Empowering Supply Chain Finance: The Impact of Supply Chain Finance on Green Innovation—From the perspective of multiple moderating effects

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ABSTRACT

This study investigates how supply chain financing influences green innovation in businesses, utilizing data from Chinese publicly listed companies between 2008 and 2024. It employs mechanism analysis to examine how green innovation is driven by supply chain finance and creates interaction terms to prove the moderating roles of corporate risk level, environmental performance, and information transparency. It passes endogeneity test by constructing an instrumental variable. Additionally, it distinguishes the characteristic of green patents and performs heterogeneity tests. The study finds that supply chain finance significantly promotes corporate green innovation through the alleviation of financing constraints. Further analysis indicates that corporate risk level inhibits this promoting effect, whereas high environmental performance and high information transparency strengthen the promoting effect. Heterogeneity analysis reveals supply chain finance poses a bigger effect on green innovation if it is a high-tech company or a manufacturing company.

Keywords: Supply Chain Finance; Green Innovation; Financing Constraints; Information Transparency; Risk Level; Environmental Performance.

1. INTRODUCTION

Nowadays, green innovation is increasingly becoming a core tool for enterprises to build sustainable competitive advantages. However, due to the characteristics of green technology research and development-high investing requirement, long return periods, and low certainty-coupled with traditional financing barriers caused by information asymmetry, enterprises often encounter severe funding bottlenecks [22]. Supply chain finance, by integrating logistics, information flow, and capital flow within the industrial chain and leveraging the credit radiation effect of core enterprises, provides credit enhancement support to upstream and downstream enterprises. It offers an innovative solution to alleviate the financing difficulties of green innovation. With the deep integration of digital technologies such as the Internet of Things and blockchain, supply chain finance has accelerated its evolution towards intelligent and dynamic tools, and its strategic value in improving resource allocation efficiency and empowering green development of the real economy has become increasingly prominent. At the policy level, the state continues to improve the system design to accelerate the development of supply chain finance. In short, the policy emphasizes that supply chain finance should focus on serving the real economy, support national strategies, and help improve the quality, efficiency and resilience of industries and supply chains. The technological evolution, industrial practice and policy guidance mentioned above together constitute the institutional environment and practical basis on which this research is based.

The following are some related literature reviews:

As an innovative financing tool embedded in the industrial ecosystem, supply chain finance can customize the financial scheme according to the actual operating conditions of enterprises. By integrating the information flow, capital flow and logistics in the upstream and downstream of the supply chain, it can significantly improve the efficiency of capital turnover, reduce the overall capital cost and accelerate the cash flow cycle [9]. This mechanism makes great contributions to alleviating corporate financing constraints and can significantly reduce corporate debt financing costs, especially providing crucial support for private enterprises with weak financial strength and low information transparency, which are often overlooked by traditional financial institutions [8][18][31][35][37]. Research shows that this tool can also combine relationship effects and knowledge spillover effects to form a triple mechanism to enhance corporate innovation [19] [25].

Green innovation, as the core of driving corporate green transformation, improves products, processes, or management, aiming to generate social, ecological, and economic benefits [9][4] [35] [9] [14] pointed out that companies with high financing constraints will restrict green innovation in green supply chain companies. When companies face a shortage of funds, limited R&D investment will directly inhibit innovation capabilities [8]. However, existing literature also proposes another perspective: the restrictions imposed by financing may help make progress in technological advances because increased financial resources will also bring uncertainty to innovation output [4]. Also, strengthening supply chain networks, meeting the green enforcement requirements of local governments, and shaping a green image are key mechanisms for supply chain finance to promote green innovation [9]. In general, only a few studies have directly investigated the impact of supply chain finance on green innovation.

Regarding methods for measuring green innovation, current academic research primarily uses the quantity and quality of green patents held by enterprises to assess the level of green innovation. Wu et al. (2025) used the sum of green invention patent disclosures, invention patent grants, and utility model patents to measure the level of green innovation. Zheng et al. (2026) distinguished between substantive innovation and strategic innovation. The former was measured using relevant data from green invention patents, while the latter was measured using green utility models. This paper argues for the use of the number of green invention patent applications as the metric for the explained variable is appropriate. My opinion is that green invention patents are subject to rigorous examination, have high application costs and long examination cycles, and a lower success rate than green utility model patents, so there is a tendency to pursue the quantity of green innovation while neglecting the improvement of its quality [7] [17]. As the patent application to grant process involves lengthy examination by the intellectual property office, this process may be disrupted by objective factors like bureaucratic procedures, leading to a lag in the granting of green patents. Moreover, during this period, the patent may have already been put into production and generated benefits (Feng et al., 2022; Liu, 2022).

Risk level, as a key dimension of corporate strategic decision-making, plays a complex moderating role in the relationship between supply chain finance and green innovation. Existing literature [16] [21] uses ROA volatility as the risk metric. However, existing literature has not yet clarified the relationship between corporate risk level and green innovation in the context of supply chain finance. This paper primarily focuses on risk level, i.e., the risk pressure faced by enterprises. Environmental performance moderates the relationship between external financing and green innovation through multiple mechanisms. Mainstream research emphasizes its positive incentive effect. For example, ESG ratings, through both capital market incentives and external monitoring pressure, force enterprises to accelerate green technology transformation [11]. However, critical research reveals potential shortcomings in environmental performance [36] [20] found a significant positive correlation between corporate ESG performance and greenwashing behavior. Existing literature largely focuses on the direct impact of environmental performance on green innovation, and has not yet clearly defined it as a moderating variable in the relationship between supply chain finance and green innovation. Information transparency forms the institutional foundation for the effective operation of supply chain finance and the coordinated development of green innovation. Its regulatory function is mainly realized through two mechanisms. In terms of governance optimization, information disclosure increases corporate resources, reduces agency costs, alleviates financing constraints, and stimulates corporate green innovation [28] [15]. At the level of legitimacy construction, high information transparency enhances the legitimacy of corporate green innovation, while companies with opaque accounting information tend to avoid environmental information disclosure, thus inhibiting green innovation investment [32]. However, existing research has significant limitations. There is a lack of discussion on how information transparency regulates the relationship between capital flows and innovation output in the context of supply chain finance. This theoretical gap provides a starting point for this paper to incorporate information transparency into the regulatory framework.

