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The Impact of Supply Chain Finance on the Level of Green Innovation of Enterprises

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Abstract: Following the onset of the global health crisis, many businesses faced disruptions in their financing channels, prompting increased focus on supply chain finance as a vital solution. Leveraging the distinct advantages of supply chain finance to foster green innovation has emerged as a key strategy for enhancing corporate performance. Drawing on data from Chinese listed companies between 2011 and 2023, this study empirically evaluates the influence of supply chain finance on corporate green innovation and its underlying mechanisms. Findings indicate that supply chain finance significantly boosts enterprises' green innovation capabilities. This positive effect is particularly pronounced in non-state-owned firms, mature companies, and those located in China's eastern and western regions. Mechanism analysis reveals that supply chain finance facilitates green innovation by alleviating financing constraints and improving asset allocation efficiency. This research contributes new insights into the role of supply chain finance in promoting sustainable corporate development and offers theoretical guidance for firms prioritizing green innovation.

Keywords: Supply Chain Finance; Green Innovation; Mechanism Analysis.

1. Introduction

The emergence of the COVID-19 pandemic in 2020 has posed significant challenges to real economies, leading to operational setbacks, diminished debt repayment capabilities, and heightened caution among banks regarding lending. As the smallest components of financing networks, micro-enterprises play a pivotal role in this context, offering critical insights for advancing high-quality development, modernizing the economic framework, and safeguarding national industrial security. The Third Plenary Session of the 20th Central Committee further advocated for "refining the policy framework to bolster financial support for small, medium, and micro-enterprises, as well as private firms, to address challenges related to financing access and costs, while improving the capital market's role in balancing investment and financing." The strategic expansion of supply chain finance is instrumental in enabling enterprises to secure funding, thereby strengthening the robustness and security of industrial and supply chains[1].

In recent years, the adoption of advanced technologies, including artificial intelligence, big data, and blockchain, has fueled the growth of supply chain finance. The "14th Five-Year Plan" highlights the importance of "enhancing resource allocation efficiency and fostering innovative advancements in supply chain financial services." In 2023, China's supply chain finance market reached a value of 37.2 trillion yuan, reflecting a 12.3% year-on-year growth. A total of 628 listed companies in China spearheaded supply chain finance platforms, supporting over 3.8 million upstream and downstream enterprises, with small and micro-enterprises comprising 83% of this group. Major banks, including the Industrial and Commercial Bank of China, Agricultural Bank of China, Bank of China, China Construction Bank, Bank of Communications, and Postal Savings Bank of China, have significantly engaged in supply chain finance, collectively holding over 45% of the market share. In 2023, supply chain finance loans amounted to 17.5 trillion yuan, up 14.2% from the previous year, while 23 securities firms, such as CITIC Securities and Huatai Securities, issued supply chain asset-backed securities (ABS) totaling 1.15 trillion yuan, a 28% increase year-on-year. Given the robust growth of supply chain finance, there is a pressing need to theoretically elucidate its mechanisms and scientifically assess its societal impacts[2].

This study analyzes data from Chinese listed companies spanning 2011 to 2023, demonstrating that supply chain finance enhances enterprises' green innovation

capabilities. This effect is more pronounced in non-state-owned enterprises compared to state-owned ones, in firms located in eastern and western regions relative to the central region, and in mature enterprises as opposed to those in decline. The underlying reasons include supply chain finance's ability to mitigate financing constraints and improve resource allocation efficiency, thereby providing greater funding and research efficiency for green innovation[3].

Supply chain finance, as a critical tool for addressing the financing challenges of small and medium-sized enterprises (SMEs), has garnered significant attention from both practitioners and academics. Grounded in supply chain theory, which views enterprise operations as a value-adding process emphasizing collaboration among upstream and downstream partners, supply chain finance has been extensively studied for its micro-level impacts. Relevant literature includes the following: Supply chain finance, as an innovative practice, has gained traction among domestic and international commercial banks, creating new markets and profit opportunities while reducing supply chain management costs (Hu Yuefei, 2009)[4]. It facilitates real-time financing for SMEs (Song Hua and Lu Qiang, 2017) and fosters symbiotic relationships and value co-creation among participants, leveraging core enterprises to alleviate capital constraints for smaller firms (Song Hua, 2018)[5]. Additionally, it extends credit at the supply chain level, strengthens bank-enterprise ties, broadens external financing avenues, and supports innovation through a "financing effect" (Ling Runze, 2021)[6]. However, some studies challenge these benefits, arguing that supply chain finance fails to fully resolve SME financing difficulties due to the market dominance of large enterprises, which may divert funds from SMEs through commercial credit, creating a dynamic of simultaneous capital infusion and depletion (Bao Changsheng, 2020)[7].

Green innovation faces significant barriers, particularly in areas such as low-carbon technology, clean energy, and the circular economy, where core patents are predominantly held by developed nations. Domestic firms grapple with high costs for technology adoption and a weak foundation for independent innovation. Moreover, green innovation projects often involve high risks and extended timelines, leading enterprises, especially SMEs, to adopt conservative strategies. Relevant literature on this topic includes the following: Supply chain finance positively influences corporate green innovation (Chai Zhengmeng, 2024), traditional finance impacts green development via industrial chain transmission (Ma Ting and Han Tingchun, 2023)[9], and inadequate capital supply is a primary barrier to green innovation (Qiao Fei and Wen Wen, 2023)[8]. Supply chain finance supports green technology innovation by improving financial conditions, increasing investment, and mitigating risks (Yu Zhaoji and Zhao Yingzi, 2024)[10]. As a key component of supply chain management, it provides stable support for utilizing peripheral resources, integrating knowledge, lowering innovation costs, and enhancing efficiency, yielding an innovative "relationship effect" (Wuttke et al., 2013; Ling Runze, 2021)[11].

