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Supply Chain Finance and Corporate Zero-Carbon Transition: An Empirical Study from China

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Abstract

This study examines the impact of supply chain finance on corporate zero-carbon transition using data from Chinese A-share listed companies from 2008 to 2023. Through text analysis, this study constructs a corporate zero-carbon transition index containing 285 keywords and a supply chain finance indicator based on a specialized dictionary. The results show that supply chain finance significantly promotes corporate zero-carbon transition, and the findings remain robust after a series of robustness and endogeneity tests. Further analysis indicates that the promoting effect is more pronounced among non-heavy-polluting firms, firms located in eastern regions, and firms with relatively weaker bargaining power within supply chains. Mechanism analysis reveals that supply chain finance mainly facilitates zero-carbon transition by alleviating financing constraints, stimulating green technological innovation, and improving green supply chain management practices. It should be noted that the text-based indicators primarily reflect firms' strategic disclosures and may not fully capture the actual implementation of zero-carbon practices. Overall, this study provides empirical evidence on the green governance role of supply chain finance and offers policy implications for advancing coordinated decarbonization across supply chains.

Keywords: supply chain finance; corporate zero-carbon transition (CZT); financing constraints; green technology innovation; green supply chain management; Scope 3 emissions

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1. Introduction

The global climate governance system is undergoing a paradigm shift. In 2023, the global average temperature approached the 1.5 °C threshold established by the Paris Agreement, intensifying physical climate risks. Simultaneously, economic and financial consequences have escalated: the World Bank reports an average annual economic loss of $223 billion from climate-related disasters during 2020–2023, representing a 152% increase compared to the previous decade. These trends highlight that climate change is not merely an environmental issue but also a systemic economic challenge that reshapes trade rules, industrial competition, and corporate strategies.

In response, major economies are increasingly integrating carbon emission constraints into industrial and supply chain policies. The European Union's Carbon Border Adjustment Mechanism (CBAM) incorporates carbon intensity into trade rules, the United States has strengthened carbon footprint requirements through legislation, and China's "dual-carbon" strategy has enhanced disclosure and management requirements at the supply chain level. These policy measures collectively signal a shift in carbon governance focus from individual firms to entire supply chains, with Scope 3 emissions—indirect emissions along value chains—emerging as a critical concern. Existing studies show that Scope 3 emissions often constitute a substantial portion of a firm's total carbon footprint and may exceed direct operational emissions in some sectors, underscoring the urgency of chain-wide decarbonization.

Despite policy support, small and medium-sized enterprises (SMEs) that form the backbone of global supply chains face persistent challenges in implementing low-carbon transitions. Key bottlenecks include financing constraints, fragmented ESG standards, and the complexity of managing multi-tier Scope 3 emissions. Traditional green finance instruments primarily favor large firms, limiting SMEs' access to long-term, high-risk, low-carbon initiatives.

Supply Chain Finance (SCF) provides a potential solution. By integrating trade, logistics, information, and capital flows, SCF alleviates financing constraints, encourages green technological innovation, and facilitates collaborative carbon management. When aligned with sustainability performance, SCF evolves into Sustainable Supply Chain Finance (SSCF), linking financing terms to performance indicators such as carbon reduction and ESG ratings, and providing preferential access for high-performing suppliers. International practices illustrate its effectiveness through sustainability-linked financing, project-based funding, and carbon-footprint-linked loans.

These innovations demonstrate that SCF extends beyond financing support to act as a hub connecting technology, capital, and industry, fostering a self-reinforcing zero-carbon innovation ecosystem. By integrating capital, information, and carbon flows, SCF supports the transition from R&D to commercialization and promotes resilient supply chain management.

This study contributes in three ways. First, it examines SCF as a financial innovation driving corporate zero-carbon transition, extending research on SCF's economic impacts to national carbon neutrality strategies. Second, it incorporates Scope 3 emissions into the analytical framework, establishing a chain credit-sharing mechanism to overcome the bottleneck of core firm credit failing to transmit to N-tier suppliers, thereby addressing gaps in multi-tier penetration, blockchain traceability, and collaborative optimization. Third, it evaluates the moderating role of macro-support conditions, providing evidence of how SCF can facilitate a low-carbon transition across the real economy. Overall, this research offers empirical insights for firms leveraging SCF to achieve zero-carbon transition and provides a theoretical and practical paradigm for building resilient, sustainable, and compliant supply chains.

2. Literature Review

2.1. Supply Chain Finance and Corporate Development

Supply chain finance (SCF) is defined as "a financial service that revolves around core enterprises to manage the cash flow and logistics of upstream and downstream SMEs, transforming the uncontrollable risks of individual enterprises into controllable risks of the entire supply chain, and achieving risk control through information integration" (Chen Xiangfeng, 2023) [1]. As an innovative intersection of the supply chain and finance domains, current international research on SCF primarily unfolds from two perspectives. The first is finance-oriented, viewing SCF as a set of financial solutions provided by financial institutions aimed at facilitating the exchange of goods and information within the supply chain, accelerating capital flow, enhancing capital availability, and reducing financing costs. The second perspective is supply-chain-oriented, emphasizing collaboration among supply chain members. It expands the boundaries of SCF beyond financial solutions to include synergy among related members for inventory optimization, incorporates supply chain processes into collaborative solutions, and reduces Scope 3 carbon emissions.

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As the "lifeblood" for enterprise development, the supportive role of SCF is increasingly evident. Existing research primarily focuses on two areas. Firstly, SCF addresses enterprise financing challenges through resource integration and risk mitigation. SMEs are major drivers of economic development but face significant financing constraints due to their small asset size and lack of sufficient collateral (Han Zhongxue and Zhao Jinpeng, 2025) [2]. SCF mitigates this by leveraging the credit transmission of core enterprises, converting the overall creditworthiness of the supply chain into capital for SMEs (Wu Jinfeng, 2025) [3]. For instance, reverse factoring allows SMEs to obtain financing without collateral, often at lower costs than traditional models (Cheng Junqi and Qi Yongxing, 2025) [4]. With advancements in blockchain technology, some scholars argue that SCF utilizes blockchain's immutable transaction records to reduce credit risk (Yan Yanqiu and Sun Yurui, 2025) [5]. Furthermore, innovations like green notes and carbon asset pledges have enriched risk mitigation tools (Yang Xiaoye, 2020) [6]. Based on the widespread application of network governance via bank e-commerce platforms, some researchers suggest that integrating operations and finance into supply chain management can address information asymmetry, high monitoring costs, and lack of qualified collateral, thereby reducing lending risks in SCF (Chen et al., 2019) [7].

