

The impact of carbon risk on corporate market value: evidence from China

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Abstract

Purpose – This study aims to investigate how carbon risk affects corporate market value, offering empirical evidence on its value implications and transmission mechanisms.

Design/methodology/approach – Using data on Chinese A-share firms for the period 2008–2023, this study empirically examines the impact of carbon risk on firm value, performing robustness, mechanism and heterogeneity analyses to identify transmission channels and differential effects.

Findings – Carbon risk significantly reduces firm value, a result that is confirmed even after robustness checks. The mechanism analysis shows that this effect operates through operational volatility, financing constraints and investor sentiment, while the heterogeneity analysis indicates that a stronger digital and green transformation mitigates this effect.

Research limitations/implications – Unlike prior research, this study explicitly examines the mechanisms – operational volatility, financing constraints and investor sentiment – through which carbon risk affects firm value. However, findings are constrained by China's specific institutional context.

Practical implications – This study has important implications to understand how carbon risk affects environmental outcomes, firm value, investment behavior and, indirectly, economic welfare.

Originality/value – This study constructs a composite carbon risk index, identifies the mechanisms through which carbon risk affects firm value via operating volatility, financing constraints and investor sentiment and characterizes heterogeneity from the perspectives of digital transformation and green transformation, providing new evidence on carbon risk pricing in China under its institutional characteristics and proposing related policy implications.

Keywords Carbon risk, Corporate market value, Operational volatility, Financing constraints, Investor sentiment

Paper type Research paper

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1. Introduction

Since the Industrial Revolution, the global economy has experienced unprecedented expansion. However, its growth model has long relied on fossil-energy-intensive production systems, leading to a continuous increase in carbon emissions and severe climate challenges, which pose systemic threats to global ecological security and economic sustainability. To address the intensification of climate risks, a strategic consensus has been reached among governments worldwide on the strengthening of carbon emission reduction constraints and the promotion of green and low-carbon transformation. These policies have been increasingly implemented in practice (Stroebe and Wurgler, 2021). To date, more than 190 countries have established or advanced relatively comprehensive carbon emission regulatory



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frameworks, indicating that the global economy's transition toward decarbonization has risen as an irreversible long-term policy trend (Zhang and Zhao, 2022).

China is an important actor and leader in global climate governance. As the world's second-largest economy and the largest carbon emitter, China has explicitly set ambitious decarbonization targets, namely to achieve carbon peak by 2030 and carbon neutrality by 2060; moreover, it has implemented a series of institutional innovations, including the establishment of the world's largest carbon trading system. Empirical evidence shows that from 2005 to 2022, China's carbon intensity per unit of GDP declined by 50.8%, reflecting substantial achievements toward sustainable development. However, with the advancement of low-carbon transformation, a new form of systemic business risk has gradually emerged – carbon risk. Carbon risk refers to the uncertainty and potential adverse impacts of climate change or dependence on fossil fuels on corporate operations (Herbohn *et al.*, 2019). Carbon risk implies not only transition risks induced by regulatory tightening and technological substitution, but also physical risks arising from extreme climate events (Svartzman *et al.*, 2021). Unlike traditional operational or market risks, carbon risk exhibits systemic characteristics across temporal horizons, industries and supply chains. Furthermore, it reshapes firms' business models, competitive structures and asset allocation and exerts cumulative impacts on a firm's value by influencing expectations of future cash flows and market valuations.

Firm market value is an important manifestation of corporate competitiveness and long-term prospects, and plays a critical role in capital market resource allocation (Zhang *et al.*, 2021). With the growing prevalence of green investments, investors increasingly scrutinize firms' exposure to carbon risk and their capacity to mitigate it. In fact, carbon risk may erode firm value through multiple channels, such as rising compliance costs due to stricter environmental regulation, declining profitability, increasing financing costs and shifting investor risk preferences (Jung *et al.*, 2018; Kleimeier and Viehs, 2021). However, the internal mechanisms through which carbon risk specifically affects firm market value remain insufficiently understood, particularly in emerging market contexts.

Against this background, this study employed panel data on Chinese A-share listed firms from 2008 to 2023 to systematically examine the impact of carbon risk on firm market value. The results showed that:

- carbon risk significantly reduces firm market value;
- carbon risk operates primarily through three channels: amplified operating volatility, tightened financing constraints and heightened negative investor sentiment; and
- the adverse effects of carbon risk are more pronounced among firms with lower levels of digital transformation and green transformation.

This study makes three main contributions to existing literature. First, prior research largely focused on developed economies or non-Chinese market samples, and primarily examined the effects of carbon risk on single dimensions such as financing costs (Owolabi *et al.*, 2024) or investment decisions (Bolton and Kacperczyk, 2021). Using Chinese A-share listed firms as the research object, this study extended the analysis to firm market value, providing new empirical evidence on carbon risk pricing in the Chinese context. Moreover, this study constructed a composite carbon risk index based on carbon intensity, environmental penalties and carbon disclosure quality, thereby enhancing the comprehensiveness and explanatory power of carbon risk measurement. Second, although existing studies emphasized the external constraint effects of carbon risk (Kiran *et al.*, 2025), there is limited systematic evidence on how carbon risk is translated into valuation discounts within firms.

By analyzing three channels – operating volatility, financing constraints and investor sentiment – this study identified the core mechanism through which carbon risk affects firm value, thereby extending the theoretical understanding of how climate risk influences the process of value creation. Third, while previous research primarily examined heterogeneity in carbon risk from the perspective of differences in asset allocation between high- and low-carbon firms (Bolton and Kacperczyk, 2023), this study investigated the moderating role of digital transformation and green transformation. The findings showed that firms with weaker digital and green capabilities are more likely to experience significant valuation discounts under carbon risk shocks, thus providing targeted empirical evidence to enhance firms' low-carbon resilience and inform policy design.