This study selects listed companies in China's A-share market from 2008 to 2024 as samples, and uses text mining technology for reference to construct an evaluation index for supply chain finance, exploring the path and underlying mechanism of supply chain finance on corporate green innovation activities. Compared with existing literature, the innovations of this study can be summarized in three points. First, it not only proves the impact of supply chain finance on green innovation, but also innovatively introduces risk level, environmental performance, and information transparency as moderating variables, thus establishing a more complete theoretical model. Second, in the context of supply chain finance and green innovation, it is the first to distinguish between green invention patents and utility model patents, systematically exploring the heterogeneous effects of supply chain finance on two types of green innovation activities, breaking through the previous research paradigm that regarded green innovation as a homogeneous variable. Finally, it pioneered a comparative analysis of the manufacturing and high-tech industries, providing data support for the government to implement differentiated policies, and helping enterprises optimize green innovation financing schemes according to ownership characteristics and industry features.

The subsequent content of the article is as follows. Part II conducts theoretical discussions and constructs research hypotheses. Part III elaborates on data selection and indicator construction. Part IV presents the basic regression results and completes robustness and heterogeneity analysis. Part V implements mechanism verification. Part VI carries out extended research, which focuses on three moderating effects. Part VII summarizes the main findings and provides countermeasures and suggestions.

2. THEORETICAL ANALYSIS

From the perspective of external factors, the widespread credit discrimination in the traditional financial system makes it difficult for financial institutions to accurately assess the true value and risks of green innovation projects, exacerbating the financing difficulties for companies pursuing green innovation. It is because green innovation requires substantial resource investment, and its high risk, high cost, long return cycle, and poor initial economic benefits can damage a company's short-term operating performance, just like what Schumpeter argued that corporate innovation is a recombination of economic factors and a disruptive activity. On the other side, from the perspective of internal factors, moral hazard can diminish corporate managers' interest in long-term green technologies because the results of green innovation are difficult to quantify and understand by investors in the short term. Thus, promoting green innovation faces real difficulties.

However, supply chain finance provides us with a new way to solve this problem. Resource-based theory [1] believes that a company can always maintain its advantages because it has scarce resources that others can hardly imitate. In supply chain finance, in-depth supply chain cooperation and financial integration ability is a unique resource of the company. It integrates the information flow, capital flow and logistics in the supply chain, and extends the credit of core enterprises (such as large companies) to small upstream and downstream companies, thus effectively alleviating the financing difficulties of companies in these supply chains. The practice of Supply chain finance can also solve the conflict of interest between suppliers and buyers, thus making their relationship better [2]. This model provides the necessary financial support for enterprises' green innovation activities by reducing financing costs and speeding up capital turnover. Supply chain finance, because it has the characteristics of borrowing money together and can strengthen the industrial chain, allows banks to know more information about companies, thus reducing the information asymmetry between banks and companies [37]. This method not only provides financial support, but also builds a special innovation ecosystem by locking the upstream and downstream technology and knowledge flows. Green innovation needs those green knowledge that can't be easily explained to flow freely, and supply chain finance strengthens the connection between various points in the supply chain network, showing a strong knowledge spillover effect and providing important knowledge resources for the company's green innovation. By integrating the credit resources of core enterprises and relying on real business dealings, it has built a multi-party cooperative loan system. This effectively fills the information gap between upstream and downstream enterprises, core companies and financial institutions in the supply chain. Therefore, it provides a good way for us to solve the financing problem of the company, and also brings enough financial support for green innovation. Moreover, sharing the green tacit knowledge that is not easy to explain clearly requires a stable external environment. The stable function of supply chain finance provides an effective contract guarantee for the transmission and sublimation of this knowledge [19], which provides a good inspiration for us to find a green development path from the perspective of the whole supply chain [25]. Therefore, we put forward the following hypothesis in this paper:

H1: Supply chain finance can promote green innovation of enterprises.

According to the pecking order theory [23] and the financing constraint mitigation theory [5], companies will prioritize using internal funds because information asymmetry leads to higher external financing costs than internal financing. But internal financing limits investment in high-risk and long-cycle green innovation. Moreover, due to short-sightedness, creditors may not be willing to invest in green innovation with low initial economic benefits, and the cost of issuing new shares is high. Therefore, green innovation faces the challenge of financing constraints. Supply chain finance mitigates this constraint through two channels: (1) Credit transfer and risk sharing: The high credit rating of core enterprises extends to other enterprises. Through mechanisms such as core enterprise guarantees and repurchase commitments, innovation risks are dispersed and transferred, reducing the risk assessment of enterprises by financial institutions [33]. (2) Asset revitalization: The current assets of enterprises, such as accounts receivable and inventory, are transformed into financeable credit resources.

Therefore, this paper proposes the following hypothesis:

H2: Supply chain finance promotes green innovation by alleviating financing constraints.

Corporate risk level plays a crucial role in corporate decision-making. From a theoretical perspective, risk level can be viewed as the objective risk pressure faced by a company. A high-risk level implies increased uncertainty in the business environment, potentially inhibiting long-term innovation investment [21]. Agency theory [12] points out that when a company's risk level is high, management tends to avoid long-term uncertain projects to protect their job security and short-term performance. While supply chain finance can alleviate corporate financing pressure to some extent, if a company's own operational risk is too high, managers may suspend investment in long-cycle projects for short-term stability. This study, from this perspective, argues that when a company already bears high risk, even with supply chain finance providing financial support, management will be cautious about green innovation due to risk aversion and short-term performance pressure. The discussion on cash flow sensitivity in Fazzari et al [5] further supports this view. Companies facing disadvantages in external financing costs are highly sensitive to cash flow in their investment decisions. While supply chain finance alleviates financing constraints, it cannot completely eliminate liquidity concerns in high-risk environments.

Therefore, this paper proposes the following hypothesis:

H3: Corporate risk levels inhibit the positive impact of supply chain finance on green innovation; that is, the higher the corporate risk level, the weaker the positive impact of supply chain finance on green innovation.