Secondly, SCF promotes industrial chain synergy and efficiency enhancement. Studies indicate that SCF can improve overall supply chain efficiency through information sharing and process optimization (Zhang Yong and Tian Yajie, 2025) [8]. Some scholars posit that SCF fosters interdependent, symbiotic relationships among participants and an ecosystem for value co-creation. It utilizes the influence diffusion mechanism of core enterprises to help "disadvantaged" members alleviate financial pressure and improve capital flexibility, effectively solving the funding constraints of SMEs (Song Hua et al., 2018) [9]. Concurrently, SCF can lead to higher inventory turnover rates and improved on-time order delivery for firms on the chain (Zhou Lei et al., 2024) [10]. A notable example is Haier Group's "Green Chain Financing" platform, which leverages the core enterprise's credit to integrate the financing needs of over 500 upstream and downstream suppliers, achieving efficient matching of capital flow and logistics within the supply chain (Liu Haohua and Yu Zhongfa, 2025) [11].

2.2. Corporate Zero-Carbon Transition Research

Corporate zero-carbon transition, serving as a central pathway for achieving the "dual-carbon" goals (carbon peaking and carbon neutrality), has become a significant focus within both academic and practical circles. Existing research primarily explores this theme along three dimensions: theoretical foundations, driving mechanisms, and practical pathways.

Regarding theoretical foundations, corporate zero-carbon transition is defined as "a strategic process of achieving net-zero emissions across entire operations through systemic change" (Pan Jiahua et al., 2023) [12]. This conceptual framework encompasses two core dimensions. The first involves a fundamental transformation of the energy structure, requiring a significant increase in the share of renewable energy. For instance, the Chongqing Zero-Carbon Park achieved clean energy substitution through large-scale photovoltaic deployment (Xia Yuan, Dong Cun Chun, 2025) [13]. Developed economies in Europe, the US, and Japan are shifting from traditional fossil fuel-dependent geoeconomic systems towards renewable energy production technology and industrial chain frameworks by strengthening green technology R&D and cultivating green industries (Li Huiming, Chen Wenshuo, 2025) [14]. The second dimension entails deep decarbonization of production processes, realized through the adoption of green technology innovation and cleaner production models (Zhang et al., 2023) [15]. This involves employing end-of-pipe treatment technological innovations to manage pollutant emissions, enabling waste reuse, alongside pursuing clean technology innovation to improve equipment efficiency from the source, thereby achieving carbon reduction and emission mitigation (Lü Hongjun et al., 2025) [16].

Research on driving mechanisms analyzes transition motivations from the perspectives of policy support and technological push. Studies indicate that governments, as creators and regulators of market rules, play a crucial role in zero-carbon development. Government financial support is an effective incentive for encouraging firms to balance financial performance with socio-environmental responsibilities (Sarfraz M, Ozturk I, Yoo S, et al.) [17]. Environmental policies can stimulate urban green technology innovation (Chen et al., 2022; Cheng et al., 2019; Qi et al., 2021; Qiu et al., 2021; Ding et al., 2025) [18–22]. The Low-Carbon City Pilot policy has proven effective by alleviating financial constraints (Zou et al., 2022; Sun, D. and Li, Y., 2025) [23,24], providing tax incentives and government subsidies (Ma et al., 2021; Zhao et al., 2022) [25,26], and enhancing overall urban technological innovation capacity, significantly impacting utility model patents and green patents (Zou et al., 2022) [23]. Green technology innovation, a key driver for transitioning to a low-carbon economy, plays an increasingly vital role (Razzaq et al., 2022; Hao et al., 2022; Deng and Chen, 2026) [27–29]. Compared to general technological innovation, green technology innovation emphasizes resource conservation and environmental protection, effectively enhancing resource and energy efficiency (Wicki and Hansen, 2019) [30]. Improving energy efficiency is considered essential for zero-carbon transition. Green technology innovation can promote the widespread use of green renewable energy, advancing the development and application of clean energy (Razzaq et al., 2021; Xin et al., 2022) [31,32]. Furthermore, green technology innovation in the energy sector helps mitigate constraints posed by traditional energy consumption, reduces the cost of using green energy, and facilitates a shift in the energy consumption structure towards low-carbon and clean energy sources (Dong et al., 2022) [33].

2.3. Research on SCF and Corporate Zero-Carbon Transition

As research deepens, the role of supply chain finance (SCF) in driving corporate zero-carbon transition is increasingly recognized. Scholars have begun to focus on the green efficacy of SCF, suggesting that the development of green supply chain finance can significantly enhance corporate carbon reduction performance. For instance, studies on chemical industrial parks indicate that SCF promotes the application of low-carbon technologies and facilitates zero-carbon construction within the parks (Zhao Xiaofei and Yang Xinye, 2025) [34]. Furthermore, by exploring the relationship between SCF and corporate digital technology innovation, research finds that digital technology innovation can substantially improve the service efficiency of SCF and its effectiveness in fostering green transformation (Song Yuchen and Zhu Mingqi, 2024; Sun, D. and Li, J., 2025) [35,36]. Concurrently, digital supply chain finance has also been shown to positively influence corporate low-carbon transition by promoting the adoption and diffusion of green low-carbon technologies, highlighting the supporting role of information technology in this process (Tong Peng and Wang Ke, 2024) [37]. Examining the impact of climate risks on corporate green innovation, studies also emphasize the moderating role of SCF in mitigating climate risks and stimulating green innovation (Liao, 2025; Alabbosh, 2024; Cui, 2024; Wattoo, 2025; Sun, D. and Luo, Q., 2026) [38–42].

3. Theoretical Background and Hypotheses

The benefits of supply chain finance in promoting corporate zero-carbon transition are mainly concentrated in three areas: corporate financing, technological innovation, and supply chain collaboration. Corporate zero-carbon transition commitment (CZT), as a strategic signal, directs internal resources and attention toward sustainable operations, thereby driving the adoption of specific green supply chain management (GSCM) practices. The implementation of GSCM contributes to overall corporate zero-carbon performance by optimizing material flows and reducing systemic environmental risks. Based on this, the present study adopts a supply chain finance perspective to examine the pathways through which supply chain finance influences corporate zero-carbon transition via these three mechanisms.

3.1. SCF and Corporate Financing

Resource Dependence Theory posits that an organization's dependence on external resources is determined by the criticality and scarcity of those resources. The technological investments required for zero-carbon transformation are characterized by high capital intensity and long payback periods (e.g., the investment payback period for green power equipment is approximately 5–8 years). Given their financial fragility, Small and Medium-sized Enterprises (SMEs) often struggle to secure necessary funding through traditional channels. In this context, supply chain finance (SCF) becomes a critical external resource. By leveraging the credit endorsement of core enterprises, SCF enables SMEs to transcend their own resource constraints, facilitating an "external injection" of the funds essential for transformation (Cai et al., 2024) [43].

