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Analysis on the Influence Mechanism of Supply Chain Finance on Enterprises' Green Technology Innovation

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Abstract: Green technological innovation serves as the driving force for enterprises' green transformation and high quality development, and supply chain financing provides guarantees for green technological innovation. Taking Chinese A share listed firms on the Shanghai and Shenzhen stock exchanges from 2012 to 2024 as research samples, this paper empirically analyzes the impact effect and mechanism of supply chain finance on corporate green technological innovation from the perspective of financing optimization, by employing the two way fixed effect model and the mediation effect model. The empirical results show that: ① Supply chain finance significantly improves the level of enterprises' green technological innovation, and this conclusion remains valid after a series of robustness tests; ② Supply chain finance affects corporate green technological innovation by alleviating financing constraints, empowering enterprises' digital transformation, controlling risk fluctuations, and improving carbon information disclosure; ③ The driving effect of supply chain finance on green technological innovation is more pronounced for firms in the growth stage, technology intensive enterprises and labor intensive enterprises. The research conclusions offer scientific empirical evidence and decision making references for guiding enterprises' green innovation development via supply chain financing, provide a basis for governments to formulate relevant policies, and promote the improvement of the green financial system and the advancement of green innovation.

Keywords: Supply chain Finance, Green Technological Innovation, Financing Constraints, Information Disclosure.

1. Introduction

Global climate governance and environmental protection have entered a new phase featuring "stringent constraints and rigorous implementation". Governments worldwide have constructed a new institutional framework for green transformation through policy legislation, market mechanisms and international cooperation. From an international perspective, the COP30 Conference in 2025 focused on "climate justice and transition finance", promoted technology-enabled climate resilience building, and gave rise to global collaborative emphasis on green innovation. Major economies have successively introduced mandatory policies: the European Union has strengthened its Green New Deal and fully implemented the Carbon Border Adjustment Mechanism, bringing chemical and textile products under regulation with explicit carbon-tariff calculation formulas and traceability mechanisms. The United States has relied on the Inflation Reduction Act, with a focus on renewable energy, electric vehicles and methane emission reduction in recent years, while taking industrial interests into account in international climate negotiations. Japan pursues transformation driven by both nuclear energy and hydrogen energy, advancing its targets of a 46 % emission cut by 2030 and carbon neutrality by 2050. Meanwhile, it addresses energy-security challenges and expands the coverage of carbon markets.

Chinese enterprises have actively responded to the "Dual-Carbon" goals and accelerated green technological innovation, yet they are confronted with prominent structural dilemmas in financing. First, the threshold for upfront investment is high. R&D of green technologies, equipment renewal, carbon capture, utilization and other sectors require substantial capital, with payback periods extending beyond 5-10 years, far longer than those of traditional projects. Second, enterprises have limited capacity for asset collateral. Green innovation mostly generates intangible assets characterized by high specificity and poor liquidity, which fail to satisfy the tangible-collateral requirements of conventional credit services. Third, innovation entails high risks. Subject to technology maturity, policy shifts and market volatility, green innovation carries a considerable failure rate, further discouraging lending by financial institutions.

Small- and medium-sized enterprises (SMEs) are particularly affected. Owing to weak risk resistance and insufficient credit qualifications, they are at a distinct disadvantage under traditional financing channels and suffer severe capital shortages. This restricts investment in green R&D and the commercialization of innovation outcomes, impedes further advancement of carbon-market and energy-transition policies, and hinders full implementation of the "Dual-Carbon" strategy.

Against this backdrop, supply-chain finance, with its unique strengths in scenario-driven empowerment, credit extension and information integration, has become an effective solution to financing bottlenecks for green innovation. Grounded in real-world transactions within industrial chains, it leverages the credit of core enterprises and integrates information on transactions, logistics and capital flows to build a collaborative financing system of "core enterprises + upstream-and-downstream firms + financial institutions", substantially mitigating information asymmetry between banks and enterprises. Through hierarchical credit transmission, high-quality credit from core enterprises is passed on to micro, small and medium-sized enterprises, lowering their financing thresholds and collateral requirements and effectively offsetting deficiencies in credit and collateral. Meanwhile, supply-chain finance can precisely match capital demands for scenarios such as green R&D, low-carbon equipment procurement and energy-saving

renovation, enabling targeted allocation of financial resources and improving allocation efficiency. Its flexible models can accommodate long-cycle and phased capital demands of green innovation, deliver sustained and stable financial support, help enterprises increase R&D investment and accelerate technology commercialization, thereby facilitating achievement of the "Dual-Carbon" goals and advancing coordinated economic and environmental development.

2. Literature Review

2.1. Research on Enterprises' Green Technological Innovation

Existing literature has extensively explored determinants of green technological innovation, mainly covering three dimensions: policy environment, corporate internal management and social-market factors.

First, policy environment provides critical external incentives for enterprises. As external constraint mechanisms, environmental laws and carbon-emission-trading policies raise enterprises' overall green-innovation level by strengthening environmental penalties, tightening environmental-information-disclosure requirements and raising managers' awareness of environmental issues (Zhou Yunbo et al., 2025). Green-credit policies guide financial institutions to provide low-interest loans for green projects and effectively reduce corporate financing costs (Chen Haohan et al., 2024). Fiscal and tax incentive policies directly cut innovation costs and boost innovation returns (Lü Hengyu et al., 2024).

