

# Review of Corporate Carbon Risk and Its Management under the "Dual Carbon" Goal

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**Abstract:** 2026 marks the 10th anniversary of the Paris Agreement, during which the global carbon neutrality transition has achieved remarkable structural progress. As a responsible major country, China has elevated the "Dual Carbon" goals to a national strategic height and repeatedly clarified them in key government documents. Against this backdrop, China's Dual Carbon regulation has become increasingly stringent, exposing enterprises to multi-dimensional uncertainties from policies, technologies, and markets—academically defined as "carbon risk". In this case, clarifying the specific impacts and inherent logic of carbon risk on enterprises is crucial for providing practical and actionable insights for corporate risk management. This paper systematically reviews existing literature. It summarizes carbon risk's connotation and mainstream measurement methods, analyzes its heterogeneous impacts on enterprises' core activities of financing, operation, and investment, discusses feasible paths for carbon risk management optimization, and finally summarizes relevant research findings and offers prospects for future studies.

**Keywords:** Carbon Risk; Carbon Risk Management; Porter Hypothesis; Literature Review

## 1. Introduction

Since the formal adoption of the Paris Agreement in 2016, the number of countries setting carbon neutrality goals has increased from 1 to 165, the global issuance scale of green bonds has grown more than 10 times, and the carbon neutrality transition has achieved structural breakthroughs. As a responsible major country, China has elevated the "Dual Carbon" goals to the national strategic level, and has repeatedly issued public statements,

clearly proposing to actively and steadily advance carbon peaking and realize carbon neutrality. However, against this backdrop, risks related to carbon emissions have continued to accumulate—meaning the carbon risk faced by enterprises is gradually intensifying, exerting a significant impact on their financing, operation, investment, and other operational activities. The strengthening of regulation and rising market attention will further amplify these impacts. Therefore, clarifying the connotation of carbon risk, as well as the economic consequences and operational mechanisms of its impacts on enterprises, holds substantial research value. By systematically sorting out and summarizing existing literature on carbon risk, this paper provides a theoretical reference for subsequent in-depth studies.

## 2. The Connotation and Measurement of Carbon Risk

### 2.1 The Connotation of Carbon Risk

There is no unified consensus in academia on the connotation of carbon risk. With the deepening of relevant research, its meaning and classification have been continuously expanded, forming multi-perspective definitions. In the early stage of the concept's emergence, academia mostly viewed carbon risk from a financial perspective. A widely recognized definition was proposed by Hoffmann and Busch, who defined carbon risk as the magnitude of changes in a firm's carbon-related monetary performance over a specific period—specifically, the degree to which the financial impacts arising from a firm's carbon use and emissions change within a given time frame [1]. As research advanced, academic understanding of carbon risk has become more comprehensive. It is no longer perceived from a single perspective but rather as a combination of diverse risks during the low-carbon transition.

Jung categorized carbon risk as a subset of environmental risk, specifically referring to "all corporate risks associated with climate change or fossil fuel use," including regulatory risk, physical risk, and operational risk [2]. Gorgen held a similar view, arguing that carbon risk refers to all positive and negative impacts on corporate value arising from carbon emission-related uncertainties as enterprises transition from a high-carbon to a low-carbon economy [3]. In essence, carbon risk is an uncertainty risk inherent in the transition process, encompassing multiple sources such as changes in policy regulation, shifts in market preferences, and technological substitution. It is not only related to enterprises' current carbon emission levels but also linked to their adaptive capacity in responding to the low-carbon transition, ultimately exerting a systemic impact on enterprises' stock returns, cash flow expectations, and market valuations.

## 2.2 The Measurement of Carbon Risk

Accurate measurement of carbon risk is the foundation of relevant research. Influenced by factors such as data availability and industry characteristics, scholars at home and abroad have formed differentiated measurement systems, which can be specifically divided into the following two categories:

Foreign studies focus on direct emission data, considering both absolute and relative dimensions, with more diverse measurement methods that align with enterprises' actual emission characteristics. The direct method focuses on carbon emissions themselves, directly using the scale of corporate carbon emissions as a proxy variable for carbon risk, under the assumption that higher emissions indicate higher carbon risk exposure. Some studies refer to the Greenhouse Gas Protocol, measuring carbon risk using three types of emissions: direct production emissions, indirect emissions from purchased energy, and other indirect emissions such as those from the supply chain [4]. The relative method constructs carbon intensity indicators to reflect carbon emission levels per unit of output or asset, with a typical indicator being the ratio of tons of carbon dioxide equivalent to annual sales revenue.