As a self-liquidating trade finance instrument, supply chain finance (SCF) leverages the creditworthiness of core enterprises to significantly enhance information transparency within the supply chain. By building upon actual supply chain transactions, SCF reduces information asymmetry in the financing process and provides upstream and downstream firms with a wider array of financing options (Song et al., 2017) [44]. These firms can leverage assets such as accounts receivable, advance payments, and inventory—all tied to the core enterprise—to secure external financing through various SCF models like accounts receivable financing, advance payment financing, and inventory pledge financing. This facilitates timely access to funds, lowers financing costs, and alleviates financing constraints (Xiong et al., 2009; Sun, 2024) [45,46]. Furthermore, SCF promotes direct connections with logistics and warehousing systems and the opening of data interfaces. This offers banks and other financial institutions real-time, accurate transaction data, broadening their channels for obtaining corporate information and mitigating information asymmetry between banks and enterprises (Tseng et al., 2019) [47]. Consequently, it fosters a mutually beneficial and symbiotic "new-type bank-enterprise relationship" [48], ultimately reducing the financing costs for small and medium-sized enterprises.

3.2. SCF and Corporate Technological Innovation

Innovation is a long-term investment process. Green innovation is characterized by substantial capital requirements, extended payback periods, and high risks (Rennings, 2000; del Río, 2009) [49,50]. Particularly in imperfect markets, the dual externality of green innovation means that sustaining such activities requires continuous financial support. Supply chain finance (SCF) can effectively leverage "relational effects" and "financing effects" at the innovation level, providing critical information and capital flows for corporate green transformation activities (Gozgor et al., 2023; Li and Wu, 2025) [51,52].

On the one hand, core enterprises, by virtue of their strong operational and innovative capabilities, occupy a central position in the supply chain's innovation structure (Cheng L, Wu L, 2025) [53]. When there is a need to drive increased green innovation among upstream and downstream partners, SCF utilizes mutually beneficial models to leverage the "relational effect." This facilitates the integration and transmission of innovation resources, thereby synergistically enhancing innovation across the entire supply chain (Agca et al., 2022; Chen, Tian, and Yu, 2022; Chiu et al., 2019; Kolay et al., 2016;

Pandit et al., 2011) [54–58]. Consequently, even other enterprises within the chain can fully access the technology and knowledge resources necessary for green transformation and maintain a high intensity of green innovation investment.

New growth theory posits that the continuous accumulation of knowledge, technology, and talent within enterprises can drive increasing returns for different types of firms (Sun Zheyuan and Bai Yan, 2024) [59]. SCF contributes to this by ensuring adequate corporate funding, enabling timely payment of employee wages and benefits, and potentially improving compensation packages. This helps attract specialized talent who bring innovative resources into the firm's production layout (Jin Chengxiao and Yu Jiaqi, 2023) [60], meeting the demands for sustained innovation required by the zero-carbon transition. Firms that strengthen their commitment to zero-carbon transition (high CZT) convey a clear strategic priority signal to internal R&D departments, which may lead to increased allocation of internal budgets or external "green credit" support. This, in turn, incentivizes and facilitates substantive green R&D activities, ultimately reflected in an increase in the number of green patent applications and grants. This positive incentive mechanism encourages continuous technological breakthroughs within enterprises.

3.3. SCF and Supply Chain Collaboration

From the perspective of supply chain management theory, Supply Chain Finance (SCF) enables small and medium-sized enterprises (SMEs) to better coordinate interest conflicts within the supply chain and optimize its overall liquidity (Ali et al., 2019) [61]. It facilitates the formation of a community of interests and a pooled interdependence relationship among supply chain members (Hofmann and Zumsteg, 2015) [62]. This allows for the sharing of resources within the supply chain network, enabling value co-creation through supply chain integration, reducing risks associated with corporate transformation, and thereby accelerating the zero-carbon transition process.

For SMEs, the supply chain network plays a critical role in accessing external resources (Song Hua and Lu Qiang, 2017) [44]. The network connectivity inherent in SCF promotes resource flow and helps firms acquire complementary assets—both tangible and intangible—from partners, thereby expanding the utilization boundaries of external resources and mitigating the inherent weaknesses of SMEs to enhance their specialization levels. Furthermore, as key suppliers and distributors become embedded within the supply chain network, SMEs engage in frequent business cooperation with core enterprises. This interaction, underpinned by transactional and financial linkages, fosters a strong-tie community of interests, which enhances trust and stabilizes supply chain relationships (Gelsomino et al., 2016) [63].

Consequently, SCF not only facilitates production collaboration between large firms and SMEs, allowing each to leverage their respective advantages, but also enables them to share the high value-added benefits arising from collaborative production (Du and Xue, 2024) [64]. This incentivizes SMEs to develop specialized capabilities and enhances synergy within the industrial supply chain. Through these mutually beneficial models, SCF leverages the "relational effect" to integrate and disseminate innovation resources, thereby driving synergistic innovation across all major entities in the supply chain (Huang et al., 2022; Wang, A., et al., 2024; Wang, F., et al., 2025; Wei et al., 2023; Yang et al., 2024; Sun, J.; Zhai, N.; Miao, J.; et al., 2022) [65–70]. As a result, even non-core enterprises within the network can gain sufficient access to the technology and knowledge required for the zero-carbon transition, sustaining a high level of green innovation investment.

Based on the above discussion, this paper proposes the core hypothesis:

H1. *Supply chain finance has a positive promoting effect on corporate zero-carbon transition.*

According to resource dependence theory, firm development depends on access to critical external resources. Zero-carbon transition requires sustained financial investment, yet small and medium-sized enterprises often face significant financing constraints due to limited collateral and information opacity.

Supply chain finance alleviates these constraints by leveraging the credit of core firms and transforming transaction information into verifiable credit signals. This reduces information asymmetry and financing costs, enabling firms to access external funding through supply chain relationships. As a result, firms gain more stable and affordable financial support, strengthening their capacity and willingness to invest in zero-carbon transition.

H2. *Supply chain finance promotes corporate zero-carbon transition by alleviating financing constraints.*

According to innovation and green development theories, technological innovation is a key driver of low-carbon transition. However, green innovation involves high costs, long cycles, and considerable risks, making sustained investment difficult without stable financial support.

Supply chain finance supports innovation through both financing and network effects. It provides stable funding that reduces uncertainty in R&D investment, while also strengthening supply chain linkages, facilitating knowledge sharing and technological diffusion. These effects lower innovation costs and improve resource allocation efficiency, thereby enhancing firms' green innovation capabilities and accelerating zero-carbon transition.