Second, internal corporate management plays a pivotal role in improving green-technological-innovation capacity. Digital transformation significantly elevates corporate management and R&D efficiency by introducing advanced information technologies, boosting productivity and fostering corporate sustainable development (Gao Zhilin et al., 2024). Equity-incentive mechanisms motivate core technicians and management, optimize internal-control quality and reduce earnings management, inducing enterprises to attach greater importance to long-term benefits and thus promoting green-technology R&D (Wang Qingyuan et al., 2024).

Third, social-market factors support corporate green technological innovation through multiple channels. Transparent environmental-information disclosure helps enterprises acquire external-resource support and enhances social reputation and market competitiveness (Bai Junhong et al., 2023). Favorable ESG performance attracts more green investment and supplies capital for corporate innovation. The development of fintech and digital finance optimizes the allocation of financial resources, lowers corporate financing costs, improves innovation efficiency and further stimulates enterprises' green technological innovation.

2.2. Research on Supply-Chain Finance

Studies concerning corporate outcomes of supply-chain finance document its significant positive effects in supporting corporate sustainable development, improving supply-chain efficiency, advancing green transformation and enhancing corporate value. By optimizing resource allocation and cutting financing costs, supply-chain finance supports enterprises in fulfilling social responsibilities and conducting green-innovation activities, thereby lifting corporate ESG performance (Qiu Jinlong et al., 2025). Via resource integration and synergy effects, supply-chain finance substantially promotes corporate adoption of green technologies, helps manufacturing enterprises reduce carbon emissions and facilitates their low-carbon transition (Yu Zhaoji et al., 2024). By optimizing capital arrangements and promoting information sharing, supply-chain finance improves supply-chain operational efficiency and business performance (C. Huang, 2022), curbs inventory and logistics costs (Yang Siying et al., 2025), and mitigates operational and financial risks (Liu Yiming et al., 2025).

Furthermore, through credit guarantees from core enterprises and confirmation of accounts receivable, supply-chain finance transfers part of innovation risks from SMEs to core enterprises or financial institutions with stronger risk-bearing capacity, raising SMEs' willingness to take risks (Wei Shiwei et al., 2023). Supply-chain finance strengthens corporate market competitiveness and economic benefits and markedly increases firm value (A. Moretto et al., 2021). It also reinforces incentives for green innovation, curbs managerial short-sightedness and encourages long-term strategic planning to advance corporate green development.

2.3. Research on the Relationship between Supply-Chain Finance and Enterprises' Green Technological Innovation

As an innovative financial model, supply-chain finance and its nexus with corporate green technological innovation have attracted growing attention from academia and practitioners. This model effectively eases corporate capital pressure and provides financial safeguards for green-technological-innovation activities. Ling Runze (2021) points out that through unique credit-bundling and risk-sharing mechanisms, supply-chain finance can significantly elevate corporate innovation levels, and this effect is particularly salient for firms suffering severe financing constraints. Although that study does not directly focus on "green" innovation, it reveals the internal logic behind supply-chain finance supporting high-risk, long-cycle innovation activities and lays a theoretical foundation for understanding its influence on green technological innovation. From the perspectives of synergy theory and information-asymmetry theory, Jian Guanqun and Bai Feifan (2024) argue that supply-chain finance fosters inter-firm collaboration and mitigates information asymmetry, creating a favorable external environment for corporate green technological innovation.

Despite multiple perspectives offered by existing research on corporate green technological innovation, certain limitations remain. First, abundant studies have explored drivers of green technological innovation, yet research from the financial sector, especially regarding innovative financial formats, remains relatively scarce. Second, no consensus has been reached on the mechanisms through which supply-chain finance promotes corporate green technological innovation, and its practical paths for empowering real-economy development still face numerous challenges. Third, sample-selection limitations persist in some studies, which mostly concentrate on specific industries or regions. The generalizability of their conclusions to other industries awaits further verification.

This paper makes the following contributions. First, innovation in influence mechanisms. Drawing on fintech and market-regulation perspectives, this paper adopts digital transformation, financial risk and information disclosure as mechanism variables and financing constraints as a threshold

variable in mechanism analysis. It explores how supply-chain finance improves listed firms' green-innovation capacity under different threshold values. Second, innovation in research objects. Whereas prior studies mostly focus on manufacturing or polluting firms within supply chains, this paper covers all enterprises participating in supply-chain finance, enriching theoretical research on supply-chain finance to some extent. Third, cross-industry comparison of enterprises. This paper investigates how supply-chain finance affects green technological innovation across firms with different industrial structures and conducts dynamic-effect analysis to examine how enterprises at different life-cycle stages benefit from supply-chain-finance businesses.

3. Theoretical Analysis and Research Hypotheses

3.1. Analysis of Supply-Chain Finance's Influence on Enterprises' Green Technological Innovation

Green technological innovation commonly encounters external financing constraints stemming from uncertain returns, high regulatory costs and information asymmetry. Supply-chain finance can address early-stage financing difficulties faced by SMEs (Aghion et al., 2012). Core enterprises within supply chains generally enjoy high credit ratings and strong financing capabilities. Their endorsement can upgrade the credit standing of upstream-and-downstream firms throughout the chain and help other enterprises obtain funds from financial institutions at lower interest rates, thus alleviating financing constraints (Guo Ye et al., 2024).

Supply-chain finance can also flexibly adjust capital amounts and maturities according to enterprises' actual operating conditions and capital demands, improving capital-use efficiency and total-factor productivity along the chain (Yu Su et al., 2023). Manufacturing enterprises can leverage blockchain-based pledge systems within supply chains to raise the pledge ratio of raw materials and expand annual financing scales. This not only revitalizes idle corporate assets but also mitigates financing constraints and cuts financing costs, granting enterprises flexible capital for green-innovation investment (Wu Yongmin et al., 2025).