This paper is organized as follows. Section 2 presents a review of the relevant literature on carbon risk and corporate valuation. Section 3 describes the theoretical framework and research hypotheses of this study. Section 4 presents the research design, including data sources, variable construction and empirical methodology. Section 5 reports and discusses the empirical results, and Section 6 provides the conclusions, including policy implications and directions for future research.

2. Literature review

2.1 *The impact of carbon risk on businesses*

Carbon risk exerts multidimensional impacts on corporate operations and performance, and existing research has focused on several of these key impacts.

Financing costs represent a primary concern in extant literature. Previous scholars consistently demonstrated that carbon risks significantly elevate corporate financing costs (Shen *et al.*, 2025; Wu and Tian, 2022). For example, high-carbon-emitting firms face elevated risk premiums in bond markets (Bolton and Kacperczyk, 2021). Financial institutions have also begun incorporating firms' carbon risk exposure into lending decisions (Degryse *et al.*, 2023). This integration directly affects firms' access to financing and the associated costs of obtaining it.

Investment decision-making displays complex responses to carbon risk exposure. For example, companies with high carbon risks are more susceptible to both underinvestment and overinvestment problems (Addoum *et al.*, 2023). Green transition pressures drive firms to increase their investment in green technology innovation (Wan *et al.*, 2025). However, reactive innovation investment in green technology innovations often exhibits low efficiency (Hsu *et al.*, 2023). Recent research indicated that carbon neutrality goals have strengthened the strategic nature of corporate green investments. Despite this, companies still face the double challenge of technological uncertainty and market risks (Wang and Zhang, 2025).

Operational performance can also suffer from erosion through multiple channels. In fact, carbon risks affect corporate performance via three primary pathways: increased production costs, elevated compliance expenses and triggered reputational risks (Nguyen and Phan, 2020).

Debt default risk has a strong correlation with carbon exposure, whereby companies with higher carbon emissions face an elevated probability of debt default (Choi *et al.*, 2020). Credit rating agencies now incorporate carbon risk into their assessment frameworks. As a result, firms with higher carbon risk face an increased likelihood of credit rating downgrades (Barth *et al.*, 2022). Climate-related extreme weather events significantly amplify the operational uncertainty for high-carbon emitting companies (Huang *et al.*, 2018).

2.2 *The determinants of corporate market value*

The determination of corporate market value is a core issue in corporate finance research, and existing literature identified several primary influencing factors.

Traditional financial and operational factors remain fundamental determinants. Empirical studies consistently confirmed that core financial indicators such as profitability, firm size and liquidity have a significantly positive impact on market value (Wang *et al.*, 2025). However, complex nonlinear relationships exist between corporate performance and capital structure. The strength and direction of this impact depend on several factors, including market environment, industry characteristics and corporate governance levels.

Environmental, social and governance (ESG) performance exhibits complex relationships with corporate value. Some scholars confirmed the existence of a positive correlation between ESG and firm value (Dossa *et al.*, 2025). Other studies, however, found no significant correlation, or even negative correlation (Chou *et al.*, 2025). This discrepancy in findings stems from the heterogeneity of characteristics across industries, regions and development stages, with different contexts exhibiting varying ESG value creation mechanisms.

Digital transformation generally enhances corporate performance through multiple channels, improving innovation capabilities, operational efficiency and dynamic capabilities (Li *et al.*, 2023). Digital transformation may also enhance value creation by improving financing capabilities (Shi and Liu, 2025). However, industry heterogeneity affects these relationships. Some studies suggested that, by increasing operational costs, digital transformation may have a negative impact on short-term performance (Khemakhem and Salah, 2022).

External environment and market factors are important systemic influences. For example, macroeconomic fluctuations, policy adjustments and global market changes significantly affect corporate value (Jiang and Li, 2025). Moreover, a weak global demand and inflation fluctuations also profoundly impact corporate performance. Changes in technological trends reshape labor market structures (Moreira, 2022), while policy environment uncertainty has become a key risk factor in corporate value assessment (Zhao *et al.*, 2025; Sun *et al.*, 2025).

Firm market value is determined not only by fundamentals, but is also strongly influenced by investor sentiment and information shocks. Previous research in behavioral finance indicated that investor sentiment is a key nonrational factor affecting firm market value (Baker and Wurgler, 2006). Cognitive biases in market participants' interpretation of climate-related information shocks – such as climate policies, environmental incidents and carbon regulatory signals – may cause asset prices to deviate from fundamental values, thereby generating “sentiment premia” or “risk discounts” (Barberis *et al.*, 1998). This not only affects investors' risk preferences, but may also alter the direction of capital allocation, leading high-carbon assets to face persistent valuation discounts while low-carbon assets obtain premia, thereby reshaping the value-pricing logic of capital markets (Santi, 2023).

2.3 Carbon risk and corporate market value

The relationship between carbon risk and market value is attracting increasing scholarly attention, with several studies that documented a significant negative correlation between corporate carbon emissions and market value (Han *et al.*, 2023; Trinks *et al.*, 2020).

In the context of green transitions, corporate environmental compliance expenditures crowd out operational resources. The carbon risk premium effect induced by regulatory pressure reduces market valuation levels (Seltzer *et al.*, 2022). Firms with a high carbon intensity face multiple pressures, including mandatory technological upgrades, carbon pricing constraints and compliance costs (Ramelli *et al.*, 2021). These pressures increase the discount rates for future cash flow risks, and prompt investors to reassess corporate value (Ginglinger and Moreau, 2023).

However, under certain conditions, positive relationships also exist. Yan *et al.* (2020) found that manufacturing companies with strong carbon performance and proactive carbon

disclosure can have a significantly positive impact on market value. This finding suggests that proactive carbon management may create – rather than merely destroy – value.