H3. *Supply chain finance promotes corporate zero-carbon transition by enhancing green technological innovation.*

According to supply chain management theory, firm performance depends on overall supply chain coordination. Zero-carbon transition, particularly involving Scope 3 emissions, requires joint efforts across supply chain partners.

Supply chain finance strengthens economic linkages and information sharing, fostering trust and long-term collaboration among firms. It also facilitates resource integration, enabling access to technologies, managerial expertise, and low-carbon solutions. These effects improve supply chain coordination and promote collective emission reduction, allowing firms to shift from isolated actions to system-wide optimization.

H4. *Supply chain finance promotes corporate zero-carbon transition by enhancing supply chain collaboration.*

4. Research Design

4.1. Sample Selection and Data Sources

This study selects A-share listed companies on the Shanghai and Shenzhen stock exchanges from 2008 to 2023 as the initial research sample. The sample was processed as follows: financial firms and ST/*ST companies were excluded; observations with missing key variables were removed; only continuous samples with no missing data for at least five consecutive years were retained; and all continuous variables were winsorized at the 1st and 99th percentiles to mitigate the influence of outliers. After processing, the final sample consisted of 27,879 firm-year observations. Patent data were sourced from the CSMAR database. Data pertaining to corporate zero-carbon transition were primarily collected from the annual reports and corporate social responsibility (CSR) reports of the sample companies.

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4.2. Variable Definition

4.2.1. Explained Variable

Corporate Zero-Carbon Transition (CZT). Based on the national "dual-carbon" strategy, this study assumes that information related to corporate zero-carbon transition is systematically reflected in strategic disclosure documents, such as annual reports and corporate social responsibility reports. Keywords such as "green patents," "carbon emission intensity," "zero carbon," and "emission reduction targets" can serve as textual indicators for identifying corporate zero-carbon strategies and implementation progress. Following the approaches of Xiang et al. (2023) [71] and Wu & Li (2022) [72], we quantify the extent of corporate zero-carbon transition using a word frequency analysis method.

The preliminary selection of keywords is based on major guiding policy documents, including the Guiding Opinions of the State Council on Accelerating the Establishment of a Green, Low-Carbon, and Circular Economy System and the 13th Five-Year Development Plan for National Environmental Protection Standards. Initial "seed words" were extracted from these policy documents and relevant literature. Based on the full-process characteristics of corporate transition, the keywords were classified into two dimensions: environmental strategy and environmental action. Environmental strategy keywords include "green planning," "environmental assessment," "ecological protection," "zero-carbon parks," and "product carbon footprint management," while environmental action keywords include "technological upgrading," "pollution compensation," and "green supply chain."

Building on machine learning methods, we first extracted terms highly associated with the initial keywords and incorporated them into the keyword set. Next, using Python 3.9's Jieba segmentation tool, we conducted keyword searches and matching across the full texts of listed companies' annual reports. Since manual screening alone cannot cover all relevant expressions in the reports, a machine learning–based semantic analysis was applied to identify additional terms that are contextually and semantically closely related to the seed words. Ultimately, the frequency of each keyword (285 in total) was computed for each annual report.

The resulting corporate zero-carbon transition index is designed to capture both the strategic emphasis and systematic disclosure of corporate zero-carbon initiatives. This index not only reflects an important dimension of transition depth but also serves as an early indicator of potential substantive actions. To validate its content, we conducted a content validity check: the 285-keyword library was derived from national guiding documents and further expanded semantically using machine learning algorithms. Covering both environmental strategy and environmental action dimensions, the keyword library comprehensively reflects the full-process characteristics of corporate zero-carbon transition, ensuring representativeness. This supports the proposition that "the higher the keyword frequency, the greater the firm's strategic commitment and overall progress toward zero-carbon transition."

To address potential information incompleteness due to reporting lags, we applied a rolling-window approach, calculating the arithmetic average of keyword frequencies for each focal year and the preceding and subsequent years, thereby smoothing temporal deviations. Furthermore, to eliminate scale effects caused by differences in text length, keyword frequencies were divided by the total word count of the annual report, producing a standardized corporate zero-carbon transition intensity indicator, which enhances comparability across years and firms.

4.2.2. Explanatory Variable

Supply Chain Finance (LnSCF). Following Zhang Lina et al. (2022) [73] and building on the different descriptions of supply chain finance (SCF) keywords in Gelsomino et al. (2016) [63], Chaku et al. (2019) [74], Parida et al. (2022) [75], and Huang et al. (2022) [76], this study innovatively applies a keyword frequency–based quantitative approach to measure corporate SCF levels. Drawing on the word frequency counting method commonly used in digital transformation research and incorporating existing literature, SCF activities and products are categorized into four types: accounts receivable–based, prepayment–based, inventory–based, and comprehensive, with more detailed keyword dictionaries presented in Table 1. The frequency of all keywords appearing in a firm's annual report was counted. To ensure the scientific validity and comparability of the indicator, we did not simply sum the raw frequencies of all keyword categories; instead, a standardized relative frequency density was calculated. Moreover, to satisfy the normality assumption of regression models and mitigate heteroscedasticity, the standardized values were log-transformed (natural logarithm), yielding the explanatory variable LnSCF, which serves as the measure of a firm's supply chain finance development level.

Table 1. Supply Chain Finance Keywords.

Category	Keywords
Receivables-based	Accounts receivable financing, factoring finance, reverse factoring, dynamic discounting, accounts receivable securitization
Prepayments-based	Prepayment financing, future warehouse receipt financing, right-of-pledge financing, confirmatory warehouse financing
Inventory-based	Movable asset pledge financing, inventory pledge financing, inventory financing, stock financing, spot pledge financing, warehouse receipt financing, purchase order financing, raw material financing
Comprehensive	Supply chain finance, supply chain financing, supply chain fund, supply chain investment, supply chain loan, supply chain management, trade credit, financial supply chain, supplier finance, buyer finance, supplier managed inventory, buyer investment, distributor financing, working capital management, logistics finance, unified credit financing, financial value chain, working capital optimization

4.2.3. Control Variables

Drawing on the research methods of Ling Runze, Zhang Lina, Zhao Danni, et al. the following control variables that may influence corporate green transition are included to improve the accuracy of the empirical regression and reduce endogeneity bias caused by omitted variables: Firm Age (Age), Tobin's Q, CEO/Chairman Duality (Dual, coded as 1 if the same person holds both positions, otherwise 0), Firm Size (Size, logarithm of total assets), Return on Assets (ROA), Number of Employees (Employ, logarithm), and Firm Age (FirmAge). Additionally, following the study by Minzhe D., Jorge A., Peter W., et al., (2022) [77], which indicate that low-carbon pilot cities significantly affect ecological efficiency, a dummy variable representing low-carbon pilot status is incorporated as a control in the baseline regression model. Whether the city is a low-carbon pilot city (Dlcc, A dummy variable equal to 1 for low-carbon pilot cities and 0 for all other cities).