When enterprises are subject to excessively tight financing constraints, they face difficulties in fund acquisition, high capital costs and low capital-utilization efficiency. Even with partial funding from supply-chain finance, enterprises may still experience capital gaps and financial burdens and fail to satisfy full investment demands for green innovation (Pan Ailing et al., 2021). By contrast, enterprises with relatively mild financing constraints boast sound financial conditions, abundant resource bases and clear strategic planning. When confronted with temporary capital shortages, they can resort to supply-chain finance to optimize capital structures and enhance green-technological-innovation capacity. Accordingly, the following hypotheses are proposed:

H1: Supply-chain finance promotes green innovation in manufacturing enterprises.

3.2. Mechanism Analysis of How Supply-Chain Finance Affects Enterprises' Green Technological Innovation

3.2.1. Financing-Constraint Mechanism

The mediating transmission mechanism of financing constraints can be analyzed from two dimensions: resource-orchestration optimization and transaction-cost saving, which cover three core paths. From the perspective of resource-orchestration theory, supply-chain finance integrates upstream and downstream resources and diversifies financing channels to alleviate corporate financing constraints, thereby supplying funds for capital-intensive, long-cycle and high-risk green technological innovation. Enterprises can allocate available capital to green-technology R&D and equipment upgrading, improving the utilization efficiency of innovation resources. According to transaction-cost economics, supply-chain finance builds information-sharing platforms to mitigate bank-firm information asymmetry, cutting credit-review and financing-negotiation costs and freeing up capital for green innovation. Under the synergy of the two theories, supply-chain finance optimizes corporate resource allocation and transaction patterns to reduce resource waste and transaction frictions. International studies also confirm that easing financing constraints lowers capital costs and transaction risks and facilitates the implementation of green technological innovation.

H2a: Supply-chain finance promotes enterprises' green technological innovation by alleviating financing constraints.

3.2.2. Digital-Empowerment Mechanism

Rapid advances in digital technology inject new vitality into supply-chain-finance innovation. Digital fintech platforms realize real-time information sharing and transparency via big data, blockchain, artificial intelligence and other technologies, effectively boosting supply-chain information-processing capacity and operational efficiency and delivering more targeted financial services to enterprises (Song Hua et al., 2023).

Moreover, digital technologies optimize internal corporate-management workflows, raising total-factor productivity and improving corporate credit ratings. By integrating data resources of upstream-and-downstream supply-chain enterprises, digital platforms deliver comprehensive financing solutions, effectively lowering financing costs, easing financing constraints and strengthening financial stability. They thereby provide capital support and an innovation environment for corporate green technological innovation (Li Xin et al., 2023). Meanwhile, blockchain applications in supply-chain finance enhance information credibility and transparency and reinforce financial institutions' trust in enterprises. Enterprises can store information related to green-technological-innovation projects on blockchains to guarantee authenticity and immutability, attracting additional investment (Gong Qiang et al., 2021). The corresponding hypothesis is proposed as follows:

H2b: Supply-chain finance promotes enterprises' green technological innovation by accelerating corporate digital transformation.

3.2.3. Risk-Management Mechanism

Supply-chain finance reduces corporate financial risks by constructing risk-sharing mechanisms and risk-assessment systems. Under supply-chain-finance models, financial institutions, core enterprises and logistics enterprises jointly participate in risk assessment and management. Supply-chain-finance platforms grant real-time access to capital-flow, information-flow and logistics information across supply chains, enabling comprehensive evaluation of corporate credit and operational risks. Risk-assessment and monitoring efficiency are improved, risks are dispersed

among multiple participants, and individual-enterprise risk exposure is reduced (Liu Yiming et al., 2025).

Through guarantees from core enterprises, supply-chain finance can provide risk-compensation funds or insurance services to offer risk safeguards for corporate green-technological-innovation projects and incentivize increased investment in green-technology innovation (Ding Jie et al., 2023). Supply-chain finance can also deploy government-enhanced-credit instruments, whereby policy-guarantee funds cooperate with re-lending tools to bring financing interest rates for green projects below LPR-100 BP and expand financing scales for SME projects (Zhu You et al., 2025). In addition, supply-chain finance can link with carbon trading, tying returns from carbon-emission-right trading to financing costs to lower corporate green-technology-financing costs and increase carbon-emission reductions. The hypothesis is presented below:

H2c: Supply-chain finance promotes enterprises' green technological innovation by mitigating financial-risk fluctuations.

3.2.4. Information-Disclosure Mechanism

Supply-chain-finance-enabled information platforms publish firm-level information along supply chains and foster information sharing, which strongly promotes corporate green technological innovation. Under traditional financial models, information asymmetry persists between financial institutions and enterprises. Especially for SMEs, opaque financial information renders accurate credit evaluation difficult for financial institutions and restricts financing channels. By integrating information from upstream-and-downstream supply-chain enterprises, supply-chain finance allows financial institutions to obtain fuller insights into corporate operating conditions, capital demands and repayment capacity, lowers information asymmetry and facilitates corporate financing (Xu Jia et al., 2020).