Also, the resource-based theory [1] suggests that companies that have achieved a certain level of success in environmental performance possess unique, exclusive resources for green innovation. This is the case in terms of environmental performance. Companies with good environmental performance usually have more experience and technology accumulation in green innovation, which enables them to turn supply chain finance resources into innovation results more effectively and gain more advantageous green competitiveness. Signaling theory [26] believes that companies with good environmental performance send credible signals to the market, indicating that they have the ability and willingness to innovate green, which reduces investors' worries about "greenwashing". In this way, the funds of supply chain finance can be more easily invested in real green innovation, thus improving the efficiency of capital use. Based on this, we propose:

H4: Corporate Environmental Performance will strengthen the promotion of supply chain finance to green innovation. In other words, the better a company's environmental performance is, the stronger the positive impact of supply chain finance on green innovation.

According to the theory of information asymmetry [27], if the company's information is opaque, banks will choose the wrong customers and everyone will take risks, and the cost of borrowing money will also increase. Supply chain finance can help banks learn more about enterprise information and reduce the information gap between banks and enterprises because it can share credit and stabilize the industrial chain [37]. However, supply chain finance needs companies in the supply chain to provide accurate and reliable information, otherwise the systemic risk of financial institutions' lending will become greater. Moreover, investors can feel that information is opaque. Earnings management theory [10] says that investors can often find clues that companies make false accounts. If the company manipulates financial information through earnings management and makes the information more opaque, external investors will have to spend more money on supervision and feel more risky. Companies with high transparency can reduce information gaps in many aspects, so that financial institutions can accurately find green innovation projects and spend their money in the most suitable places.

Therefore, this paper puts forward the following assumptions:

H5: Corporate transparency can enhance the positive influence of supply chain finance on green innovation; In other words, the higher the transparency of enterprises, the stronger the role of supply chain finance in promoting green innovation.

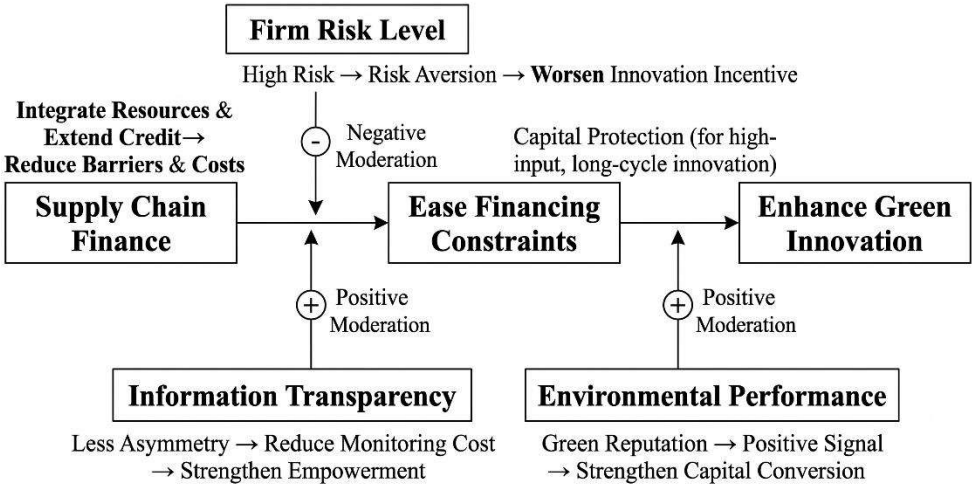

Figure 1. Theoretical framework of supply chain finance empowering green innovation

Figure 1 shows the theoretical framework of this study, focusing on the core intermediary mechanism of supply chain finance to promote green innovation by alleviating corporate financing constraints. In addition, it also describes the complex boundary conditions of this main path, indicating that the risk level of enterprises will have a negative regulatory effect, while information transparency and environmental performance, as positive catalysts, can strengthen capital transformation and overall innovation incentives.

3. SAMPLE SELECTION AND RESEARCH DESIGN

3.1 Sample Selection and Data Sources

This paper selects China's listed companies from 2008 to 2024 as the initial sample. Following the research approaches of Zhou and Wu [38], Zhang et al. [34] and Wang et al. [29], this study uses supply chain finance keyword frequency analysis (see Table 1) to assess the development level of supply chain finance among listed companies. Financial indicator data are sourced from the CSMAR database, while green innovation-related data are obtained from the World Intellectual Property Organization (WIPO) and the China National Intellectual Property Administration. Based on the methodology of Wang and Wang (2021), this study categorizes A-share listed companies' green patents into two main categories: invention patents and utility model patents by comparing their patent classification numbers with the WIPO "International Patent Classification Green List." The following measures were taken in the data processing stage. First, samples with severely missing financial information were deleted. Second, ST and PT companies, financial companies, and listed companies with negative net assets were excluded. Finally, 1% and 99th percentile shrinkage was applied to all continuous variables to control the interference of outliers.

Table 1. Keywords for Supply Chain Finance (SCF1)

Type	Keywords
Inventory	Movable property pledge financing, inventory pledge financing, inventory financing, warehouse receipt financing, spot pledge financing
Accounts Receivable	Accounts receivable financing, accounts receivable transfer, factoring financing, reverse factoring agreement
Prepaid	Prepayment financing, future title financing, title pledge financing, and confirmed warehouse receipt financing
Comprehensive	Supply chain finance, supply chain funds, supply chain investment, supply chain loans, supply chain finance strategic alliances, supply chain finance service platforms, supply chain management

3.2 Variable Design and Model Building

For the dependent variable, this paper refers to Wang and Wang (2025) and uses the natural logarithm of the number of green invention patent applications plus 1 as an indicator to measure corporate green innovation (lnGI1). To distinguish different types of innovation and facilitate subsequent robustness tests, this paper additionally defines lnGI2 as the natural logarithm of the total number of green patent applications plus 1, and lnGI3 as the natural logarithm of the number of green utility model patent applications plus 1.

For the core explanatory variables, this paper refers to the research of Zhang et al. [34] and performs word frequency statistics on supply chain finance keywords in the financial reports of listed companies. By summarizing the number of keyword frequencies and logarithmizing them, the supply chain finance level (SCF1) of each enterprise can be obtained.