However, the situation in China is different, mainly due to the difficulty in obtaining accurate carbon emission data. Therefore,

Chinese scholars usually adopt the following methods to measure carbon risk: First, approximate estimation based on industry energy consumption. Due to the lack of direct carbon emission data, some domestic scholars have verified the short-term value-enhancing effect of carbon emission trading on low-carbon intensity enterprises by calculating industry carbon intensity [5]. Second, indirect measurement using proxy variables. Some studies use market data such as trading volume, turnover, and carbon price indices of carbon exchanges, or carbon emission violation penalty types and dummy variables to indirectly reflect carbon risk levels. Third, quantitative measurement through evaluation models. Some scholars use SVM machine learning models to achieve carbon risk assessment and early warning; others use Python crawlers to extract carbon risk keywords from corporate social responsibility reports released by Chinese industrial listed companies and construct quantitative models to measure corporate carbon risk [6].

Another approach is to conduct quasi-natural experiments using turning-point policies. Some studies regard environmental regulation policies such as the new Environmental Protection Law and the Ambient Air Quality Standards (2012) as carbon risk-related shocks. However, such policies are mostly limited to specific industries or regions, making it difficult to fully reflect the overall impact of carbon risk [7,8]. In addition, China's signing of the Paris Agreement in 2016, a strong carbon regulatory signal, has been regarded by some studies as an important turning point for corporate carbon risk. A quasi-natural experiment is constructed using the difference-in-differences method to indirectly measure the policy transmission effect of carbon risk.

## 3. The Economic Consequences of Carbon Risk

Enterprises' core operational activities cover three dimensions: financing, operation, and investment. To clarify the specific microeconomic impacts of carbon risk on enterprises, we can analyze the operational logic of carbon risk's impact on each activity from these three perspectives. A review of existing literature shows that there is no unified academic consensus on whether carbon risk exerts a positive or negative impact in these

three core operational areas—which is a typical manifestation of the "Porter Hypothesis Puzzle" in the carbon field.

In terms of financing, the mainstream view holds that capital markets consider carbon risk as an important factor in pricing financing, pushing up corporate financing costs through both debt and equity channels. Some viewpoints suggest that carbon risk significantly increases enterprises' debt financing costs, as creditors require additional risk premiums to hedge against carbon risk [2]. Some scholars have focused on the carbon emission trading market, an important mechanism for enterprises to reduce emissions and improve efficiency. It has attracted the attention of capital market investors to enterprises' carbon emission issues, thereby affecting investors' risk assessment and value judgment of enterprises, ultimately significantly increasing enterprises' cost of equity capital [9]. However, carbon risk may also play a positive role in enterprises' financing behaviors—for example, adjusting financial decisions to reduce internal financial risks, hedging against the gradual increase in external carbon risk, and thus better adapting to green development. Some scholars have found that carbon-intensive enterprises significantly reduced their financial leverage after the signing of the Paris Agreement; this effect is more pronounced in state-owned enterprises and enterprises with high financing constraints. At the same time, carbon risk also compresses the debt maturity structure and inhibits the "short-term borrowing for long-term investment" behavior [10].

In terms of operation, the "Porter Hypothesis Puzzle" also exists. Carbon risk ultimately affects corporate value by influencing operational activities. For enterprises, carbon risk may not only bring operational challenges, increase operational costs, and reduce corporate value but also force green transformation, achieve long-term development, and thereby drive value enhancement. As carbon risk receives increasing attention from policies and markets, enterprises must operate within regulated boundaries to ensure their operational activities comply with environmental regulatory requirements and respond to market expectations. This will undoubtedly increase enterprises' operational costs and may even require adjusting corporate strategies to cope with carbon risk. Therefore, carbon risk may

affect core business profits and reduce corporate value by increasing operational costs, including compliance costs and penalty costs. However, some studies argue that when facing carbon risk, enterprises will actively disclose carbon information as a response. High-quality disclosure reduces information asymmetry, which has a positive impact on corporate value—and this promotion effect is more significant for enterprises with higher carbon emissions [11].

In terms of investment, carbon risk increases the environmental uncertainty faced by enterprises, making them more likely to make inefficient investments and reduce investment efficiency. Based on data from Chinese industrial enterprises, some scholars have confirmed that carbon risk causes enterprises' investments to deviate from the optimal level—either reducing necessary investments due to risk aversion or triggering over-investment due to blind transformation, ultimately leading to inefficient investment [6]. However, many studies have also proven that carbon risk forces enterprises to increase green and environmental protection investments [12].

In summary, a review of existing literature shows that carbon risk has multi-dimensional impacts on enterprises' three core operational activities: financing, operation, and investment. However, whether in the financing dimension, the operational dimension, or the investment dimension, academia has not yet reached a unified consensus on the direction of its impact. This controversy constitutes the core manifestation of the "Porter Hypothesis Puzzle" in the carbon field, which awaits further clarification through future research.

#### 4. The Management of Carbon Risk

Carbon risk management is a key support for the implementation of the Dual Carbon goals and a core means for enterprises to adapt to green transformation and achieve sustainable development. Its core logic lies in balancing the potential losses and transformation opportunities brought by carbon risk through a full-cycle closed-loop management of "risk identification—assessment—response."