As societal attention to environmental protection and sustainable development rises, consumers, investors and the public pay increasing attention to corporate green-technological-innovation behaviors. Enterprises that disclose progress, capital utilization and environmental benefits of green-technological-innovation projects can better accept social supervision, improve the quality and transparency of corporate information disclosure, enhance corporate social image and reputation, strengthen market competitiveness and boost market confidence in green-innovation projects (Gong Ning et al., 2024). Information disclosure under supply-chain finance also furnishes information support for internal corporate management. By disclosing green-innovation-related information, enterprises can promptly identify project progress and existing problems and optimize internal-management decisions (Jian Guanqun et al., 2024). Hence the hypothesis is formulated:

H2d: Supply-chain finance promotes enterprises' green technological innovation by improving information disclosure.

4. Research Design

4.1. Data Sources and Processing

This paper adopts empirical analysis to investigate the influence and mechanisms of supply-chain finance on corporate green innovation. The sample consists of A-share listed firms on the Shanghai and Shenzhen stock exchanges spanning 2012-2024. Raw data are processed as follows:

Financial-sector listed enterprises are excluded.

Firms marked ST, *ST, PT during the sample period, or delisted or revoked from listing are removed.

Enterprises listed after 2012 and those with over 50 % missing key variables are excluded to guarantee data integrity and consistency.

Finally, 16 770 firm-year observations covering 1 290 enterprises are obtained. Green-patent data are sourced from the Green Patent (GPRD) database of the China Research Data Service Platform. Data on supply-chain finance and corporate finance are obtained from the China Stock Market & Accounting Research (CSMAR) database. To mitigate disturbances from potential outliers on regression results, a 1 %-99 % winsorization is applied to all continuous variables.

4.2. Variable Setting and Descriptive Statistics

4.2.1. Explained Variable

Corporate Green Technological Innovation (GIN). The World Intellectual Property Organization (WIPO) released the IPC Green Inventory in 2010, classifying green technologies into seven categories: alternative energy, transportation, energy conservation, waste management, agriculture-forestry, administrative-regulatory-design, and nuclear energy. Following the mature classification framework of Xu Jia et al. (2020), this paper selects alternative-energy, waste-treatment and energy-conservation-related green patents and filters green-patent data via IPC patent classification codes. Corporate green-innovation capacity is measured by the natural logarithm of one plus the number of green-invention-patent applications, reflecting substantive corporate green-innovation capacity.

Measurement of corporate green technological innovation:

GIN = In(Number of green invention patent applications + Number of green utility model patent applications

4.2.2. Explanatory Variable

Supply-Chain Finance (SCF). Existing text-analysis indicators such as 0-1 dummy variables or word-frequency statistics cannot accurately reflect enterprises' real supply-chain-finance capacity; some non-supply-chain-finance content is misincluded, while certain supply-chain-finance activities are insufficiently captured. Supply-chain financing covers not only short-term loans offered by financial institutions but also trade-credit financing provided by core enterprises to upstream-and-downstream partners. Drawing on Yao Wangxin et al. (2017), this paper adopts the ratio of the sum of short-term borrowings and notes payable to total corporate assets as the indicator for supply-chain-finance development level, which better captures enterprises' actual utilization of supply-chain finance.

4.2.3. Mechanism Variables

Financing Constraints (SA). To avoid biases induced by endogeneity, this paper follows Ju Xiaosheng et al. (2013) and employs the SA index to measure financing-constraint severity:

$$SA_{i,t} = -0.737 \times SIZE_{i,t} + 0.043 \times SIZE2_{i,t} - 0.040 \times AGE_{i,t}$$

Where SIZE=LN(Corporate total assets/1000000); AGE denotes corporate operating years. The SA index takes

negative values; larger absolute values correspond to severer financing constraints.

Digital Transformation (DIG). Measured via text-analysis methods. Based on annual reports of listed firms, a lexicon of digital-feature words including "artificial intelligence", "big data", "cloud computing", "blockchain" is constructed. Python crawlers extract annual-report texts of listed firms, match feature words and count word frequencies with negative-form expressions eliminated. The entropy-weight method and factor-analysis method assign weights to word frequencies of different categories to synthesize a comprehensive index.

Risk Fluctuation (RT). The three-year rolling standard deviation of industry-adjusted corporate return on assets (ROA) is adopted as the indicator for financial-risk fluctuation. As a core measure of corporate profitability, the rolling standard deviation of ROA effectively characterizes dynamic uncertainty in corporate earnings.

Carbon Information Disclosure (CDI). A scoring system is built through content-analysis methods. Annual reports, social-responsibility reports and ESG reports of enterprises are reviewed across six dimensions with item-by-item scoring. A point-assignment approach is applied: 0 points for non-disclosure, 1 point for qualitative description, 2 points for quantitative data or concrete measures, and 3 points for decomposed detailed data or third-party assurance. The sum of dimension-specific scores yields the carbon-information-disclosure index.

4.2.4. Control Variables

To control for other factors affecting supply-chain finance, this paper selects firm size (Size), firm age (Age), capital structure (Lev), cash-flow level (CF), fixed-asset ratio (PPE), Tobin's Q (Q), and proportion of independent directors (IND) as control variables.