This paper sets the following control variables: firm size (Size by the logarithm of total assets), equity multiplier (EM), capital intensity (CAP), return on equity (ROE), Tobin's Q, percentage of independent directors (Indep), and firm age (logarithmized). Furthermore, this paper controls for firm-specific effects and year-based effects. Based on these variables, this paper designs the following empirical model:

$$\mathrm{lnGI1}_{it} = \alpha_0 + \alpha_1 \mathrm{SCF1}_{it} + X\delta + \eta_i + \mu_t + \epsilon_{it} \quad (1)$$

Where i and t represent the enterprise and year respectively, $\mathrm{lnGI1}$ is the explained variable, SCF1 is the core explanatory variable, X is the control variable, η_i is the enterprise fixed effect, μ_t is the year fixed effect, ϵ_{it} is the random disturbance term. This paper focuses on the coefficient α_1, where a positive and larger coefficient indicates that supply chain finance can promote green innovation in enterprises. Descriptive statistics are shown in Table 2.

Table 2. Descriptive Statistics

VarName	Obs	Mean	SD	Min	Median	Max
lnGI1	25974	0.74	1.121	0.000	0.000	7.217
SCF1	25974	0.66	0.793	0.000	0.693	3.045
Size	25974	22.51	1.262	19.415	22.319	26.452
EM	25974	2.10	1.130	1.031	1.772	11.159
CAP	25974	2.41	1.965	0.332	1.870	20.812
ROE	25974	0.05	0.149	-2.438	0.063	0.361
TobinQ	25974	1.98	1.227	0.795	1.607	17,676
Indep	25974	0.38	0.054	0.250	0.364	0.600
FirmAge	25974	3.01	0.299	1.609	3.045	4.263

As shown in Table 2, the sample size is 25,974. The minimum value of lnGI1 is 0, and the maximum value is 7.217. This reflects a significant gap in the level of green innovation among different enterprises. Enterprises with high levels of green innovation have already surpassed many enterprises without green innovation in this dimension. The mean of lnGI1 is 0.74, and the median is 0. This indicates that at least half of the enterprises have not applied for green invention patents. The development of green innovation at the enterprise level is uneven, or perhaps these enterprises are not heavily polluting and are not driven by policy or social environmental pressure to carry out green innovation. The minimum value of Supply Chain Finance Level (SCF1) is 0, and the maximum value is 3.045, with a mean of 0.66. This also reflects an uneven level of supply chain finance among enterprises, or perhaps the enterprises themselves have a low dependence on the supply chain.

4. EMPIRICAL RESULTS

4.1 Regression Test and Results Analysis

Table 3 shows the baseline regression results for Hypothesis 1. As defined previously, lnGI3 is the logarithm of the number of green utility model patent applications plus 1, used to measure strategic green innovation behavior of enterprises.

Column (1) shows the results without control variables and fixed effects. Based on this, columns (2) to (4) show the regression results with control variables, time-fixed effects, and firm-fixed effects added in sequence. The regression coefficient of the core explanatory variable SCF1 is consistently significantly positive at the 1% statistical level, indicating that supply chain finance can increase the amount of green invention patents developed by enterprises and promotes substantive innovation by enterprises [17]. According to column (5), SCF1 is not significant with lnGI3. Therefore, supply chain finance is not related to the number of green utility model patent applications. Supply chain finance does not induce enterprises to engage in strategic, speculative, and low-quality green innovation. Thereby, supply chain finance promotes the improvement of the level of green innovation of enterprises, thus verifying Hypothesis 1.

Table 3. Benchmark Regression

	(1)	(2)	(3)	(4)	(5)
	lnGI1	lnGI1	lnGI1	lnGI1	lnGI3
SCF1	0.280***	0.062***	0.036***	0.038***	0.017
	(21.43)	(5.91)	(3.21)	(3.24)	(1.52)
Size		0.440***	0.426***	0.407***	0.333***
		(23.40)	(22.24)	(14.46)	(13.11)
EM		-0.056***	-0.048***	-0.050***	-0.039***
		(-4.50)	(-3.87)	(-3.69)	(-3.04)
CAP		-0.018***	-0.018***	-0.016***	-0.024***
		(-3.63)	(-3.61)	(-2.79)	(-4.37)
ROE		-0.227***	-0.195***	-0.172***	-0.151***
		(-4.94)	(-4.24)	(-3.61)	(-3.31)
TobinQ		0.026***	0.039***	0.038***	0.028***
		(4.70)	(5.89)	(5.38)	(4.31)
Indep		0.412**	0.333**	0.325*	0.040
		(2.51)	(2.03)	(1.82)	(0.24)
FirmAge		0.369***	-0.111*	0.129	0.072
		(8.69)	(-1.74)	(0.62)	(0.44)
_cons	0.498***	-10,321***	-8,833***	-9.009***	-7.096***
	(29.95)	(-26.01)	(-20.73)	(-12.07)	(-11.09)
Time FE	No	No	Yes	Yes	Yes
Firm FE	No	No	No	Yes	Yes
N	25974	25974	25974	25974	25974
Adj. R^2				0.22	0.19

Note: (1) *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively. The values in parentheses are t-values. The same applies below.

4.2 Robustness Test and Endogeneity Test

According to Table 5, ① after changing the measurement method of the explanatory variables, the level of supply chain finance still shows a positive correlation with the level of green innovation at a significance level of 1%. SCF2 uses another set of supply chain finance keywords to conduct word frequency statistics on corporate annual reports [38], as shown in

Table IV. As defined previously, lnGI2 is the logarithm of the total number of green patent applications of enterprises plus 1. ② After changing the measurement method of the explained variable, its significance level and correlation coefficient decreased compared with the baseline regression data, but at a significance level of 5%. lnGI2 includes the number of applications for green utility models, which may be due to the low correlation between supply chain finance and green utility models, thus lowering the overall correlation. ③ After adding new control variables such as debt-to-asset ratio (Lev), whether it is a state-owned enterprise (SOE), and the natural logarithm of the total compensation of directors, supervisors and senior executives (TMTPay2), the level of supply chain finance still shows a positive correlation with the level of green innovation at a significance level of 1%. The reason for choosing Lev is that the debt-to-asset ratio affects the financial risk and financing constraints of enterprises. Highly indebted enterprises may face greater debt repayment pressure, reducing the funds available for green innovation and affecting their access to supply chain finance support. SOEs were chosen because ownership structure influences corporate behavior. State-owned enterprises face different policy pressures, financing environments, and performance evaluation systems, resulting in systemic differences in their attitudes and capabilities towards green innovation compared to non-state-owned enterprises. Executive compensation (TMTPay2) reflects the enterprise's talent incentive mechanism and management quality. High-quality management teams are better able to identify the strategic value of green innovation and balance short-term performance with long-term development. This variable also controls for the impact of corporate human capital investment on corporate innovation behavior. ④ Even after adding the fixed effect of the product of province and year, the level of supply chain finance remains positively correlated with the level of green innovation at the 1% significance level, indicating that the relationship is independent of the province where the enterprise headquarters is located.