Although research on carbon risk has expanded rapidly, some important limitations and gaps still persist. First, existing studies largely emphasized the outcomes of isolated firms, offering little systematic evidence on how carbon risk is incorporated into market valuation. Second, extant literature provided only fragmented discussions of the internal channels through which carbon risk affects firms, leaving the concrete mechanisms that shape valuation impacts insufficiently understood. Third, empirical analyses rarely considered how firm strategic capabilities, particularly digitalization and green transformation, alter their exposure to carbon risk. These gaps highlight the need for integrated valuation evidence, clearer mechanism identification and a deeper understanding of firm-level heterogeneity.

3. Research hypotheses

Against the backdrop of China's dual carbon goals and the intensification of the global transition toward a low-carbon economy, carbon risk has emerged as a critical external shock that shapes firms' operational activities and capital-market performance. With the tightening of carbon emission regulations and the intensification of climate-related uncertainties, firms face mounting pressures in terms of operational stability, capital accessibility and investor confidence. This study examined the mechanisms through which carbon risk affects corporate market value by analyzing three key channels, namely, operational volatility, financing constraints and investor sentiment.

First, carbon risk negatively affects corporate market value by amplifying operational volatility. From a resource-based perspective, firms' competitive advantages rely on scarce and efficiently-allocated resource bundles, and operational stability is a critical prerequisite for effective resource deployment (Sirmon *et al.*, 2011; Li *et al.*, 2024). When firms confront tightening carbon emission regulations, rising carbon costs and fluctuations in carbon prices, their resource allocation efficiency is substantially disrupted (Su and Fan, 2025). Firms are, therefore, compelled to make continuous, highly-specific, long-term investments in production-process optimization, energy restructuring, equipment upgrading and environmental governance. These adjustments necessitate the short-term reallocation of internal resources, thereby generating a resource crowding-out effect. As a result, firms become more sensitive to external shocks; they experience greater volatility in operating profits and face heightened operational instability, which ultimately erode their market value. From the standpoint of transaction cost theory, carbon risk intensifies both external uncertainty and contractual hazards. Carbon emission policies are typically characterized by stringent oversight, rapid iterations and high uncertainty, all of which serve to increase firms' production, operational and compliance costs (Eccles *et al.*, 2011). Concurrently, carbon risk is often accompanied by sharp energy price fluctuations, supply chain delays and shifts in the demand structure, thereby increasing the uncertainty in production planning and inventory management (Guo *et al.*, 2024; Hambel and Van Der Ploeg, 2025). According to the transaction cost theory, an elevated uncertainty reduces firms' effective output, deteriorates the cost structure and compresses profit margins. This, in turn, amplifies operational volatility and transmits the firms' instability, thereby affecting market value. Furthermore, from the lens of capital market behavior, the operational volatility induced by carbon risk magnifies investor uncertainty regarding future cash flows. Accordingly, capital markets demand higher risk premia (Chen *et al.*, 2021), increasing firms' cost of capital and making their stock prices more susceptible to sharp corrections under carbon risk shocks. With the accumulation of operational instability over time, investors will systematically revise their

expectations of firm value downward, leading to persistent pressure on corporate market value.

Second, carbon risk also depresses corporate market value by exacerbating financing constraints. From an institutional theory perspective, in the context of China's dual goals of carbon peak and carbon neutrality, local and national governments have strengthened their environmental regulations and emission controls. At the same time, credit resources are gradually being directed toward green and low-carbon sectors. Clearly, this shift imposes an institutional penalty on high-carbon firms. Firms with high emission levels often struggle to obtain fiscal subsidies, green credit or preferential loan rates, thereby resulting in reduced credit availability, shrinking financing channels and shorter maturities. Consequently, the long-term financing capacity of these firms weakens, which in turn generates persistent capital constraints (Ben-Nasr *et al.*, 2025). Chronic capital shortages restrict strategic implementation, technological investment and expansion capabilities, while also diminishing firms' resilience to external shocks, thereby exerting downward pressures on market value. From the perspective of corporate reputation mechanisms, environmental performance plays a critical role in shaping a firm's public image and credibility. Due to their substantial emissions, high-carbon firms are frequently perceived as "high-pollution, high-risk, and low-responsibility" entities in public discourse, media scrutiny and stakeholder evaluations (Le *et al.*, 2025). With the intensification of reputational damage, capital markets downgrade high-carbon firms' creditworthiness and financial institutions become more risk-averse toward them. This deterioration in reputation induces banks to raise loan rates and reduce credit lines; in parallel, creditors and supply-chain finance participants may demand higher collateral and guarantees, magnifying external financing friction (Herbohn *et al.*, 2019). Weakened bargaining power and deteriorating financing terms further impair firms' capital allocation efficiency, exerting sustained downward pressures on market value. From the standpoint of the capital-supply structure, the rise of green finance has created a structural reallocation of capital toward low-carbon, green and sustainable sectors. In effect, a "structural contraction" in financing has been generated for high-carbon firms. In this environment, high-carbon firms face reductions in bank lending, restrictions on bond issuance, equity financing discounts and avoidance by long-term investors. These shifts generate a financing crowding-out effect on the supply side. The resulting structural bias elevates the marginal cost of capital for high-carbon firms and limits their access to stable, long-term, low-cost funding (Ren *et al.*, 2025). Consequently, insufficient financing undermines environmental governance, technological upgrading and structural transition efforts, while simultaneously weakening the expectations of future cash-flow growth. Capital markets respond by applying higher discount rates to high-carbon firms, ultimately leading to a decline in their corporate market value.