Table 1. Variable Definitions

Variable Type	Variable Name	Symbol	Variable Description
Explained variable	Corporate Green Technological Innovation	GIN	Ln(Green inwention patent applications+Grenn utility-model patent applications+1)
Explanatory variable	Supply-Chain Finance	SCF	(Short-term borrowings + Notes payable) / Year-end total assets
Mediator variable	Financing Constraints	SA	SA index
	Digital Transformation	DIG	Corporate digital-transformation index
	Financial Risk Fluctuation	RT	Three-year rolling standard deviation of industry-adjusted ROA
	Carbon Information Disclosure	CDI	Carbon-information-disclosure index
Control variable	Firm Size	Size	Ln(Firm operating years)
	Firm Age	Age	(ln(Firm operating years)
	Capital Structure	Lev	Total liabilities / Year-end total assets
	Cash-flow Level	CF	Corporate current-year stock price / Corporate replacement cost
	Fixed-asset Ratio	PPE	Net fixed assets / Total assets
	Tobin's Q	Q	Corporate market value / Total assets
	Proportion of Independent Directors	IND	Number of independent directors / Total number of board directors

4.3. Model Specification

Following Song Hua (2023), Ling Runze (2023) and related studies, this paper constructs a two-way fixed-effect model controlling for firm- and time-fixed effects to test the direct impact of supply-chain finance on corporate green technological innovation. The baseline model is specified as:

$$GIN_{i,t} = \alpha_0 + \alpha_1 SCF_{i,t} + \sum \alpha_n Con_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \quad (4\text{-}6)$$

In Equation (4-6): i denotes individual firms; t denotes years; $Con_{i,t}$ represents corporate green technological innovation; $SCF_{i,t}$ denotes supply-chain-finance development level; $Con_{i,t}$ stands for control variables including Size, Age, Lev, CF, PPE, Q and IND; α_0 is the constant term; μ and δ represent firm-fixed effects and time-fixed effects respectively; ε i,t is the random error term. Hypothesis H1 holds if coefficient α_1 is statistically significant.

To further test mediation effects of supply-chain finance on corporate green technological innovation, the following models are constructed:

$$SA_{i,t} = \beta_0 + \beta_1 SCF_{i,t} + \sum \beta_n Con_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \quad (4\text{-}7)$$

$$DIG_{i,t} = \beta_0 + \beta_1 SCF_{i,t} + \sum \beta_n Con_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \quad (4\text{-}8)$$

$$RT_{i,t} = \beta_0 + \beta_1 SCF_{i,t} + \sum \beta_n Con_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \quad (4\text{-}9)$$

$$CDI_{i,t} = \beta_0 + \beta_1 SCF_{i,t} + \sum \beta_n Con_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \quad (4\text{-}10)$$

In Equations (4-7)-(4-10), mediator variables include financing constraints (SA), digital-transformation index (DIG), financial-risk fluctuation (RT) and carbon-information-disclosure index (CDI). A significant \(\beta_1\) indicates that the independent variable exerts significant influence on the mediator variable. After this condition is satisfied, relationships between mediator variables and the explained variable are supported by authoritative existing literature, verifying overall mediation effects.

5. Empirical Analysis

5.1. Descriptive Statistics

Descriptive statistics for major variables are presented in Table 5-1. The mean value of corporate green technological innovation (GIN) is 1.330, implying an overall low level of green technological innovation among sample enterprises. Its standard deviation equals 1.287, reflecting substantial heterogeneity across sample firms, possibly attributable to differences in firm capital scale and market-environment conditions. The mean value of supply-chain finance (SCF) is 0.140 with a minimum value of 0, indicating that some enterprises are not engaged in supply-chain-finance activities

and that supply-chain-finance business in capital markets awaits further promotion.

Table 2. Descriptive Statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
GIN	16770	1.511	1.37	0	1.386
SCF	16770	-2.953	2.653	-13.682	-2.207
SA	16770	-3.88	.286	-4.59	-3.885
DIG	16770	39.539	11.481	23.52	37.93
RT	14190	.042	.057	.002	.022
CDI	16770	2.447	.835	0	2.565
SIZE	16770	22.838	1.391	20.165	22.66
AGE	16770	3.016	.316	2.079	3.045
LEV	16770	.467	.194	.078	.469
CF	16770	.048	.061	-.121	.045
PPE	16770	.227	.163	.005	.19
Q	16770	1.83	1.091	.804	1.48

5.2. Baseline Regression Analysis

Empirical analysis is implemented using Stata 18. According to Hausman-test results, the fixed-effect model is adopted. Table 5-2 reports baseline-regression results based on the two-way fixed-effect model. Column (1) presents regression results with only the core explanatory variable SCF included. Column (2) shows full-specification regression results after incorporating firm-characteristic control variables. Both models control for year- and firm-fixed effects, and robust standard errors are reported in parentheses.

Regarding the core explanatory variable, the coefficient of SCF in Column (1) is 0.0470 and significantly positive at the 1 % level, suggesting that supply-chain-finance level exerts a significant positive driving effect on corporate green innovation (GIN) without control variables. After adding firm-characteristic variables in Column (2), the SCF coefficient drops to 0.0136 yet remains significantly positive at the 1 % level. This indicates that after controlling for firm size, age, financial status and other factors, the positive influence of supply-chain finance on green innovation remains robust. The result corroborates the theoretical logic that supply-chain finance promotes corporate green innovation by alleviating financing constraints and optimizing capital allocation.

In terms of control-variable effects, firm size (SIZE) and firm age (AGE) are both significantly and positively associated with green innovation at the 1 % level. Larger and older enterprises generally possess more abundant resources and technological accumulation and are more capable of conducting green-innovation activities. Growth-opportunity indicator Tobin's Q (Q) and proportion of independent directors (IND) also exhibit significantly positive coefficients, implying that enterprises with better growth potential tend to seize development opportunities via green innovation, while industrial attributes shape foundational conditions for green innovation.

