemination is dominated by positive media coverage (Deboskey & Gillett, 2013). Most existing studies focus on the effect of carbon disclosure on the cost of debt financing, emphasizing the importance of voluntary carbon disclosure in reducing the corporate cost of debt financing (He, Tang, & Wang, 2014; Kleimeier & Viehs, 2016). We go beyond that and investigate the effect of the information dissemination mechanism on the relationship between carbon risk and the cost of debt financing.
3. We examine the role of media in moderating the relationship between carbon risk and the cost of debt financing. We introduce positive media attention into the analytical framework of carbon risk and the cost of debt financing. We examine the moderating effect by studying the geometric characteristics of the quadratic curve with respect to sensitivity and tolerance, and provide a new perspective for future research.

Similarly, our study also offers managerial implications:

1. With the implementation of a unified carbon emission trading market in 2017, China's carbon regulation is continuously increasing and carbon constraints are increasing. As the carbon constraints increase, the turning point of the U-shaped curve will move leftward. If firms do not carry out effective carbon risk management, they will face greater risk of carbon regulation in the future. With the increase in carbon risk, the cost of debt financing will increase, which has an adverse effect on firms' financial performance. Therefore, firms should focus on long-term interests, strengthen carbon risk awareness and initiate the implementation of carbon risk management via low-carbon production, green innovations, and so on. In so doing, corporate carbon risk will be reduced, and the confidence of creditors will be enhanced, therefore reducing the cost of debt financing.
2. In today's digital business environment in which new social media networks are widely spread, stakeholders now are more demanding that firms disclose information—they require more information beyond basic financial statements. Attention has been diverted to corporate carbon and other environmental information. The media play an active and important role in disseminating corporate carbon information to creditors and other stakeholders. Therefore, firms should optimize their use of the media and improve the transparency of carbon information to reduce the cost of debt financing.

Although this study reveals the relationship between carbon risk, positive media attention and the corporate cost of debt financing, its potential limitations deserve further in-depth research. First, China lacks mandatory carbon disclosure standards. Carbon disclosures of the listed companies are voluntary. Therefore, specific and accurate carbon emission data for many firms are not available. To a certain extent, this issue has influenced our research. Therefore, the U-shaped relationship between carbon risk and the cost of debt financing identified in our research needs more empirical evidence and more reasonable explanation, especially for the left side of the curve. With the development of China's carbon information disclosure policy, follow-up studies can access high-quality quantitative data about firms' carbon emissions and re-examine the relationship between carbon risk and the cost of debt financing empirically. Second, owing to the low degree of awareness on carbon information in China, we do not analyze the different type of media attention (e.g., negative media attention), which limits the depth of the study. Follow-up research can explore how negative media attention plays the role of external corporate governance through a supervision mechanism. Third, firms operating in high-carbon industries are mainly state-owned. Thus, state-owned enterprises account for the majority in our sample. However, the finalized model works better for private firms, which may affect the generalizability of our empirical results. Future research may explore the generalizability of the empirical findings by using samples with balanced numbers of state-owned and private firms.

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