Third, by amplifying negative investor sentiment, carbon risk also reduces corporate market value. From a behavioral finance perspective, when analyzing highly uncertain environmental information, investors tend to rely on emotions and heuristic judgments, rather than on a strictly rational analysis (Merton, 1987). Carbon risk is characterized by rapid policy shifts, stringent regulatory penalties and high technological upgrading costs; as such, it is perceived in capital markets as a negative and highly uncertain signal, triggering loss aversion. Under these emotionally driven conditions, investors are prone to undervalue firms' intrinsic worth and engage in sentiment-driven sell-offs. This reinforces the systematic discount applied to high-carbon firms and markedly depresses their market value (Gao *et al.*, 2024). Drawing on the prospect theory, investors exhibit significantly greater sensitivity to potential losses than to equivalent gains. Hence, when confronted with the negative environmental information typically associated with carbon risk, they often display

responses driven by heightened fear. The loss-amplification effect induces investors to overestimate the adverse impact of carbon risk and to price related stocks in an “overshooting” manner (Mei *et al.*, 2025). In capital markets, such loss-sensitive behavior manifests as sentiment-driven selling and excessive reactions to negative environmental events. This often results in deeper and more persistent stock price declines following carbon risk shocks. From the perspective of the sentiment spillover theory and the noise-trading theory, investor sentiment is shaped not only by firm-specific information, but also by broader macro policy dynamics, media coverage intensity and public attention (Bolton and Kacperczyk, 2021). Under the “dual-carbon” agenda adopted by China and other nations, carbon risk has become highly prominent in the media and in the public discourse, and can trigger sentiment spillovers. When public narratives, media reports and policy debates repeatedly link firms with environmental risks, negative sentiment further amplifies investor risk aversion. This results in a deviation of the expectations from fundamental values (Bose *et al.*, 2021). In this process, noise traders’ sentiment-driven behavior contributes to nonfundamental market volatility, increasing the likelihood that market values deviate from firms’ true values. Moreover, sentiment spillovers weaken investors’ confidence in firms’ long-term green transition capabilities, thereby prompting capital markets to systematically downgrade the growth prospects and valuation premium of high-carbon firms. With the accumulation of pessimistic sentiment, firms will experience persistent and structural downward pressures on their market value.

On the basis of this analysis, this study proposed the following hypotheses:

- H1. Higher levels of corporate carbon risk negatively affect firm market value.
- H2. Carbon risk negatively affects corporate market value by increasing operational volatility, tightening financing constraints and amplifying negative investor sentiment.

4. Empirical design

4.1 Variables

4.1.1 Dependent variable. The market value of a listed firm refers to that firm’s total valuation in the stock market. In this study, market value (*lnMV*) was measured as the natural logarithm of the firm’s end-of-period market capitalization.

4.1.2 Independent variable. In this study, *CarbonRisk* was considered as the core explanatory variable. To comprehensively assess firms’ exposure to carbon risk, this study constructed a composite carbon risk index based on three dimensions: carbon intensity (*CI*), environmental penalties (*EP*) and the quality of carbon disclosure (*CDQ*). The weights of these indicators were determined using the entropy method. This composite measure allowed to capture carbon risk exposure from the perspectives of emission levels, regulatory enforcement risk and information transparency. This multi-indicator approach provides a more systematic and holistic assessment of firms’ carbon-related risks than any single indicator.

4.1.3 Control variables. This study draws on the research frameworks proposed by Bissoondoyal-Bheenick *et al.* (2023) and Shin *et al.* (2023) to select control variables. Apart from year and industry fixed effects, the following three categories of controls were included.

Firm-level characteristics:

- Firm size (*Size*) was measured as the natural logarithm of total assets.
- Age was measured as the natural logarithm of a firm’s age, calculated by subtracting the year of establishment from the current year and adding 1.

- Return on assets (*ROA*) is the net profit to total assets ratio, and reflects a firm's profitability.
- Current Ratio (*Cr*) is the current assets to total assets ratio, which was used to measure asset liquidity.

Financial structure:

- Financial leverage (*Lev*) is the firm's total liabilities to total assets ratio, which reflects debt levels.
- Cash flow (*Cflow*) is the ratio of cash flow from operating activities to total assets.
- Earnings per share (*EPS*) was used to measure stock return levels.

Equity structure:

- Equity concentration (*lnTop1*) is the shareholding ratio of the largest shareholder.

4.2 Model design

To examine how carbon risk affects corporate market value, the following panel data model was constructed:

$$\ln MV_{i,t} = \alpha_0 + \alpha_1 CarbonRisk_{i,t} + \alpha_2 Controls_{i,t} + \mu_i + \gamma_t + \varepsilon_{i,t} \tag{1}$$

where $\ln MV_{i,t}$ represents firm market value; $CarbonRisk_{i,t}$ represents firm carbon intensity; $Controls_{i,t}$ represents the control variable; μ_i and λ_t denote the individual fixed effects and time fixed effects, respectively; $\varepsilon_{i,t}$ represents the random error term and α_0 is the constant term. Table 1 presents the descriptive statistics of the key variables. The model includes year and firm fixed effects to control for unobserved heterogeneity, and standard errors were clustered at the firm level.

4.3 Data sources

This study employed a sample of Chinese A-share listed firms, with data taken from 2008 to 2023, to examine the impact of carbon risk on corporate market value. The data used in this research are primarily from the CSMAR database, the Wind database, the *China Industrial Economy Statistical Yearbook* and the *China Energy Statistical Yearbook*.

To ensure data quality and the reliability of empirical results, the sample was refined according to the following criteria: (1) Firms designated as ST or *ST were excluded. (2) Firms in the financial industry were removed. (3) Observations with missing values in key variables were eliminated. (4) All continuous variables were winsorized at the 1% level to mitigate the influence of extreme values. These procedures effectively reduced outlier interference and enhanced the robustness of the statistical inferences. The final sample consisted of 33,006 firm-year observations, covering 3,378 unique firms.