Table 4. Keywords for Supply Chain Finance (SCF2)

Type	Keywords
Accounts Receivable	Accounts receivable financing, factoring, reverse factoring, dynamic discount, accounts receivable securitization
Prepaid	Prepayment financing, future title financing, title-backed financing, and confirmed warehouse receipt financing
Inventory	Movable property 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 funds, supply chain investment, supply chain loans, supply chain management, trade credit, financial supply chain, supplier finance, buyer finance, supplier managed inventory, buyer investment, distributor finance, working capital management, logistics finance, unified credit financing, financial value chain, working capital optimization

Table 5. Robustness Tests

	(1)	(2)	(3)	(4)
	lnGI1	lnGI2	lnGI1	lnGI1
SCF2	0.368***			
	(3.64)			
SCF1		0.032**	0.038***	0.038***
		(2.44)	(3.21)	(3.25)
Size	0.413***	0.484***	0.420***	0.406***
	(14.75)	(16.57)	(14.40)	(14.33)
EM	-0.065***	-0.052***	-0.059***	-0.043***
	(-4.70)	(-3.50)	(-3.34)	(-3.66)

Table 5. (continued) Robustness Tests

	(1)	(2)	(3)	(4)
	lnGI1	lnGI2	lnGI1	lnGI1
CAP	-0.012**	-0.026***	-0.018***	-0.018***
	(-2.18)	(-3.77)	(-2.99)	(-3.13)
ROE	-0.169***	-0.205***	-0.163***	-0.151***
	(-3.52)	(-3.82)	(-3.41)	(-3.25)
TobinQ	0.040***	0.039***	0.040***	0.041***
	(5.65)	(4.90)	(5.62)	(5.75)
Indep	0.321*	0.243	0.302*	0.337*
	(1.81)	(1.27)	(1.69)	(1.96)
FirmAge	0.106	0.092	0.115	0.031
	(0.51)	(0.44)	(0.55)	(0.14)
Lev			0.078	
			(0.76)	
SOE			0.055	
			(1.21)	
TMTPay2			-0.046**	
			(-2.25)	
_cons	-9.164***	-10.387***	-8.610***	-9.023***
	(-12.26)	(-13.53)	(-10.99)	(-10.42)
Time FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Time FE*Province FE	No	No	No	Yes
N	25974	25974	25948	25973
Adj. R^2	0.22	0.26	0.22	0.23

4.3 Endogeneity Test

Considering reverse causality, measurement errors, and endogeneity issues caused by omitted variables, this paper employs the median value of city-industry supply chain finance as an instrumental variable. From the perspective of relevance, the higher the level of supply chain finance in an industry in a city, the more enterprises in this industry participate in supply chain finance activities in this city. After the weak instrumental variable test, we get the F value of 516.59, far exceeding 10, which shows that this is a strong instrumental variable. This tool variable meets the correlation requirements.

In terms of externality and exclusiveness, the decision of enterprises to make green innovation is mainly influenced by financial situation, technical prospect and policy compliance. Supply chain finance at the city and industry level has little to do with green innovation at the enterprise level.

Table 6 shows the regression results of the second stage. The coefficient of SCF1 is 0.054, which is significantly positive at the level of 1%. The tool variable test passed, which shows that our findings are reliable. This shows that supply chain finance can still promote green innovation after solving endogenous problems.

Table 6. Endogeneity Test

	(1)	(2)
	lnGI1	SCF1
SCF1	0.054***	
	(3.44)	
IV		0.840***
		(82.40)
Size	0.405***	0.072***
	(14.41)	(5.83)
EM	-0.050***	0.000
	(-3.68)	(0.04)
CAP	-0.016***	-0.003
	(-2.76)	(-0.88)
ROE	-0.172***	-0.002
	(-3.60)	(-0.08)
TobinQ	0.038***	0.005
	(5.37)	(1.22)
Indep	0.328*	-0.125
	(1.84)	(-1.45)
FirmAge	0.133	-0.158*
	(0.64)	(-1.69)
_cons	-8.971***	-1.069***
	(-12.05)	(-3.01)
N	25974	25974
Adj. R^2		0.68

4.4 Heterogeneity Test

Existing heterogeneity tests mostly focus on the ownership nature of enterprises (state-owned versus non-state-owned [9].

This paper studies the heterogeneity effect on manufacturing enterprises. The classification of manufacturing enterprises is mainly based on the "National Industrial Classification of Economic Activities" (GB/T 4754-2017). As shown in Table 7, supply chain finance for manufacturing enterprises shows a positive correlation with lnGI1 at the 1% significance level. Due to the greater importance of upstream and downstream supply chains linking product production in manufacturing, the level of supply chain finance in manufacturing is more developed compared to non-manufacturing enterprises. Non-manufacturing supply chains may not be as stable and robust. Therefore, the benefits of supply chain finance are not as significant as those in manufacturing enterprises.

This study further explores the differentiated impact on high-tech enterprises. Based on the resource-based view [1], building a unique and valuable resource system is a key way for enterprises to gain a competitive advantage, a characteristic particularly prominent in high-tech enterprises. In terms of sample segmentation, this study adopts the classification criteria proposed by Peng and Mao [24], dividing listed companies into high-tech and non-high-tech categories. For specific classification, authoritative sources such as the "Strategic Emerging Industries Classification Catalogue", the "Strategic

Emerging Industries Classification (2012) (Trial)", relevant OECD documents, and the "Guidelines for Industry Classification of Listed Companies (2012 Revision)" were comprehensively referenced. The experimental results show that the development level of supply chain finance is positively correlated with the green innovation performance of high-tech enterprises at the level of 1%. This is mainly because of the characteristics of high-tech industries, such as rapid technological update and fierce competition, which will prompt enterprises to continuously increase R&D investment to promote green innovation. In contrast, the competitive core of non-high-tech enterprises is not technological innovation, but more concerned about other markets. Therefore, the development of supply chain finance has played an important role in promoting the green innovation activities of high-tech enterprises.