Table 3. Baseline Regression Results

	(1)	(2)
Variable	GIN	GIN
SCF	0.0470***	0.0136***
	(0.00347)	(0.00323)
SIZE		0.578***
		(0.0150)
AGE		0.732***
		(0.0424)
LEV		-0.315***
		(0.0644)
CF		0.159
		(0.125)
PPE		-0.315***
		(0.0883)
Q		0.0360***
		(0.00820)
IND		0.370**
		(0.165)
Constant	1.650***	-13.84***
	(0.0123)	(0.286)
Observations	16,770	16,770
R-squared	0.012	0.263
Number of id	1,290	1,290

Notes: ***, **, * denote statistical significance at the 1 %, 5 %, and 10 % levels respectively. Robust standard errors are shown in parentheses. The same applies hereafter.

5.3. Robustness Tests

5.3.1. Replacing the Explained Variable

To test result stability, the explained-variable corporate-green-innovation index is replaced by the natural logarithm of one plus corporate green-invention-patent-application counts. Regression results in Column (1) of Table 5-3 show that the coefficient of SCF remains significantly positive at the 1 % level. The sign and statistical significance of regression coefficients are highly consistent with baseline-regression outcomes, confirming that supply-chain finance significantly improves corporate green-technological-innovation levels and verifying the robustness of Hypothesis H1.

5.3.2. Reducing the Sample Size

To verify whether baseline-regression significance holds in subsamples, considering drastic stock-market volatility in China in 2015, the sample window is narrowed to post-2015 (2016-2024), dropping observations from 2015 and earlier periods. Re-estimation results in Column (2) of Table 5-3 display a significantly positive SCF coefficient, showing consistency with full-sample conclusions and reinforcing the stability of Hypothesis H1.

5.3.3. Changing the Model Specification

To examine whether regression-model choices affect research outcomes, the two-way fixed-effect model in baseline regressions is substituted with the random-effect model for re-estimation of core relationships. Column (3) in Table 5-3 demonstrates that the magnitude and significance of the SCF coefficient remain consistent with prior results. Adjustments in model specification do not generate material changes in regression outcomes, indicating high model stability.

Table 4. Robustness-Test Results

	(1)	(2)	(3)
ariables	Replace explained variable	Reduced sample size	Alternative model specification
	GIN	GIN	GIN
SCF	0.00800***	0.0161***	0.0154***
	(0.00297)	(0.00471)	(0.00455)
Constant	-9.031***	-13.39***	-13.92***
	(0.263)	(0.434)	(0.502)
Control variables	Yes	Yes	Yes
Observations	16,770	16,770	11,610
R-squared	0.133	0.2761	0.113
Number of id	1,290	1,290	1,290

5.3.4. Endogeneity Test

To address endogeneity stemming from reverse causality between the explained and explanatory variables, this paper adopts the industry-level mean of supply-chain finance (Ind.SCF) and the one-year lagged term of supply-chain finance (L.SCF) as instrumental variables and applies the two-stage least-squares (2SLS) estimator. First-stage estimation results in Columns (1) and (3) of Table 5-4 reveal that regression coefficients of Ind.SCF and L.SCF are both significantly positive at the 1 % statistical level, meaning instrumental variables are correlated with the core explanatory variable. Second-stage estimation results in Columns (2) and (4) of Table 5-4 show that the regression coefficient of SCF remains significantly positive. After accounting for endogeneity concerns, the promoting effect of supply-chain finance on corporate green technological innovation remains statistically significant.

Table 5. Endogeneity-Test Results

	(1)	(2)	(3)	(4)
Variables	Industry-mean IV		Lagged-term IV	
	SCF	GIN	SCF	GIN
SCF		0.283***		0.0424***
		(0.0410)		(0.00989)
Ind.SCF	0.895***			
	(0.0737)			
L.SCF			0.609***	
			(0.0143)	
Constant	0.904	-10.36***	0.437	-10.91***
Control variables	Yes	Yes	Yes	Yes
	(0.769)	(0.584)	(0.357)	(0.601)
Observations	16,770	16,770	15,480	15,480
R-squared	0.251	0.096	0.533	0.278

5.4. Mechanism Analysis

5.4.1. Financing-Constraint-Alleviation Mechanism

The foregoing theoretical analysis argues that supply-chain finance revitalizes inventories, accounts receivable and other assets by virtue of core-enterprise credit, lowers financing thresholds and difficulties for SMEs, and thereby facilitates capital investment in green-technology R&D and innovation. If this mechanism holds, supply-chain finance should significantly alleviate corporate financing constraints. Following Ju Xiaosheng et al. (2013), this paper uses the SA index to measure financing-constraint severity (SA) and adopts mediation-effect tests to verify the financing-constraint-alleviation mechanism. Results are shown in Columns (1)-(2) of Table 5-5. Column (1) reports the main effect with a significantly positive coefficient. Column (2) shows that the regression coefficient of SCF on SA is significantly negative at the 1 % level, indicating that supply-chain finance effectively mitigates financing constraints. The negative impact of financing constraints on corporate green technological innovation is widely recognized in existing literature. Financing constraints thus exert partial mediation between supply-chain finance and green innovation. Supply-chain finance provides stable and sufficient capital guarantees for enterprises and promotes green innovation by lowering financing barriers and difficulties. Hypothesis H2a is verified.