5. Empirical results

5.1 Benchmark regression results

Table 2 presents the baseline regression results; column (1) includes only the core explanatory variable, with no control variables, while column (2) incorporates all control variables. All regressions were controlled for firm and year fixed effects, and the standard errors were clustered at the firm level. As shown in Table 2, the coefficients of the core explanatory variable, *CarbonRisk*, were consistently negative and statistically significant at

Table 1. Descriptive statistics

Variable	Obs	Mean	SD	Min.	Max.
<i>lnMV</i>	33006	22.806	1.218	19.741	28.726
<i>CarbonRisk</i>	33006	0.000	0.005	0.000	0.984
<i>Size</i>	33006	22.265	1.364	17.757	28.697
<i>Age</i>	33006	2.918	0.354	1.099	3.689
<i>ROA</i>	33006	0.040	0.068	-1.856	0.786
<i>Cr</i>	33006	2.579	2.802	0.214	35.501
<i>Lev</i>	33006	0.419	0.204	0.007	0.995
<i>Cflow</i>	33006	0.051	0.069	-0.197	0.263
<i>Eps</i>	33006	0.441	143.362	-1.51e + 04	12306.635
<i>Top1</i>	33006	0.348	0.148	0.075	0.758

the 1% level. This finding clearly indicates that carbon risk substantially reduces corporate market value. In particular, the estimated coefficient of *CarbonRisk* in Column (2) of [Table 2](#) was significantly negative at the 1% level; this indicates that a one-unit increase in carbon risk leads to a 12.44% decrease in corporate market value. This implies that carbon risk is systematically priced by the capital market as a significant valuation discount, rather than as a marginal statistical fluctuation, which demonstrates its clear economic significance. In synthesis, these results provide strong empirical support for Hypothesis *H1*.

Furthermore, we conducted a short sensitivity analysis on the individual components of the carbon risk index by running separate regressions on *CI*, *EP* and *CDQ*, to enhance the reliability of our measurement. As shown in columns (3) and (4) of [Table 2](#), the estimated coefficients for both *CI* and *EP* were significantly negative; this indicates that higher carbon emissions and increased environmental penalties elevate carbon costs and regulatory shocks, thereby substantially depressing firm value. In contrast, column (5) of [Table 2](#) shows a significantly positive coefficient for *CDQ*, suggesting that higher-quality carbon disclosure helps mitigate information asymmetry and market uncertainty, reducing the risk premium and enhancing firm value. These results demonstrate that the individual dimensions of the carbon risk index are economically aligned and mutually reinforcing, thereby validating the rationale and robustness of our composite carbon risk measure.

5.2 Robustness tests

5.2.1 Alternative dependent variable. This study examined whether the results were sensitive to the specific measure of market value. Following [Zhang et al. \(2021\)](#), the original market value indicator was replaced with the *Tobin's Q* ratio. *Tobin's Q* is a classic corporate valuation metric that allows to capture the market expectations of firms' future profitability and growth potential.

The results, presented in column (1) of [Table 3](#), show that the *CarbonRisk* coefficient remained significantly negative at the 5% level. This finding confirms that carbon risk substantially reduces corporate market value, regardless of the valuation measure employed, thus validating the robustness of the main conclusions of this study.

5.2.2 Excluding the COVID-19 period. In 2020, China's economy was severely disrupted by the COVID-19 pandemic. Therefore, business operational data from this period may not be representative of normal economic conditions. Following [Ren et al. \(2022\)](#), to mitigate the potential confounding effects from this pandemic, the sample window of this study was adjusted to the period 2008–2019.

Table 2. Baseline regression results

Variable	(1) <i>lnMV</i>	(2) <i>lnMV</i>	(3) <i>lnMV</i>	(4) <i>lnMV</i>	(5) <i>lnMV</i>
<i>CarbonRisk</i>	-0.1436*** (0.0218)	-0.1244*** (0.0160)	-0.0084** (0.0042)	-0.0708*** (0.0090)	
<i>CI</i>					0.0013*** (0.0004)
<i>EP</i>					0.7766*** (0.0094)
<i>CDQ</i>		0.7797*** (0.0095)	0.7797*** (0.0095)	0.7797*** (0.0095)	0.3212*** (0.0441)
<i>Size</i>		0.3215*** (0.0439)	0.3214*** (0.0439)	0.3215*** (0.0439)	0.7677*** (0.0677)
<i>Age</i>		0.7701*** (0.0679)	0.7698*** (0.0679)	0.7701*** (0.0679)	
<i>ROA</i>		-0.0149*** (0.0017)	-0.0149*** (0.0017)	-0.0149*** (0.0017)	
<i>Cr</i>		0.2296*** (0.0344)	0.2297*** (0.0344)	0.2296*** (0.0344)	0.2340*** (0.0344)
<i>Lev</i>		0.3602*** (0.0380)	0.3607*** (0.0379)	0.3602*** (0.0380)	0.3592*** (0.0379)
<i>Cflow</i>		-0.0000** (0.0000)	-0.0000** (0.0000)	-0.0000** (0.0000)	-0.0000*** (0.0000)
<i>Eps</i>		-0.3571*** (0.0480)	-0.3571*** (0.0480)	-0.3571*** (0.0480)	-0.3615*** (0.0480)
<i>Top1</i>		4.5262*** (0.2284)	4.5507*** (0.2281)	4.5262*** (0.2284)	4.5798*** (0.2266)
<i>Constant</i>	22.8065*** (0.0000)				Yes
<i>Firm/year FE</i>	Yes	Yes	Yes	Yes	Yes
<i>N</i>	33,006	33,006	33,006	33,006	33,006
<i>R²</i>	0.8878	0.9589	0.9589	0.9589	0.9589

Note(s): ***, **, and * denote statistical significance at the 1, 5 and 10% levels, respectively. The values in parentheses are standard errors clustered at the firm level

Table 3. Robustness test results

Variable	(1) Replace the dependent variable <i>Tobin's Q</i>	(2) Excluding the COVID-19 period <i>lnMV</i>	(3) Subsample regression test <i>lnMV</i>	(4) DID <i>lnMV</i>
<i>CarbonRisk</i>	-17.7702** (8.6345)	-0.1231*** (0.0107)	-0.1241*** (0.0171)	-0.0421*** (0.0129)
<i>Treat × Post</i>				4.5383*** (0.2279)
<i>Constant</i>	11.2648*** (0.6827)	5.6613*** (0.2538)	4.5758*** (0.2616)	Yes
<i>Controls</i>	Yes	Yes	Yes	Yes
<i>Firm/year FE</i>	Yes	Yes	Yes	Yes
<i>N</i>	32,997	20,178	26,729	33,006
<i>R</i> ²	0.6142	0.9651	0.9474	0.9590

Note(s): ***, ** and * denote statistical significance at the 1, 5 and 10% levels, respectively. The values in parentheses are standard errors clustered at the firm level

The results, reported in column (2) of Table 3, show that the *CarbonRisk* coefficient was equal to -0.1231 and remained statistically significant at the 1% level. As can be seen, the negative effect of carbon risks persisted even after excluding the impact of COVID-19. This further supports the robustness of the conclusions of this study across different economic periods.