Table 7. Heterogeneity Test

	Manufacturing	Non-manufacturing	Hitech	Non-hi-tech
	lnGI1	lnGI1	lnGI1	lnGI1
SCF1	0.042***	0.022	0.044***	0.025
	(3.13)	(1.07)	(2.88)	(1.46)
Size	0.447***	0.376***	0.459***	0.343***
	(12.47)	(7.88)	(11.73)	(8.33)
EM	-0.045***	-0.041**	-0.047***	-0.039**
	(-2.84)	(-2.46)	(-2.67)	(-2.53)
CAP	-0.014	-0.022***	-0.020**	-0.017**
	(-1.38)	(-3.02)	(-2.07)	(-2.49)
ROE	-0.187***	-0.124*	-0.191***	-0.136*
	(-3.10)	(-1.76)	(-3.25)	(-1.86)
TobinQ	0.039***	0.027*	0.039***	0.034***
	(4.80)	(1.90)	(4.25)	(2.65)
Indep	0.207	0.599*	0.242	0.559**
	(1.07)	(1.89)	(1.10)	(2.17)
FirmAge	-0.623**	1.077***	-0.600**	0.674**
	(-2.35)	(3.19)	(-2.02)	(2.28)
_cons	-8.025***	-10.828***	-8.363***	-9.186***
	(-8.65)	(-8.20)	(-8.04)	(-8.23)
Time FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
N	17384	8590	15567	10407
Adj. R^2	0.22	0.23	0.23	0.20

5. MECHANISM TESTING

It is found that supply chain finance is of great help to improve the company's financial situation (Zhao et al., 2024). As an innovative financial service model, supply chain finance not only strengthens the cooperative relationship between banking institutions and upstream and downstream enterprises, but also greatly improves the efficiency of capital flow by optimizing capital allocation [35]. More importantly, by alleviating the company's financing difficulties, supply chain

finance provided the necessary financial support for the company's green innovation, thus promoting technological breakthroughs and transformation and upgrading on the road of sustainable development.

Therefore, this paper constructs the following model:

$$SA\_abs_{it} = \beta_0 + \beta_1 SCF1_{it} + X\delta + \eta_i + \mu_t + \epsilon_{it} \quad (2)$$

$$lnGI1_{it} = \gamma_0 + \gamma_1 SA\_abs_{it} + X\delta + \eta_i + \mu_t + \epsilon_{it} \quad (3)$$

This paper uses the absolute value of the SA index as a standard to measure financing constraints because the SA index does not include financing variables with endogenous characteristics, is easy to calculate, and yields robust results [13]. Similar studies construct external financing dependence and whether the SA index is higher than the median as dummy variables to measure the degree of financing constraints for enterprises [9], This paper uses SA as a continuous variable to measure the easing effect of supply chain finance on financing constraints. The greater the absolute value of SA index, the more serious the financing constraints of enterprises. From the results in the first and second columns of Table 8, the level of supply chain finance is negatively correlated with the absolute value of SA at 1% significance level, while the absolute value of SA is negatively correlated with the level of green innovation of enterprises at 1% significance level, which is consistent with the expected conclusion. That is to say, supply chain finance promotes the green innovation of enterprises by alleviating their financing constraints, thus verifying Hypothesis 2.

Table 8. Test of Financing Constraint Mechanism

	(1)	(2)
	SA_abs	lnGI1
SCF1	-0.005***	
	(-3.57)	
SA_abs		- 2.422** *
		(-9.18)
Size	-0.038***	0.319***
	(-6.75)	(11.64)
EM	-0.002	-0.056***
	(-0.95)	(-3.91)
CAP	0.001	-0.013**
	(1.09)	(-2.16)
ROE	0.014***	-0.139***
	(2.67)	(-2.98)
TobinQ	-0.010***	0.014**
	(-10.32)	(2.12)
Indep	-0.040**	0.220
	(-1.96)	(1.30)
FirmAge	0.096***	0.356*
	(3.44)	(1.85)
_cons	4.117***	0.900
	(33.75)	(0.76)

Table 8. (continued) Test of Financing Constraint Mechanism

	(1)	(2)
	SA_abs	lnGI1
N	25974	25974
Adj. R^2	0.89	0.25

6. EXTENDED ANALYSIS

6.1 Analysis of The Moderating Effect of Risk-Bearing Capacity

Supply chain finance affects the level of green innovation of enterprises under different risk levels. Existing research mainly uses the volatility of corporate profits (i.e., standard deviation) to measure this (Li and Yu, 2012). Therefore, this paper constructs the following model to examine the moderating effect of corporate risk level on the two variables. Following the approach of the scholars, this paper calculates the standard deviation and range of ROA of enterprises over a five-year observation period as indicators of corporate risk-taking. The larger the values of both, the greater the level of corporate risk. The formula is:

$$\mathrm{risk1}_{i,t} = \sqrt{\frac{1}{N-1}\sum_{n=1}^{N}\left(\mathrm{ADJ\_ROA}_{in} - \frac{1}{N}\sum_{n=1}^{N}\mathrm{ADJ\_ROA}_{in}\right)^2} \mid N = 5 \tag{4}$$

$$\mathrm{risk2}_{i,t} = \mathrm{MAX}\left(\mathrm{ADJ}_{\mathrm{ROA}_{i,t}}\right) - \mathrm{MIN}\left(\mathrm{ADJ}_{\mathrm{ROA}_{i,t}}\right) \tag{5}$$

$$\mathrm{ADJ\_ROA}_{in} = \frac{\mathrm{EBIT}_{in}}{\mathrm{ASSETS}_{in}} - \frac{1}{X_n}\sum_{k=1}^{X}\frac{\mathrm{EBIT}_{kn}}{\mathrm{ASSETS}_{kn}} \tag{6}$$

Therefore, this paper constructs the following model:

$$\mathrm{lnGI1}_{i,t} = \vartheta_0 + \vartheta_1\mathrm{SCF1}_{i,t} + \vartheta_2\mathrm{SCF} * \mathrm{risk1}_{i,t} + \vartheta_3\mathrm{risk1}_{i,t} + X\delta + \eta_i + \mu_t + \epsilon_{it} \tag{7}$$

$$\mathrm{lnGI1}_{i,t} = \iota_0 + \iota_1\mathrm{SCF1}_{i,t} + \iota_2\mathrm{SCF} * \mathrm{risk2}_{i,t} + \iota_3\mathrm{risk2}_{i,t} + X\delta + \eta_i + \mu_t + \epsilon_{it} \tag{8}$$

$$\mathrm{lnGI1}_{i,t} = \kappa_0 + \kappa_1\mathrm{SCF1}_{i,t} + \kappa_2\mathrm{SCF} * \mathrm{OCFvol}_{i,t} + \kappa_3\mathrm{OCFvol}_{i,t} + X\delta + \eta_i + \mu_t + \epsilon_{it} \tag{9}$$

This paper selects cash flow risk as a supplement to further study how the level of risk affects the relationship between supply chain finance and green innovation. Referring to the calculation method of Chen and Wang (2015), this paper selects OCFvol as a measure of cash flow risk. OCFvol is the standard deviation of the ratio of net cash flow from operating activities to total assets from year t-2 to year t. The larger this indicator, the greater the cash flow risk.