5.4.2. Digital-Empowerment Mechanism

Prior theoretical analysis proposes that supply-chain finance fosters the establishment and improvement of digital fintech platforms and elevates corporate green-technological-innovation levels by enhancing corporate information-processing capacity and operational efficiency. If this mechanism holds, supply-chain finance should significantly raise corporate digital-transformation levels. Drawing on Li Xiangrong et al., this paper uses the corporate digital-transformation index to measure digital empowerment (DIG) and conducts mediation-effect tests for the digital-empowerment mechanism. Results are presented in Columns (1) and (3) of Table 5-5. Column (1) reports the main effect with a significantly positive coefficient. Column (3) displays a significantly positive coefficient of SCF on DIG at the 1 % level, suggesting that supply-chain finance effectively drives corporate digital transformation. The positive effect of digital transformation on corporate green technological innovation is well-documented in academia. Digital transformation therefore plays a partial-mediation role between supply-chain finance and green innovation. Supply-chain finance promotes corporate digital transformation, optimizes resource allocation and technology integration, and consequently boosts green innovation. Hypothesis H2b is validated.

Table 6. Mechanism-Test Results

	(1)	(2)	(3)	(4)	(5)
Variables	GIN	SA	DIG	RT	CDI
SCF	0.0136***	-0.0044***	0.114***	-0.0014***	0.00623***
	(0.00323)	(0.000292)	(0.0182)	(0.000247)	(0.00217)
Constant	-13.84***	-2.232***	-43.53***	0.530***	-6.226***
	(0.286)	(0.0259)	(1.617)	(0.0240)	(0.192)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	16,770	16,770	16,770	14,190	16,770
R-squared	0.263	0.794	0.365	0.053	0.356
Number of id	1,290	1,290	1,290	1,290	1,290

5.4.3. Risk-Management Mechanism

As previously argued, supply-chain finance constructs risk-sharing and risk-assessment systems, reduces information bias and corporate financial risks, and thereby advances corporate green technological innovation. If this mechanism holds, supply-chain finance should significantly reduce corporate financial risks. Following He Ying (2019) et al., this paper adopts the three-year rolling standard deviation of ROA to measure financial-risk fluctuation (RT) and performs mediation-effect tests for the risk-management mechanism. Results in Columns (1) and (4) of Table 5-5 show that Column (1) reports the main-effect significantly positive coefficient. The coefficient of SCF on RT in Column (4) is significantly negative at the 1 % level, demonstrating that supply-chain finance notably suppresses financial-risk fluctuations. The adverse impact of financial risks on corporate green technological innovation is widely acknowledged in literature. Financial-risk fluctuation thus exerts partial mediation between supply-chain finance and green innovation. Supply-chain finance reduces corporate financial risks and releases more resources for green-R&D and innovation investment. The risk-control mechanism is supported and Hypothesis H2c is verified.

5.4.4. Information-Disclosure Mechanism

As discussed above, supply-chain finance integrates and publishes operational and financial information of upstream-and-downstream supply-chain enterprises, mitigates information asymmetry, facilitates corporate financing and incentivizes corporate green technological innovation. If this mechanism holds, supply-chain finance should promote information disclosure. Following Chen Hua et al. (2013), this paper uses the carbon-information-disclosure index of listed firms to measure corporate information-disclosure levels (CDI) and implements mediation-effect tests. Columns (1) and (5) of Table 5-5 show that Column (1) reports the main-effect significantly positive coefficient. The coefficient of SCF on CDI in Column (5) is significantly positive at the 1 % level, meaning supply-chain finance significantly improves information disclosure among listed enterprises. Positive effects of carbon information disclosure on corporate green technological innovation are well-established in existing studies. Carbon information disclosure accordingly plays a partial-mediation role between supply-chain finance and green innovation. Supply-chain finance shapes corporate carbon-information-disclosure behaviors, strengthens environmental responsibility and information transparency, and drives green innovation. The information-disclosure mechanism is supported and Hypothesis H2d is verified.

5.5. Heterogeneity Analysis

5.5.1. Enterprise Life-Cycle Analysis

According to enterprise life-cycle theory, enterprises at different life-cycle stages exhibit heterogeneous financing demands and operational strategies, which may moderate the facilitating effect of supply-chain finance on green technological innovation. To investigate heterogeneous effects across life-cycle phases, this paper divides full-sample enterprises into three groups: growth stage, maturity stage and decline stage, following Liu Shiyuan et al., and conducts grouped regressions. Empirical outcomes in Columns (1)-(3) of Table 5-6 offer full validation. The SCF coefficient for growth-stage enterprises equals 0.0161 and is significantly positive at the 1 % statistical level. A plausible explanation is that growth-stage enterprises undergo rapid business-scale expansion yet suffer insufficient internal accumulation, incomplete credit records and scarce collateralizable assets. They face the severest financing constraints and constitute core target groups for supply-chain-finance services.

In the maturity-stage subsample, the SCF coefficient is 0.0251 and lacks statistical significance. Mature enterprises maintain stable operations, abundant internal cash flows and sound credit qualifications, with unobstructed traditional bank-credit channels. Their financing-constraint intensity is low, and reliance on supply-chain finance declines substantially. For decline-stage enterprises, the SCF coefficient is 0.00642 and statistically insignificant. Enterprises in decline confront shrinking market shares, deteriorating profitability and mounting financial risks. Their core operational objective is to stabilize cash flows and resolve debt risks rather than conduct high-risk green-technological-innovation activities.

5.5.2. Industrial-Structure Analysis

Industrial-structure characteristics, namely factor intensity, influence enterprises' utilization of fintech platforms and may moderate the empowering effect of supply-chain finance on green technological innovation. To further explore heterogeneous empowering effects of supply-chain finance across factor-intensity categories, this paper classifies sample enterprises into labor-intensive, technology-intensive and capital-intensive groups following Xu Jia (2020) et al., and performs grouped regressions. Empirical results are reported in Columns (4)-(6) of Table 5-6.