5.2.3 *Subsample regression test.* Manufacturing firms dominate the sample considered in this study, with 26,729 observations (over 80% of the total sample). The characteristics of manufacturing firms may, therefore, have significantly influenced the overall regression results; therefore, this study conducted separate regression tests for manufacturing firms alone.

The results, reported in column (3) of Table 3, show that the *CarbonRisk* coefficient remained significantly negative, a finding that confirms the robustness of the conclusions of this study within specific industries.

5.2.4 *Dual carbon strategy.* This study also introduced an exogenous policy shock, and employed a difference-in-differences (DID) model to better identify the causal relationship between carbon risk and corporate market value. The policy variable for the dual-carbon goals ($Treat \times Post$) was constructed by the interaction term of *Treat* and *Post*. Regarding the measurement of *Post*, *Post* was set to 0 for the period before 2020 and to 1 from 2020 onwards. As for the measurement of *Treat*, firms in heavily-polluting industries were assigned to the treatment group ($Treat = 1$), while firms in nonpolluting industries were included in the control group ($Treat = 0$).

As shown in column (4) of Table 3, the coefficient on $Treat \times Post$ was -0.0421 and was statistically significant at the 1% level. This finding indicates that, following the implementation of China's dual-carbon strategy, the market value of firms in heavily-polluting industries declined significantly relative to that in nonpolluting industries. The dual-carbon policy is exogenous at the firm level, and is not influenced by changes in corporate market value. For these reasons, this shock effectively mitigates concerns regarding potential reverse causality between carbon risk and firm value. The negative policy effect suggests that China's dual-carbon strategy increased the carbon risk exposure of heavily-polluting firms, thereby reducing their market value. This result is consistent with the baseline regression findings, and also provides additional support for the causal interpretation that carbon risk adversely affects corporate market value.

5.3 *Heterogeneity analysis*

5.3.1 *Heterogeneity analysis based on the degree of digital transformation.* Considering that the heterogeneity in firms' digital transformation may affect their ability to respond to carbon risk shocks and sustain market value stability, following Zhao et al. (2021), this study constructed a digital transformation index (*DIGI*) based on keyword disclosures across four dimensions: digital technology application, Internet-based business models, intelligent manufacturing and modern information systems. Keyword frequencies were first standardized, and then weighted using the entropy method. The resulting digital transformation index was scaled by multiplying by 100. Higher values of this indicator corresponded to greater levels of digital transformation.

Table 4 reports the results of the heterogeneity analysis regarding the moderating effect of digital transformation on the relationship between carbon risk and firm value. Both the median-split subsample regressions and the interaction-term regressions were employed to this purpose. Columns (1) and (2) of Table 4 present the results for firms below and above the median level of digital transformation, respectively. The estimated coefficient of *CarbonRisk* for firms with lower levels of digital transformation was significantly negative, indicating that carbon risk suppresses corporate market value. In contrast, the coefficient was positive

Table 4. Heterogeneity results based on digital transformation

Variable	(1) <i>lnMV</i>	(2) <i>lnMV</i>	(3) <i>lnMV</i>
<i>CarbonRisk</i>	−0.1145*** (0.0131)	12.3152 (9.9812)	−2.1898** (0.9189)
<i>CarbonRisk</i> × <i>DIGI</i>			4.6166** (2.0634)
<i>DIGI</i>			0.0101*** (0.0033)
<i>Constant</i>	5.2013*** (0.3121)	4.0595*** (0.3414)	4.6002*** (0.2262)
<i>Controls</i>	Yes	Yes	Yes
<i>Firm/year FE</i>	Yes	Yes	Yes
<i>N</i>	16,238	16,264	33,005
<i>R</i> ²	0.9602	0.9681	0.9590

Note(s): ***, ** and * denote statistical significance at the 1, 5 and 10% levels, respectively. The values in parentheses are standard errors clustered at the firm level

for highly-digitalized firms, suggesting that digital transformation alleviates the adverse effect of carbon risk on firm value.

The results of the interaction-term regression, presented in column (3) of Table 4, show that the coefficient of the interaction term *CarbonRisk* × *DIGI* was significantly positive at the 5% level. In synthesis, the heterogeneity results indicate that the main regression finding – i.e. that carbon risk depresses firm market value – does not hold uniformly across all firms, but rather depends critically on their digital capabilities. More in detail, the value-destroying effect of carbon risk gradually diminishes with the increase in the degree of digital transformation.

Several mechanisms may explain this moderating effect. First, digital transformation enhances firms' capabilities to identify, process and respond to changes in carbon policies and emissions-related information, enabling more timely adjustments in production processes and resource allocation, thereby mitigating the operational volatility and valuation discounts caused by information lags. Second, digital transformation facilitates smart manufacturing and data-driven process optimization, which improve energy efficiency and resource allocation, thus reducing compliance pressures and cost shocks under tightening carbon constraints. Moreover, digital transformation strengthens firms' strategic flexibility and the ability to iterate low-carbon business models; this helps stabilize capital markets' expectations regarding the firms' long-term green transition prospects, and enhances their capacity to absorb external carbon risk shocks while maintaining market value stability. Consequently, higher levels of digital transformation fundamentally bolster firms' resilience to external environmental risks, thereby attenuating the adverse impact of carbon risk on firm market value.