Based on the results in Table 9, this paper finds that although there is no significant impact between corporate risk level and corporate green innovation level, the promoting effect of supply chain finance on green innovation is significantly moderated by corporate risk status: when risk1 and risk2, especially when OCFvol, increase, the marginal effect of supply chain finance weakens, and the interaction term coefficients are all significantly negative. This is because when considering the development of green innovation, companies consider their current risk-bearing status and capabilities. The higher the risk, the more uncertain the money we will receive in the future. Because green innovation itself is risky, and it doesn't make much money at first, when companies are under great financial pressure, they will be more worried about how to pay their debts in the future, so they are unwilling to spend a lot of money on green patents. At this time, green innovation is not the company's biggest concern. The money they borrowed through supply chain finance may be used more in other places, such as making the company's books look better. These practices can often improve the company in a short period of time, which is good for the market value of the company and managers. This result verifies Hypothesis 3.

Table 9. Moderating Effect of Risk-Taking

	(1)	(2)	(3)
	lnGI1	lnGI1	lnGI1
SCF1	0.057***	0.058***	0.063***
	(3.69)	(3.76)	(4.24)
risk1	-0.004		
	(-1.50)		
risk2		-0.002	
		(-1.53)	
OCFvol			0.168
			(0.74)
c.risk1# c.SCF 1	-0.005**		
	(-2.24)		
c.risk2# c.SCF 1		-0.002**	
		(-2.35)	
c.OCFvol#c. SCF1	-		-0.630***
Size	0.400***	0.399***	0.406***
	(14.12)	(14.11)	(14.45)
EM	-0.049***	-0.049***	-0.050***
	(-3.57)	(-3.57)	(-3.67)
CAP	-0.017***	-0.017***	-0.016***
	(-2.88)	(-2.88)	(-2.77)
ROE	-0.207***	-0.207***	-0.172***
	(-4.22)	(-4.23)	(-3.60)
TobinQ	0.039***	0.039***	0.038***
	(5.46)	(5.46)	(5.43)
Indep	0.331*	0.331*	0.331*
	(1.86)	(1.86)	(1.86)
FirmAge	0.147	0.147	0.127
	(0.70)	(0.71)	(0.61)
_cons	-8.878***	-8.873***	-9.002***
	(-11.89)	(-11.89)	(-12.08)
N	25974	25974	25974
Adj. R^2	0.22	0.22	0.22

6.2 Analysis of The Moderating Effect of Environmental Performance

This paper also studies how the level of supply chain finance will affect green innovation under different environmental performance conditions. ESG is a super-important evaluation dimension in company operation, which mainly depends on the company's performance in environmental, social and corporate governance. Because the companies with high environmental performance have established the foundation of green reputation and compliance, the funds of supply chain finance are more likely to be used for green innovation. At the same time, high environmental performance can also enhance the trust between companies, upstream and downstream partners and financial institutions, and reduce the evaluation cost of green project, thus forming a virtuous circle from green repayment to financing efficiency improvement, and then to investment in green innovation. The disclosure of environmental information by enterprises can send positive signals to the market, improve operational transparency, attract more potential investors, and provide financial support for green innovation of enterprises. The Epoints data in this paper comes from the annual ESG performance evaluation data of China A-share listed companies on CNRDS platform. Table 10 shows the evaluation index of Epoints.

Table 10. Explanation of Environmental Performance Evaluation Indicators

Primary indicators	Secondary indicators	Indicators	Details	Data source
E	Climate change	Green patents	Record the number of green patents applied for by enterprises during the reporting period	CNRDS
		Emergency response plan for sudden environmental risks	Does the company implement emergency management?	Enterprise Disclosure Published report
		Environmental management system and regulations	Does the company have established a sound environmental management system?	Enterprise Disclosure Published report
	Pollution control	Measures to reduce waste	Have enterprises taken management measures to reduce emissions of waste gas, wastewater, and solid waste?	Enterprise Disclosure Published report
	circular economy	Green Office	Does the company have energy-saving and environmentally friendly office policies?	Enterprise Disclosure Published report
		Resource recycling	Does the company recycle energy in its operations?	Enterprise Disclosure Published report
	Environmental risks	Waste discharge	Does the company involve the emission of substances that deplete ozone, affect weather change, or pollute water?	CNRDS

Companies with good environmental performance have accumulated experience and relevant research resources in green innovation, while companies with poor environmental performance lack these resources and do not pay enough attention to innovation in the environmental field, thus creating a Matthew effect: the strong gets stronger and the weak gets weaker. Therefore, this paper designs the following model:

$$\ln GI1_{i,t} = \lambda_0 + \lambda_1 SCF1_{i,t} + \lambda_2 SCF * Epoints_{i,t} + \lambda_3 Epoints_{i,t} + X\delta + \eta_i + \mu_t + \epsilon_{it} \quad (10)$$

According to the results in Table 11, SCF1, Epoints, and lnGI1 are not significant, but the interaction term between Epoints and SCF1 and lnGI1 show a positive correlation at the 1% significance level. Therefore, the better the environmental performance, the stronger the promotion of green innovation by supply chain finance, indicating that it can promote the development of high-quality green innovation. Corporate environmental performance sends a positive signal to the market that the company has the capability to promote green transformation. Those companies with good environmental performance have established a green reputation and compliance foundation, and the funds of supply chain finance are more likely to flow to green innovation, reducing the situation of being accused of "greenwashing" by the media and the government. At the same time, their high-quality environmental performance enhances the trust of upstream and downstream partners and financial institutions, and reduces the evaluation cost of green projects. In this way, a cycle is formed: improving green reputation → improving financing efficiency → investing in green innovation. This finding echoes with signaling theory and institutional theory, indicating that environmental performance is the key catalyst for the green effect of supply chain finance. This result verifies Hypothesis 4.