Essentially, it is the dynamic optimization of enterprises' operational decisions in the context of low-carbon transformation. Effective carbon risk management can not only help enterprises avoid direct losses such as policy penalties and

brand depreciation but also promote enterprises to tap new growth drivers in technological innovation and resource allocation, realizing a transformation from "passive compliance" to "active value creation," and laying a micro-foundation for the overall advancement of the Dual Carbon goals.

Based on the systematic review of the connotation, measurement methods, and economic consequences of carbon risk in the previous sections, the practical advancement of carbon risk management faces two core challenges. On the one hand, there are inherent obstacles to the quantitative measurement of carbon risk. As mentioned earlier, carbon risk is not only linked to enterprises' carbon emission levels but also a comprehensive risk covering multiple factors, with significant complexity and diversity in its connotation. At the measurement level, although some enterprises have carried out carbon emission disclosure and mastered direct data, long-term and full-chain emission monitoring requires continuous investment in human and technological costs, which is difficult for small and medium-sized enterprises to fully cover. On the other hand, the impact of carbon risk on enterprises' three core operational activities is characterized by significant complexity and uncertainty. As summarized in the previous analysis of economic consequences, in the financing field, carbon risk may not only push up debt and equity financing costs but also force enterprises to optimize their financial structures; at the operational level, it may not only increase compliance and transformation costs but also enhance corporate value through information disclosure; in the investment link, it may not only trigger inefficient investment but also drive green investment transformation. This two-way impact echoes the manifestation of the "Porter Hypothesis Puzzle" in the carbon field, further increasing the difficulty of management decisions.

Existing research provides theoretical support and practical references for carbon risk management from multiple perspectives. Based on the "carbon value chain" theory, some studies propose that enterprises should build low-carbon competitiveness from three dimensions: internal emission reduction potential, cost transfer capacity, and carbon asset management capacity. Through strategies combining carbon footprint management, full-

life-cycle emission accounting, direct emission reduction and indirect emission reduction, enterprises can achieve the synergy of risk control and competitiveness enhancement. Targeting the special risks in the carbon financial field, relevant research has identified four core types of risks: policy risk, credit risk, operational risk, and market risk. It is proposed that a multi-level policy and regulatory system, a full-cycle mechanism of pre-prevention, in-process resolution, post-event accountability, and cross-departmental regulatory coordination should be established to prevent the impact of risks such as carbon price fluctuations and default fraud on markets and enterprises. Additionally, empirical research has verified the transmission mechanism of "carbon risk awareness—low-carbon innovation—carbon performance," finding that carbon risk awareness positively promotes enterprises' low-carbon patent innovation and process innovation, and low-carbon innovation plays an incomplete mediating role between carbon risk awareness and carbon performance. This provides direct evidence for enterprises to cope with carbon risk through internal capacity building.

## 5. Conclusion

A comprehensive review of existing literature shows that although research on carbon risk has formed a preliminary framework, there are still three core deficiencies. First, the measurement and quantification of carbon risk face significant challenges. Constrained by data availability, methods such as direct measurement, indirect proxy, and policy quasi-natural experiments each have limitations, and a unified and universal comprehensive measurement system has not yet been formed. Second, there is significant uncertainty in the research conclusions on the economic consequences of carbon risk. There is no unified academic consensus on the direction of its impact on the three core activities of financing, operation, and investment, which reflects the core connotation of the "Porter Hypothesis Puzzle." Third, research on carbon risk management is relatively weak and fragmented. Most existing studies focus on the identification and impact of carbon risk, with few systematic discussions on management strategies. Moreover, these studies are mostly limited to a single dimension—either focusing

on enterprises' internal emission reduction technologies and governance mechanisms or focusing on carbon financial market risk prevention and control. There is a lack of research on an integrated management framework of "internal capacity building—external resource integration", making it difficult to effectively guide enterprises in coping with complex and diverse carbon risks. To address the above deficiencies, future research can be further deepened from three aspects. First, improve the carbon risk measurement system. On the one hand, digital technology and big data can be used to expand carbon emission data acquisition channels and build a comprehensive evaluation index system covering enterprises' production, supply chain, policy response, and other dimensions. On the other hand, optimize the adaptability of measurement methods in combination with industry heterogeneity and enterprise characteristics—for example, designing differentiated risk assessment models for high-carbon and low-carbon industries to improve the accuracy and practicality of measurement results. Second, deepen the research on the mechanism of carbon risk's economic consequences. Future research can further explore the boundary conditions of carbon risk's impact on enterprises' operational activities, focusing on the regulatory role of heterogeneous factors such as enterprise ownership, industry attributes, and strategic types. Third, construct a systematic carbon risk management framework. Future research can integrate internal governance and external collaboration perspectives to explore differentiated management models for different types of enterprises. At the same time, strengthen research on the synergistic effect of policy tools and market mechanisms, analyze how carbon trading markets, green financial instruments, and environmental regulatory policies can form a joint force with enterprises' internal management strategies, and provide enterprises with operable and implementable integrated risk management solutions to support the sustainable transformation of enterprises under the Dual Carbon goals.

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