4.3. Model Specification

Equation (1) is established to investigate the core relationship between supply chain finance and corporate zero-carbon transition:

$$\mathrm{CZT}_{\mathrm{i,t}} = \varphi + \varphi_1 \mathrm{LnSCF}_{i,t} + \sum \varphi CVs + \sum Year + \sum Ind + \varepsilon \quad (1)$$

where *i* and *t* denote firm and year, respectively. CZTit represents the zero-carbon transition intensity of firm in year t. LnSCFit denotes the level of supply chain finance development for firm in year t. *CVs* represents the set of control variables. *Ind* and *Year* represent industry and year fixed effects, respectively, included to absorb unobservable macro-shocks and industry characteristics as much as possible. ε is the error term.

5. Empirical Results and Economic Interpretation

5.1. Baseline Regression

The baseline regression results for the "Supply Chain Finance—Corporate Zero-Carbon Transition" relationship are presented in the table below. A progressive regression approach was adopted. Column (1) includes two-way fixed effects for year and industry. Column (2) further incorporates the relevant control variables.

The empirical results show that the regression coefficients for corporate supply chain finance are positive (0.0499 and 0.0390, respectively) and statistically significant at the 1% level. The slight reduction in the coefficient in column (2) may be due to some factors affecting zero-carbon transition being absorbed by the control variable set, but the direction and significance of the effect remain unchanged. This supports the hypothesis that "supply chain finance has a positive promoting effect on corporate zero-carbon transition."

Variables	(1) CZT	(2) CZT
SCF	0.0499 *** (7.12)	0.0390 *** (5.57)
Size		0.135 *** (13.43)
ROE		0.273 *** (4.18)
ROA		−0.385 *** (−2.66)
Dual		0.00792 (0.70)
TobinQ		0.00592 (1.48)
FirmAge		−0.0448 (−0.95)
Employ		0.00000225 ** (2.13)
Dlcc		0.126 *** (12.05)
_cons	1.365 *** (60.43)	−1.3919 *** (−6.15)
Year/Ind FE	YES	YES
N	27,879	27,879
R^2	0.320	0.328

Note: *** $p < 0.001$, ** $p < 0.01$; t-statistics in parentheses.

In this study, we mainly examine "stability" through robustness tests, alternative variable definitions, and model specification comparisons, which differs from the formalized chaos theory analysis method adopted by Kyurkchiev, N.; Zaevski, T.; Iliev, A.; et al. (2026) [78].

5.2. Robustness Tests

To ensure the robustness of the regression results, this study conducts a series of robustness tests on the baseline regression model, including: (1) excluding specific subsamples to mitigate the impact of unobservable special factors; (2) replacing the explanatory variable, Given the variations in the measurement of supply chain finance (SCF) across existing studies, and to ensure the accuracy of the experimental findings, this paper refers to the approach of Ling Runze, Pan et al. (2020) [79] to redefine the measure of supply chain finance for robustness testing; (3) controlling for high-dimensional fixed effects, which is a key method for addressing omitted variable bias and heterogeneity interference; and (4) addressing endogeneity using instrumental variable (IV) methods, the Heckman two-stage model, and a placebo test to strengthen the reliability of the core findings.

5.2.1. Subsample Exclusion

As shown in Table 2, this section excludes specific samples to reduce potential omitted variable bias. Given the two major exogenous shocks during the sample period—the 2015 stock market crash and the 2020 COVID-19 pandemic—we exclude observations from these years to isolate their extreme impacts. Furthermore, considering the significant economic disparities between eastern and non-eastern regions in China, which may lead to differences in SCF development and zero-carbon transition behaviors, we exclude firms located in the eastern region. Additionally, since zero-carbon transition in high-tech industries is highly dependent on technological breakthroughs and policy subsidies—where SCF instruments might be substituted by zero-carbon mandates from core firms—we exclude this sector to avoid interference from this specific mechanism. After excluding these respective samples, the regression coefficients for SCF remain positive and statistically significant (at least at the 5% level), indicating that the core conclusion—"SCF promotes corporate zero-carbon transition"—remains unchanged.

Table 2. Robustness Tests: Subsample Exclusion/Variable Replacement.

Variable	Excl. 2015 Crash	Excl. 2020 COVID-19	Excl. Eastern Region	Excl. High-Tech Sector	Alternative SCF Measure
	(1)	(2)	(3)	(4)	(5)
SCF	0.0406 *** (5.66)	0.0434 *** (5.80)	0.0486 *** (5.98)	0.0344 *** (3.39)	0.0378 *** (3.15)
Controls/Year/Ind FE	Yes	Yes	Yes	Yes	Yes
N	22,867	21,782	17,150	12,293	21,335
R^2	0.3300	0.3339	0.3250	0.3407	0.2948

Standard errors in parentheses; *** $p < 0.001$.

5.2.2. Alternative Explanatory Variable Measurement

Given the lack of a unified standard for measuring supply chain finance (SCF) levels, traditional indicators may fail to identify whether a firm genuinely conducts supply chain finance services. To address the "words exceed deeds" issue and ensure the accuracy of empirical results, this study follows the approach of Ling Runze et al. (2021) [80] to re-measure corporate SCF. Specifically, we first searched for the company name combined with keywords such as "supply chain finance," "supply chain financing," and "supply chain management" using the Baidu search engine to identify news reports mentioning the company. This allowed us to determine whether the firm provides SCF services to upstream and downstream partners in the supply chain.

Next, we conducted text analysis of listed companies' annual reports to perform a secondary screening of core supply chain firms engaged in SCF. If a firm explicitly discloses that it provides SCF services to upstream and downstream enterprises, it is classified as conducting SCF in the capacity of a core supply chain firm. Subsequently, we excluded firms in the online and information services sector, internet-related services, firms for which the business start year could not be clearly determined, cases where the substantive nature of the business could not be ascertained, or firms with missing data that could not be manually obtained.

We then defined a dummy variable, "whether the firm conducts supply chain finance (SCF)," where SCF equals 1 if the firm engages in SCF and 0 otherwise. The results are presented in Table 1. Even when the dependent variable is measured differently, the estimated coefficient of SCF remains significantly positive at the 1% level, indicating the robustness of the baseline regression results.