6.3 Analysis of The Moderating Effect of Information Transparency

Supply chain finance solves the information asymmetry between financial institutions and enterprises by sharing trade and financial information between upstream and downstream companies, thus alleviating the financing difficulties of enterprises. However, if the enterprises themselves lack transparency, it will offset the benefits of supply chain finance. This paper also sets corporate information transparency as a moderating effect to analyze the promoting relationship between supply chain finance and the level of green innovation. Zhang and Jin (2022) argue that the environmental information disclosure behavior of buyer companies can cross corporate boundaries and affect the green technology innovation of seller companies. This spillover effect is transmitted through the supply chain network, further strengthening the promoting role of supply chain finance in green innovation. Xia et al. (2023) believe that corporate information transparency affects the legitimacy of green innovation through three channels: accounting information transparency, analyst supervision transparency, and external audit transparency. Due to the low level of attention on analysis about the supply chain effect and green innovation of A-share listed companies in China, and the low level of ESG auditing, relevant data are difficult to obtain and statistically analyze. Therefore, this paper chooses corporate accounting information transparency, i.e., earnings quality, as the standard for measuring information transparency. This study adopts the methodology of Wang et al. (2009) and uses the volatility of manipulative accruals to assess the level of corporate information transparency. Specifically, this paper quantifies information transparency by calculating the sum of the absolute values of manipulative accruals over the past three years (Opaque), with a higher value indicating lower transparency. Therefore, this paper constructs the following model:

$$\mathrm{lnGI1}_{i,t} = \nu_0 + \nu_1 \mathrm{SCF1}_{i,t} + \nu_2 \mathrm{SCF} * \mathrm{Opaque}_{i,t} + \nu_3 \mathrm{Opaque}_{i,t} + X\delta + \eta_i + \mu_t + \epsilon_{it} \quad (11)$$

As shown in Table XI, the interaction between SCF1 and Opaque is negatively correlated with lnGI1, and this relationship is significant (1% level). Therefore, the more opaque the company information, the weaker the positive impact of supply chain finance on green innovation. If the information transparency is high, it can reduce the information asymmetry and make it easier for stakeholders to understand the rationality of the company's green innovation, so that supply chain finance will play a stronger role in promoting green innovation. High transparency can also effectively alleviate the multilateral information asymmetry in supply chain, so that financial institutions can more accurately judge the true value and risk of green innovation projects, and thus better allocate funds. At the same time, it can also reduce the upstream and downstream monitoring costs of core companies and improve the operation efficiency of supply chain finance. This result verifies Hypothesis 5.

Table 11. Moderating effect of environmental performance and information transparency

	(1)	(2)
	lnGI1	lnGI1
Epoints	-0.000	
	(-0.75)	
Opaque		0.038
		(0.78)

Table 11. (continued) Moderating effect of environmental performance and information transparency

	(1)	(2)
	lnGI1	lnGI1
SCF1	0.009	0.064***
	(0.67)	(4.08)
c. Epoints # c.SCF 1	0.001***	
	(3.07)	
c.Opaque# c.SCF 1		-0.134***
		(-2.69)
Size	0.405***	0.408***
	(14.39)	(14.54)
EM	-0.049***	-0.049***
	(-3.62)	(-3.57)
CAP	-0.016***	-0.017***
	(-2.75)	(-2.97)
ROE	-0.172***	-0.176***
	(-3.59)	(-3.62)
TobinQ	0.038***	0.039***
	(5.35)	(5.50)
Indep	0.325*	0.329*
	(1.83)	(1.85)
FirmAge	0.127	0.126
	(0.61)	(0.60)
_cons	-8.953***	-9.044***
	(-12.03)	(-12.02)
N	25974	25813
Adj. R^2	0.22	0.22

7. CONCLUSIONS AND POLICY RECOMMENDATIONS

7.1 Conclusion

This paper, using the data of our listed companies in China from 2008 to 2024, systematically studies the influence of supply chain finance on the company's green innovation. What we found is this. First, supply chain finance is an important engine to promote the company's green innovation. The empirical results show that the improvement of supply chain finance can obviously promote enterprises to apply for green invention patents, and this conclusion has passed a series of robustness tests. This shows that supply chain finance provides a guarantee for green innovation by integrating industrial chain resources. Second, easing financing constraints is the core intermediary mechanism. The mechanism test shows that supply chain finance releases the restrained innovation vitality by lowering the external financing threshold and cost of enterprises. Thirdly, the regulatory effect reveals the influence path of differentiation. The negative moderating effect of enterprise risk level indicates that in a high-risk environment, high enterprise risk weakens the innovation incentive of

supply chain finance. Conversely, high environmental performance and high information transparency significantly strengthen the promoting effect of supply chain finance on green innovation through signal transmission. Fourth, significant industry heterogeneity exists. The promoting effect of supply chain finance on green innovation is more prominent for manufacturing and high-tech enterprises, which is consistent with the characteristics of these industries: close supply chain linkages and rapid technological iteration.

7.2 Policy Recommendations

Based on the research findings, the following policy recommendations are proposed:

Supply chain finance products should be linked to corporate green performance. Simultaneously, the standardization of green information disclosure should be strengthened, and big data platforms should be used to integrate environmental enforcement and credit data to reduce risk control costs for financial institutions and guide funds precisely towards green innovation.

At the enterprise level, companies should make full use of supply chain finance tools but must act within their means. Manufacturing and high-tech companies should actively align themselves with core enterprises to enhance their position and transparency within the supply chain, thereby securing low-cost funding. Simultaneously, companies need to establish risk warning mechanisms and prudently plan the pace of green innovation investment when risk tolerance is high, avoiding liquidity crises caused by excessive debt.

At the financial institution level, institutions should break away from the path dependence of traditional collateral and guarantees, and incorporate the number of green patents and environmental performance ratings of enterprises into their credit assessment systems. By leveraging blockchain technology to achieve tamper-proof and real-time sharing of supply chain information, and while controlling risks, they can increase credit support for green supply chains.

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