5.3.2 Heterogeneity analysis based on firms' green transformation. This study also examined the heterogeneous effects of firms' green transformation in moderating the relationship between carbon risk and corporate market value. Following Zhou et al. (2022), a green transformation index was constructed, based on 113 keywords related to five dimensions: (1) advocacy and disclosure; (2) strategic orientation; (3) technological innovation; (4) pollution control and (5) monitoring and management. The frequency of each keyword in the text of firms' annual reports was counted, and the natural logarithm of (frequency + 1) was employed to measure firms' green transformation (*Gre*). Based on the median value of this index, the sample was divided into two groups, characterized by low and high green transformation, for subgroup regression. In addition, an interaction term was introduced to assess the moderating role of green transformation in the relationship between carbon risk and firm value, thereby enhancing the robustness of the results.

The results of the heterogeneity analysis based on green transformation are reported in Table 5. Columns (1) and (2) of Table 5 present the regression results for firms with low and high levels of green transformation, respectively. Among those firms with low levels of green transformation, the coefficient of *CarbonRisk* was significantly negative. This finding indicates that carbon risk substantially depresses market value. Conversely, although this coefficient was negative also for those firms with a high green transformation, its magnitude was notably smaller, suggesting that a higher green transformation significantly mitigates the adverse impact of carbon risk. In other words, green transformation exhibited a clear buffering effect. Furthermore, column (3) of Table 5 shows that the coefficient of *CarbonRisk* × *Gre* was significantly negative at the 5% level. This finding is consistent with the subgroup results, and indicates that the higher the degree of green transformation, the weaker the negative effect of carbon risk on firm value.

The underlying reasons of this finding may be as follows. First, firms with a higher level of green transformation are more likely to obtain policy-based resources, such as green credit, tax incentives, technology upgrade subsidies and carbon allowances. This strengthens their ability to hedge rising carbon prices and compliance costs, thereby reducing cash-flow and earnings volatility and mitigating valuation discounts. Second, green transformation is often associated with stronger ESG performance and third-party certifications, which help attract long-term and stable investors. This, in turn, curbs market overreactions to negative environmental information, lowers risk premia and enhances market value resilience. Moreover, those firms with a more advanced green transformation are better positioned to meet the green procurement requirements of core customers, as well as domestic and international sustainability standards. This enables them to secure more stable orders and greater bargaining power, improve revenue predictability and reduce sensitivity to policy and price fluctuations. Collectively, these factors fundamentally attenuate the adverse impact of carbon risk on firm market value.

5.4 Analysis of the influencing mechanisms

5.4.1 Operational volatility mechanism. To test Hypothesis H2, operational volatility was considered as the mechanism variable. Following prior studies, operational volatility (*Volatility*) was measured as the standard deviation of industry-adjusted ROA over the period from *t* – 2 to *t*. ROA was defined as the ratio of net profit to total assets, whereby a higher value indicated greater operational volatility.

Table 5. Heterogeneity results based on green transformation

Variable	(1) <i>lnMV</i>	(2) <i>lnMV</i>	(3) <i>lnMV</i>
<i>CarbonRisk</i>	-37.1837** (17.3911)	-0.1188*** (0.0116)	-42.0175** (20.6517)
<i>CarbonRisk</i> × <i>Gre</i>			13.7594** (6.7836)
<i>Gre</i>			-0.0018 (0.0045)
<i>Constant</i>	5.0533*** (0.3364)	4.4653*** (0.2757)	4.5299*** (0.2285)
<i>Controls</i>	Yes	Yes	Yes
<i>Firm/year FE</i>	Yes	Yes	Yes
<i>N</i>	14,277	18,163	32,976
<i>R</i> ²	0.9505	0.9723	0.9589

Note(s): ***, ** and * denote statistical significance at the 1, 5 and 10% levels, respectively. The values in parentheses are standard errors clustered at the firm level

As shown in Column (1) of Table 6, the coefficient of *CarbonRisk* was significantly positive at the 1% level. This finding confirms that carbon risk increases operational volatility, thereby affecting firm market value. Building on the main finding that carbon risk significantly depresses firm market value, these results reveal a key transmission channel: carbon risk increases operational volatility, which in turn lowers firm market value, thereby providing direct evidence in support of Hypothesis *H2*. Several factors may explain this mechanism. First, stricter carbon emission regulations and rising carbon costs crowd out resources that were originally allocated to production and operations. This makes it more difficult for firms to maintain stable resource structures in the short term. As a result, their performance becomes more sensitive to external shocks, operational volatility is increased and market value is ultimately reduced.

Second, carbon risk introduces additional policy and compliance uncertainty, increasing production, inventory management and supply-chain coordination costs and risks. This heightened instability amplifies profit fluctuations, which are then transmitted into lower firm valuation.

Third, rising operational volatility reinforces capital market uncertainty with regard to firms' future cash flows. Investors, consequently, demand higher risk premia, leading to further discounts on firm market value.

5.4.2 Financing constraint mechanism. To test Hypothesis *H2*, financing constraints were used as the mechanism variable. They were measured using the KZ index, whereby a higher KZ value indicated more severe financing constraints.

The regression results, reported in column (2) of Table 6, show that the coefficient of *CarbonRisk* was significantly positive at the 1% level. This finding indicates that carbon risk significantly increases firms' financing constraints, supporting the mechanism of influence of carbon risk on firm value through the financing channel. The results of the baseline regressions showed that carbon risk significantly depresses firm market value, further indicating that this valuation discount is not incidental, but rather stems from the fact that carbon risk exacerbates firms' financing constraints. Several factors may explain this result. First, the tightening of carbon emission regulations imposes more stringent capital restrictions on high-carbon firms at the institutional level. These restrictions, in turn, lead to a notable contraction in the amount of external financing available to high-carbon firms. The subsequent increase in financing constraints results in insufficient capital accumulation, which ultimately places greater downward pressure on firm market value.