5.2.3. High-Dimensional Fixed Effects

Although the baseline regression controls for year and industry fixed effects, it might still omit important variables influencing both SCF and corporate zero-carbon transition. Therefore, following Yang Jinyu et al. (2022) [81], this study further incorporates year-region interaction fixed effects to control for time-varying environmental factors at the regional level. The results, shown in Table 3 below, indicate that the estimated coefficient for SCF remains significantly positive after including these high-dimensional fixed effects, reaffirming the main hypothesis.

Table 3. Controlling for High-Dimensional Fixed Effects.

Variables	(1) CZT	(2) CZT
SCF	0.0403 *** (6.35)	0.0384 *** (5.92)
Size	0.105 *** (20.58)	0.104 *** (20.43)
ROA	−0.656 *** (−4.32)	−0.694 *** (−4.60)
ROE	0.306 *** (3.92)	0.316 *** (4.22)
Dual	−0.00661 (−0.71)	−0.00412 (−0.43)
TobinQ	−0.0192 *** (−5.14)	−0.0198 *** (−5.04)
FirmAge	−0.112 *** (−8.03)	−0.107 *** (−7.45)
Employ	0.00000119 * (2.01)	0.00000125 * (2.09)
_cons	−0.0856 (−0.71)	−0.0593 (−0.51)
Year/Ind FE	Yes	Yes
Year#Region FE	Yes	Yes
N	27,879	27,878
R^2	0.380	0.395

Standard errors in parentheses; *** $p < 0.001$, * $p < 0.05$.

5.2.4. Addressing Endogeneity: Instrumental Variable Approach

As shown in Table 4, given that the regression results might be affected by omitted variables, reverse causality, and measurement errors, this study employs an IV approach to further test Model (1) and mitigate endogeneity concerns. We select the one-period lagged SCF variable and a dummy indicating whether the firm is located in a pilot city for SCF as instruments, and re-estimate the model using two-stage least squares (2SLS). The lagged SCF is a standard choice in dynamic panel models, as historical SCF levels are not affected by current carbon emissions, effectively addressing reverse causality. The pilot city policy, as a quasi-natural experiment, has been shown to be exogenous in many studies. The combination captures both temporal dynamics and cross-sectional variation due to policy shocks, providing dual identification. The results indicate that both instruments in the first-stage regression are statistically significant, confirming their relevance. Tests for weak instruments and identification also confirm the validity of the chosen instruments. In the second-stage regression, the coefficient of the core explanatory variable (SCF) remains positive and significant at the 1% level, consistent with the baseline results, suggesting that the main conclusion holds after controlling for endogeneity.

Table 4. Addressing Endogeneity: Instrumental Variable Approach.

	(1) SCF	**(2) GI**
L.SCF	0.4570 *** (0.0063)	
Pilot City	0.0812 * (0.0440)	
SCF		0.0567 *** (0.0169)
Size	0.0700 *** (0.0091)	0.1338 *** (0.0113)
ROA	−0.0268 (0.1318)	−0.3900 ** (0.1609)
TobinQ	0.0023 (0.0036)	0.0002 (0.0044)
Employ	0.0000 ** (0.0000)	0.0000 (0.0000)
FirmAge	−0.0937 ** (0.0453)	−0.0682 (0.0553)
Dual	0.0164 (0.0101)	0.0000 (0.0124)
ROE	−0.0611 (0.0587)	0.2685 *** (0.0717)
Anderson canon. corr. LM statistic	4198.981 (0.0000)	
Cragg-Donald Wald F statistic	2625.557 [19.93]	
N	24,215	23,881
R^2	0.3087	0.3240
Adjusted R^2	0.1967	0.2253

Standard errors in parentheses; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$; Note: The value in square brackets [] for the Cragg-Donald Wald F statistic in column (1) is the critical value at the 10% level of the Stock-Yogo test.

5.2.5. Addressing Endogeneity: Heckman Two-Stage Model

Based on the results from the Heckman two-stage model, the core explanatory variable (SCF) continues to exert a significantly positive influence on the dependent variable, with a coefficient of 0.0533 significant at the 1% level. This indicates that SCF significantly promotes corporate zero-carbon transition. Notably, the coefficient of the Inverse Mills Ratio (IMR) is 0.479 and also significant at the 1% level, confirming the presence of significant sample selection bias. This implies that the sample selection is non-random, and endogeneity arises from unobserved factors. Therefore, correcting for this bias using the Heckman two-stage model is necessary. This adjustment effectively mitigates the interference of endogeneity, making the estimated relationship between SCF and zero-carbon transition more reliable. The model has a large number of observations (28,112) and a high R-squared (0.706), indicating strong explanatory power and further supporting the robustness of the conclusion. The specific regression results are shown in Table 5.

Table 5. Endogeneity Test: Heckman Two-Stage Model.

	(1) GI_dum	**(2) GI**
SCF	0.0554 *** (4.2663)	0.0533 *** (7.4705)
Size	0.1747 *** (16.9950)	0.1822 *** (16.8394)
ROA	−1.4904 *** (−5.0041)	−0.8923 *** (−5.9434)
TobinQ	−0.0276 *** (−3.5401)	−0.0007 (−0.1717)
Employ	−0.0000 (−0.7765)	0.0000 (1.2569)
FirmAge	−0.1518 *** (−5.2786)	−0.1052 ** (−2.2836)
Dual	−0.0191 (−1.0095)	0.0025 (0.2168)
ROE	0.6998 *** (4.7376)	0.4850 *** (7.2073)
Inverse Mills Ratio (imr)		0.4788 *** (10.8377)
_cons	−4.0191 ***	−2.2703 ***
	(−16.4271)	(−8.5265)
Firm FE (Id.fe)	Yes	Yes
Year FE (Year.fe)	Yes	Yes
N	28,328	28,112
R^2	0.2199	0.706

Standard errors in parentheses; *** $p < 0.001$, ** $p < 0.01$.

5.3. Heterogeneity Analysis

Traditional economic models often assume firms are "homogeneous agents," but in reality, firms differ in resource endowments, institutional pressures, and positions within the supply chain. Full-sample regressions only reflect the "average effect" and might mask significant variations across subgroups. From a firm perspective, the direction and quality of financial products offered through SCF can vary. From a supply chain perspective, a firm's position (upstream/downstream) and its relationships within the chain influence its economic activities. Spatially, regional differences in policies and economic conditions can lead to varying impacts of SCF on zero-carbon transition. Therefore, this paper conducts heterogeneity analysis from three dimensions: industry attributes, supply chain bargaining power, and geographical region. The specific regression results are summarized in Table 6 below.

Table 6. Heterogeneity Analysis Results.