For technology-intensive industries, the SCF coefficient is 0.0185 and significantly positive at the 1 % statistical level. Technology-intensive enterprises constitute core subjects of green technological innovation, and their innovation activities depend heavily on external financing. Beyond alleviating short-term financing constraints by revitalizing working capital, supply-chain finance builds platforms for technology,

information and resource sharing relying on industrial-chain synergy effects and helps enterprises break through bottlenecks in green-technology R&D.

For labor-intensive industries, the SCF coefficient is 0.0150 and also significantly positive at the 1 % level. Most labor-intensive enterprises adopt traditional production modes and are plagued by low fixed-asset ratios, insufficient collateralizable assets and high thresholds for traditional credit. Leveraging core-enterprise credit and taking movable properties such as accounts receivable and inventories as pledges, supply-chain finance matches operational characteristics of these asset-light, high-liquidity and short-payback-cycle enterprises, effectively alleviating financing constraints and delivering stable capital support for green-technology-R&D investment.

The SCF coefficient for capital-intensive industries fails to pass significance tests, indicating limited facilitating effects of supply-chain finance on green technological innovation within such enterprises. Green transformation for capital-intensive enterprises generally involves large-scale fixed-asset investment and long-cycle green-project construction, requiring massive long-term capital. Their capital demands are mostly satisfied by large-scale policy-oriented financial instruments and special green funds. Supply-chain finance mainly focuses on short-term capital turnover for upstream-and-downstream firms in industrial chains and can hardly satisfy large-scale long-term capital requirements for green investment among capital-intensive enterprises. Hence its empowering effect is not statistically manifested.

Table 7. Heterogeneity-Test Results

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	GIN (Life cycle)			GIN (Industrial structure)		
	Growth	Maturity	Decline	Labor-intensive	Technology-intensive	Capital-intensive
SCF	0.0161***	0.0251	0.00642	0.0150***	0.0185***	0.00659
	(0.00413)	(0.0153)	(0.00720)	(0.00578)	(0.00466)	(0.00759)
Constant	-14.01***	-15.84***	-12.76***	-14.31***	-13.91***	-14.10***
	(0.363)	(1.072)	(0.861)	(0.601)	(0.425)	(0.696)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11,898	1,727	3,096	4,618	8,079	3,882
R-squared	0.269	0.305	0.175	0.246	0.251	0.247
Number of id	1,287	744	980	408	672	330

6. Conclusions and Policy Recommendations

Based on data of A-share listed firms on the Shanghai and Shenzhen stock exchanges over 2012-2024, this paper investigates the effects and mechanisms of supply-chain finance on corporate green technological innovation. The main findings are as follows. First, supply-chain finance significantly improves corporate green-technological-innovation levels, and this conclusion remains valid after robustness tests including replacement of the explained variable, sample-size reduction and model-specification adjustment. Second, the significant positive driving effect of supply-chain finance on corporate green technological innovation operates through four channels: alleviation of financing constraints, digital empowerment, risk management and carbon information disclosure. All four paths pass mediation-effect tests, corroborating the theoretical logic that supply-chain finance empowers green innovation by optimizing capital allocation and mitigating risks and information asymmetry. Third, heterogeneity analysis reveals that the positive influence of supply-chain finance on green technological innovation is more pronounced for enterprises in the growth stage, as well as labor-intensive and technology-intensive enterprises.

Based on the above conclusions, corresponding recommendations are put forward:

① At the government level, policy guidance and institutional-environment optimization should be strengthened to lay a solid foundation for supply-chain finance to empower green technological innovation. Special incentive policies should be issued to provide tax reductions and fiscal-interest subsidies for green-supply-chain-finance businesses targeting growth-stage, maturity-stage, capital-intensive and technology-intensive enterprises, guiding precise allocation of financial resources. To address dilemmas of enterprises under heavy financing constraints, special guarantee funds for green innovation ought to be established. Construction of a nationwide unified supply-chain-finance information-sharing platform should be promoted. Management of accounts receivable and green-patent-transaction systems should be standardized, and intellectual-property-right protection improved to build a sound institutional environment for corporate green innovation.

② Enterprises should proactively seize opportunities brought by supply-chain finance and take targeted actions according to their own characteristics. Growth-stage, technology-intensive and labor-intensive enterprises should give full play to their strengths, acquire capital via diversified supply-chain-financing modes, focus on green-technology R&D and patent commercialization, and core enterprises can take the lead in constructing green-supply-chain ecosystems. Meanwhile, enterprises ought to optimize financial structures, improve credit ratings and ease financing constraints, increase investment in digital transformation, perfect financial-risk-management and green-information-disclosure mechanisms, and smooth transmission paths from supply-chain finance to innovation. Start-ups or non-intensive-type enterprises can embed themselves into green supply chains relying on core-enterprise partners and gradually accumulate innovation capacity.

③ Financial institutions should prioritize product innovation and risk-control upgrading to enhance service precision. Differentiated products should be designed for enterprises at diverse development stages and with different industrial attributes, such as green-patent-pledge financing

and special loans for innovation projects. Meanwhile, risk-control models integrating green-patent, carbon-emission and supply-chain-transaction data ought to be built. Cooperation with information-service institutions should be strengthened to reduce over-reliance on core-enterprise credit. In addition, green-innovation performance should be incorporated into credit-evaluation frameworks, special credit quotas should be set up, and priority support ought to be granted to projects aligned with green-development strategies, so as to channel financial resources toward high-benefit green-innovation activities.

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