Second, high-carbon firms tend to exhibit poorer environmental performance and suffer reputational damage; this causes financial institutions and investors to have poorer perceptions of the risks of these firms. Consequently, lenders are more likely to raise interest

Table 6. Mechanism test results

Variable	(1) <i>Volatility</i>	(2) <i>KZ</i>	(3) <i>Sentiment</i>
<i>CarbonRisk</i>	0.0055*** (0.0016)	0.4150*** (0.0387)	-18.9185* (9.9920)
<i>Constant</i>	0.2579*** (0.0375)	5.0582*** (0.6428)	1.4205** (0.6348)
<i>Controls</i>	Yes	Yes	Yes
<i>Firm/year FE</i>	Yes	Yes	Yes
<i>N</i>	26,333	33,005	31,617
<i>R</i> ²	0.4913	0.8345	0.4793

Note(s): ***, ** and * denote statistical significance at the 1, 5 and 10% levels, respectively. The values in parentheses are standard errors clustered at the firm level

rates, increase collateral requirements, or directly reduce credit lines, thereby intensifying financing friction and also raising the cost of capital. This constrains firms' investment and operational capacity, weakening their market value.

Third, the development of green finance has led to a structural shift away from high-carbon firms in terms of capital allocation. As a result, these high-carbon firms face increasingly limited access to debt, equity and long-term funding markets. This, in turn, reduces the likelihood of future cash-flow improvement, further contributing to valuation discounts in capital markets.

5.4.3 Investor sentiment mechanism. This study measured investor sentiment following Rhodes–Kropf *et al.* (2005) and Zhang and Zhu (2014). Specifically, firms' market valuation (Tobin's Q) was decomposed into two components: the intrinsic value associated with growth fundamentals, and the mispricing component. The mispricing component, which reflects sentiment-driven valuation deviations, was used as the proxy for investor sentiment and was denoted as "Sentiment."

The regression results, reported in column (3) of Table 6, show that the coefficient of *CarbonRisk* was equal to -18.9185 and was statistically significant at the 10% level. This finding indicates that carbon risk significantly dampens investors' sentiment-driven optimism toward firms, making valuations more susceptible to negative information shocks. These results corroborate the baseline evidence that carbon risk materially depresses firm market value. Several mechanisms may explain this result. First, carbon risk increases the uncertainty surrounding future cash flows. This uncertainty prompts investors to revise downward their subjective expectations of firms' growth prospects when confronted with negative environmental events. Consequently, sentiment-driven valuations are reduced, and market values are depressed.

Second, the tightening of carbon emission regulations and rising carbon costs are perceived by capital markets as loss-related signals. These signals trigger loss aversion and lead investors to overreact to carbon risk, resulting in sentiment-driven selling, deeper mispricing and further declines in firm value.

Third, under China's dual-carbon policy environment, carbon risk exhibits a high media sensitivity and strong amplification effects in public discourse. Negative carbon-related information is more likely to induce sentiment spillovers and excessive pessimism among noise traders. This will cause stock prices to deviate from fundamentals and exert sustained downward pressure on corporate market value.

6. Conclusions and recommendations

6.1 Conclusions

Understanding how carbon risk affects corporate market value is crucial not only to deepen our knowledge of capital market pricing mechanisms under environmental constraints, but also to improve resource allocation efficiency. Using panel data on Chinese A-share listed firms from 2008 to 2023, this study employed a fixed-effects model to empirically examine the impact of carbon risk on corporate market value and carbon risk's underlying mechanisms. The main findings are as follows. First, carbon risk significantly reduces corporate market value; this conclusion remained robust after multiple robustness checks.

Second, carbon risk lowers firm value through three transmission channels: heightened operational volatility, intensified financing constraints and increased negative investor sentiment.

Third, the adverse impact of carbon risk exhibits significant heterogeneity. Specifically, higher levels of digital transformation and green transformation effectively mitigate the negative effects of carbon risk on corporate market value.

6.2 Policy recommendations

Based on the abovementioned research findings, the following targeted recommendations were proposed to effectively mitigate the negative impact of carbon risks' on corporate market value. First, at the firm level, given that carbon risk significantly depresses firm market value, primarily through operational volatility, financing constraints and negative investor sentiment, firms should develop resilient business practices guided by the principle of stabilizing operations, cash flows and expectations. Firms should strengthen operational risk management by optimizing their energy structures, advancing energy-saving measures and upgrading their production processes to reduce emissions and cost volatility, thereby enhancing their capacity to withstand tightening carbon policies and rising carbon costs. Digital and green transformation should be embedded as key protective mechanisms against carbon risk within corporate decision-making. In fact, digital monitoring and data governance improve carbon information transparency and traceability, facilitate cross-departmental coordinated decision-making and enable rapid responses to changes in carbon costs, mitigating operational volatility and stabilizing market expectations. At the same time, investments in green technology research and development and low-carbon process upgrades can reduce carbon intensity and compliance pressures, enhance the ability to secure green orders and long-term capital support, alleviate financing constraints, restore investor confidence and maintain stable firm valuation.

Second, at the government and financial institution level, carbon risk not only represents an environmental constraint, but also affects resource allocation efficiency and macroeconomic welfare through adjustments in firm value and investment behavior. To this respect, governments and financial institutions should strengthen the coordination among regulation, information and finance to mitigate the financial amplification of carbon risk. More in detail, banks and other financial institutions should incorporate firms' carbon performance, governance capacity and transformation investments into credit approval and risk pricing, providing differentiated financing support. Moreover, green finance and transition-oriented lending can help firms alleviate financing constraints and avoid curtailing productive investment. Furthermore, capital market regulators and intermediaries should enhance their disclosure standards, verification quality and professional interpretation of carbon information, so as to reduce investor sentiment-driven mispricing and excessive volatility. Governments should also use fiscal incentives and green finance policies to guide firms in developing digital infrastructure and green technological upgrades, reducing transformation costs and uncertainties and promoting a transparent, financeable and transformative pathway for value restoration, thereby enhancing market stability and long-term resource allocation efficiency.

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