Variable	Industry Attribute		Supply Chain Bargaining Power		Region	
	Heavy Polluting	Non-Heavy Polluting	High Bargaining Power	Low Bargaining Power	Eastern Region	Non-Eastern Region
	(1)	(2)	(3)	(4)	(5)	(6)
SCF	0.0294 (1.94)	0.0436 *** (5.52)	0.0291 ** (2.27)	0.0452 *** (5.24)	0.0486 *** (5.98)	0.0098 (0.70)
Controls/Year/Ind FE	Yes	Yes	Yes	Yes	Yes	Yes
N	6298	17,961	6030	17,046	17,150	7078
R^2	0.6589	0.7203	0.7703	0.7060	0.7117	0.7047

Standard errors in parentheses; *** $p < 0.001$, ** $p < 0.01$.

Columns (1) and (2) of Table 6 show that regarding industry attributes, the SCF coefficient is significantly positive at the 1% level for non-heavy polluting firms, but insignificant for heavy polluting firms. This heterogeneity finding challenges the linear perception that "the heavier the pollution, the stronger the financial intervention," suggesting that the effectiveness of green financial instruments is highly contingent on the intrinsic techno-economic characteristics and transition logic of the industry. To illustrate this heterogeneity, we use the electronics manufacturing and biopharmaceutical industries as representative examples of non-heavy-polluting sectors. In these industries, supply chain finance (SCF) can effectively drive zero-carbon transition. The underlying mechanism is that corporate transition activities are largely concentrated in the electrification and digitalization of production processes and green supply chain management (e.g., green packaging, low-carbon logistics). These investments typically have short cycles and clear return pathways. For example, a consumer electronics firm may leverage accounts receivable financing to quickly introduce automated production lines, reducing per-unit energy consumption. The investment payback period is often within 1–3 years; although this does not perfectly match the typical maturity of mainstream SCF products (usually less than one year), rolling financing can bridge the gap. This enables SCF to flexibly and swiftly support incremental innovation, rapidly translating into green patents or energy efficiency improvements, forming a virtuous cycle of "financing—R&D—emission reduction—market value creation."

In contrast, in heavily polluting industries such as steel, cement, and basic chemicals, the driving effect of SCF is not significant. The deep-rooted reasons are closely related to the industry's inherent "technology-capital dual path lock-in" and the financial characteristics of SCF products themselves. First, the core production assets in these industries (e.g., blast furnaces, cement kilns) are highly asset-specific and have long physical renewal cycles, often spanning 5–8 years or more. Deep decarbonization requires breakthrough technologies such as hydrogen-based steelmaking or carbon capture and storage (CCS), which involve large-scale investment, high technical risk, and long payback periods. Second, current SCF products, such as accounts receivable factoring and inventory financing, are essentially short-term liquidity tools designed to optimize working capital. Their maturity structures (typically less than one year), risk pricing models, and trustee-managed payment arrangements focus on trade authenticity and certainty of fund recovery, making them ill-suited to support long-cycle, high-risk, capital-intensive green technological upgrades. Consequently, even when heavily polluting firms access SCF funding, under existing incentives and constraints, the funds are more likely to be allocated to "end-of-pipe" interventions (e.g., desulfurization or denitrification equipment upgrades) or marginal efficiency improvements in existing processes, rather than fundamental technological substitution capable of achieving systemic decarbonization. This results in a scenario where SCF in heavily polluting industries appears to "exist" but is effectively "ineffective"—it optimizes operational ecosystems but cannot penetrate the entrenched barriers to transformation.

Columns (3) and (4) indicate that the promoting effect is stronger for firms with lower supply chain bargaining power. A possible explanation is that these firms face coercive pressure from core firms, which may impose carbon intensity clauses, transferring emission reduction pressure down to weaker suppliers. Faced with a "reduce or be eliminated" choice, low-bargaining-power firms are compelled to prioritize allocating SCF funds towards green technological upgrades. Conversely, firms with high bargaining power may have already exhausted low-cost reduction options (e.g., energy efficiency), and face technological barriers for deep decarbonization, leading to diminishing marginal utility of SCF funds.

Columns (5) and (6) reveal a significantly positive SCF coefficient for firms in the eastern region but an insignificant effect for non-eastern firms. This disparity could be due to cluster network effects in the east, where low-carbon technology sharing pools allow SCF funds to flow rapidly to innovation nodes, shortening the technology conversion cycle. Additionally, the eastern region benefits from relatively mature carbon trading markets and supportive financial policies, reducing financing costs and aiding technological emission reduction. In non-eastern regions, insufficient IoT coverage might lead to data gaps, forcing financial institutions to rely solely on financial statements for lending decisions. This could cause SCF to devolve into traditional working capital loans, losing its emission reduction orientation.

5.4. Mechanism Tests

Previous empirical findings confirm a significant positive effect of SCF on corporate zero-carbon transition, with heterogeneity analyses revealing variations across regions, industries, and supply chain positions. However, the specific pathways through which SCF exerts its influence remain unclear. This section, drawing on the approach of Wen Zhonglin et al. (2004) [82], employs a stepwise regression model ("three-step method") to empirically unpack the "black box" of mechanisms linking SCF to corporate zero-carbon transition, analyzing the following three channels.

5.4.1. Test of the Mediating Effect of Financing Constraints

This section examines the transmission mechanism between supply chain finance and corporate zero-carbon transition from the perspective of financing constraints. Following Hadlock and Pierce (2010) [83], the SA index ($SA = -0.737 \times Size + 0.043 \times Size^2 + 0.04 \times Age$) is used to measure financing constraints, with the SA index from the year before engaging in supply chain finance serving as the indicator. A larger SA index value signifies a higher degree of financing constraints faced by the firm. The results, presented in Table 6, show that supply chain finance significantly alleviates financing constraints at the 1% level. The regression coefficient between financing constraints and corporate zero-carbon transition is significantly negative at the 1% level, indicating that lower financing obstacles are associated with a higher degree of zero-carbon transition. Simultaneously, supply chain finance continues to exert a significant positive effect on zero-carbon transition at the 1% level. These findings confirm that financing constraints play a partial mediating role, supporting the main hypothesis.

The study posits that firms commonly encounter limitations in internal financing and external channels during zero-carbon transition. Supply chain finance addresses the credit gap for SMEs by leveraging the credit of core enterprises. This "leverage effect" allows upstream and downstream firms to share the core enterprise's credit rating, lowering entry barriers for SMEs and reducing credit risk for financial institutions through risk sharing, thereby alleviating financing constraints. Furthermore, supply chain finance mitigates information asymmetry in credit markets. Core enterprises act as "information hubs," transmitting real trade background and performance data of upstream and downstream partners to banks. This shifts credit assessment from relying on single-firm assets to evaluating the overall supply chain credit, fostering closer bank-firm relationships, broadening financing channels for firms on the chain, and ultimately easing their financing constraints. By alleviating financing constraints, supply chain finance releases internal funds, providing crucial financial support and risk resilience for zero-carbon transition, thus driving the process forward. The specific regression results are shown in Table 6.

5.4.2. Test of the Mediating Effect of Corporate Technological Innovation

This section investigates the internal mechanism through which supply chain finance influences corporate zero-carbon transition from the perspective of green innovation output. The empirical results demonstrate that the development of supply chain finance significantly increases the number of green invention patent applications (the coefficient for SCF is statistically significant), and the enhancement of green innovation capability further promotes the zero-carbon transition process (the coefficient for GT is also significant). This suggests that supply chain finance provides crucial support for corporate green innovation activities by fostering a more efficient innovation ecosystem.

Specifically, firms can utilize the capital coordination and business linkage functions inherent in supply chain finance to enhance supply chain stability, promote the integration and flow of green innovation knowledge, and effectively control cost risks during the innovation process. Under this mechanism, firms' R&D resources can be more focused on green technology fields, thereby improving the green conversion efficiency of R&D investments. Green technological innovation serves as the foundational driver for achieving a comprehensive corporate green transition, providing a sustained and solid basis for it.

5.4.3. Test of the Mediating Effect of Green Supply Chain Management

This section tests the transmission mechanism between supply chain finance and corporate zero-carbon transition from the perspective of green supply chain management (GSCM). The results indicate that supply chain finance significantly enhances GSCM at the 1% level. The regression coefficient between GSCM and corporate zero-carbon transition is significantly positive at the 5% level, while the relationship between supply chain finance and zero-carbon transition remains significantly positive at the 1% level. This confirms that supply chain finance promotes zero-carbon transition by advancing GSCM, demonstrating the partial mediating role of GSCM (Table 7).

GSCM encompasses full-lifecycle carbon management from raw material procurement to product recycling, focusing particularly on addressing Scope 3 emissions. Based on the resource orchestration theory, this paper argues that supply chain finance assists firms in orchestrating low-carbon resources by optimizing capital allocation, thereby activating GSCM capabilities and ultimately achieving zero-carbon goals. As achieving zero-carbon targets emphasizes the importance of Scope 3 emissions, GSCM becomes a core tool for addressing Scope 3 by systematically managing environmental responsibilities across the supply chain. It requires suppliers to disclose carbon data and builds end-to-end carbon traceability systems through digital tools, resolving the "visibility black hole" of Scope 3 emissions. The input from supply chain finance drives GSCM capabilities from point-based breakthroughs to ecological synergy. By integrating order, logistics, and energy consumption data on supply chain finance platforms, a supply chain carbon information pool is constructed, enabling real-time monitoring of transportation carbon emissions, optimizing the GSCM system, improving overall chain carbon efficiency, and propelling corporate zero-carbon transition.

Table 7. Mechanism Test Results (Financing Constraints/Green Patents/Supply Chain Collaboration).

Variable	(1) SA	(2) GI	(3) GT	(4) GI	(5) GSCM	(6) GI
SCF	−0.0064 *** (−9.54)	0.0479 *** (5.40)	−0.015 * (−2.25)	0.0405 *** (6.32)	0.0093 *** (8.67)	0.0315 *** (4.51)
SA		−0.1806 *** (−2.71)				
GT				0.1435 ** (2.56)		
GSCM						0.0928 * (2.15)
Sobel Test	10.4040 ***		3.9896 ***		6.1857 ***	
Controls/Year/Ind FE	Yes	Yes	Yes	Yes	Yes	Yes
N	27,893	26,523	27,789	26,692	25,822	26,823
R^2	0.0061	0.0231	0.0357	0.0284	0.0083	0.0125

Standard errors in parentheses; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

6. Research Conclusions and Policy Implications

Against the backdrop of accelerating global climate governance and the low-carbon restructuring of industrial chains, this study empirically examines the impact of supply chain finance (SCF) on corporate zero-carbon transition using a sample of Chinese A-share listed firms from 2008 to 2023. The main findings are as follows.

First, SCF has a significantly positive and robust effect on corporate zero-carbon transition. Baseline regressions indicate a significant positive effect of SCF on firms' zero-carbon transition index, robust to endogeneity checks (IV approaches, Heckman two-stage model) and multiple robustness tests. SCF thus constitutes an effective financial instrument for corporate green transformation.

Second, the effect of SCF on zero-carbon transition exhibits notable heterogeneity. SCF's impact varies across industries, supply chain positions, and regions: it is stronger in non-polluting sectors, for firms with lower bargaining power, and in eastern regions, highlighting the role of industry characteristics and institutional environments.

Third, mechanism analysis reveals three primary channels through which SCF facilitates corporate zero-carbon transition. SCF facilitates zero-carbon transition through three channels: alleviating financing constraints, promoting green technological innovation, and enhancing green supply chain management. These channels form a "financial support–technological innovation–supply chain coordination" loop.

Finally, it should be noted that the text-based indicators used in this study mainly capture firms' strategic disclosures in annual and CSR reports. Although content validity has been carefully examined, potential measurement bias due to discrepancies between "words and actions" may still exist. Future research could incorporate actual emissions data or micro-level behavioral data to provide a more precise assessment of corporate zero-carbon transition.

In summary, this study provides robust empirical evidence on the role of SCF in promoting corporate zero-carbon transition, enriches the literature at the intersection of

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green finance and supply chain governance, and offers new insights into coordinated decarbonization across multi-tier supply chains.

Based on the above findings, this study proposes the following policy implications.

First, policymakers should improve the sustainable supply chain finance (SCF) system and strengthen targeted financial support for corporate green transition. By incorporating SCF into the broader green finance framework, regulators can encourage financial institutions to provide more effective financing support for enterprises' low-carbon transformation, particularly for small and medium-sized firms. At the same time, unified carbon information disclosure standards and digital technologies should be promoted to improve the transparency and reliability of supply chain environmental data.

Second, differentiated financial instruments should be developed according to industry characteristics and regional development levels. For heavily polluting industries with high capital demand and long transition cycles, medium- and long-term green financing instruments should be expanded to support deep decarbonization. Meanwhile, greater efforts are needed to improve green finance infrastructure and professional services in less-developed regions, thereby narrowing regional disparities in SCF effectiveness.

Third, enterprises should strengthen their own green transition capabilities and promote coordinated supply chain governance. Core firms should integrate carbon performance requirements into procurement and financing decisions, while enterprises more broadly should increase investment in green technological innovation and shift from compliance-oriented to strategy-oriented sustainability management. Through stronger collaboration among firms, financial institutions, and regulators, SCF can better facilitate coordinated emission reduction and sustainable development across supply chains.

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