While prior research has established a connection between supply chain finance and green innovation, the pathways through which supply chain finance drives corporate green innovation remain underexplored. This study offers the following marginal contributions: First, it extends the analysis of supply chain finance's role in fostering green innovation, providing robust empirical evidence to support enterprises' expansion of supply chain finance and their green transformation, as well as informing government policies to promote this sector. Second, it accounts for variations in business environments, enterprise life cycles, and ownership structures, enabling a nuanced understanding of supply chain finance's economic impacts across different regions, periods, and firm types. Third, it systematically examines the mechanisms—financing constraints and management expense rates—through which supply chain finance promotes green innovation, enriching the theoretical framework.

The paper is organized as follows: Section 2 provides a theoretical analysis of supply chain finance's impact on green innovation and formulates hypotheses. Section 3 outlines the research design, including variable selection, measurement methods, model design, and descriptive statistics. Section 4 presents the empirical findings and analysis. Section 5 conducts mechanism tests based on the proposed hypotheses. Section 6 summarizes the empirical results and offers recommendations for stakeholders.

2. Theoretical Analysis and Research Hypothesis

2.1 The Impact of Supply Chain Finance on Green Innovation

Green innovation helps enterprises stimulate new market demand, improve resource utilization, and achieve the "dual goals" of improving economic efficiency and protecting the environment (Magat, 1978). The overall national policy requires enterprises to develop green, and the speed of green product updates and iterations is accelerated. Enterprises are required to make full use of supply chain resources for high-quality innovation. Supply chain finance can take full advantage of peripheral resources such as supply chain in innovative business, integrate and develop various knowledge that enterprises can obtain, reduce innovation costs and improve efficiency, and provide stable relationship support (Ling Runze, 2021). Since the scope of supply chain finance has become more and more extensive, domestic and foreign real cases have shown that some enterprises have made full use of supply chain resources to stimulate enterprises to carry out green innovation. In September 2024, Asda, a Walmart subsidiary and the third largest retailer in the UK, cooperated with HSBC Bank UK Branch to launch a supply chain finance program related to sustainable development. With the support of financial institutions, chain leader enterprises launch sustainable supply chain finance programs, which can encourage suppliers to disclose their sustainable development performance data (such as carbon performance data), set sustainable development goals and take action, and promote supply chain enterprises to reduce carbon emissions and achieve common sustainable development goals. Based on this, this paper proposes the following hypothesis:

Hypothesis 1: Enterprises carrying out supply chain finance business will significantly improve the level of green innovation.

2.2 Relieving Financing Constraints, Supply Chain Finance and Green Innovation

At present, Chinese enterprises are facing great financing pressure. Due to the restrictions on enterprise scale and collateral in the traditional credit industry, most small and medium-sized enterprises have great resistance to carrying out green finance business. Green innovation projects have large initial R&D investment and long payback cycle. Financiers need a lot of funds to cover the costs and risks encountered in the innovation process. And due to the risk premium brought by the high risk of R&D innovation, the financing cost of external investors also increases (Yang Yi and Shi Shuhe, 2021)[12]. As an important financing method that has emerged in recent years, supply chain finance can effectively reduce the information asymmetry problem between banks and enterprises. Relying on the real transaction data of the supply chain, it can reduce information friction and eliminate the concerns of lenders. It can effectively alleviate the problem of "reluctant to lend" of financial institutions and help enterprises quickly obtain financing. Enterprises can directly use funds to cover the inventions and creations of green innovation technologies. At the same time, there are specific examples that supply chain finance business can help enterprises carry out green innovation by providing channels to alleviate financing constraints. Founded in 2008, Zhejiang Jinteng Pipe Technology Co., Ltd. is a manufacturing company mainly engaged in the production of energy-saving cable protection pipes. Since becoming a supplier of State Grid Corporation of China in 2020, the company has developed well and its development has entered the fast lane. However, affected by the rising prices of upstream raw materials, the company has been under great financial pressure after winning the bid for the new project. Relying on the "Electricity e-Finance" platform to deepen the synergy between industry and finance, State Grid Deqing County Power Supply Company actively promotes the province's first green emission reduction supply chain financial product which named "Jiaotanbao" to land in the company based on the "Carbon Credit Evaluation System", alleviating the difficulty of corporate financing. At present, the "Jiaotanbao" emission reduction supply chain financial business has achieved its first landing in Deqing, and will be rolled out and promoted throughout Zhejiang Province. The total loan amount is expected to be 20 billion yuan, with a maximum loan of 50 million yuan per loan. This business also provides conditions for financial institutions to obtain carbon emission reduction support tools from the central bank, thereby attracting financial institutions to provide long-term,

low-cost funds for more green and low-carbon projects, enriching the financing channels for low-carbon enterprises. Since 2022, Deqing County has established a wetland carbon sink trading platform and carried out wetland carbon sink collection and storage services, promoting the formation of a new ecological enrichment mechanism of "wetland cultivation-carbon sink collection and storage-platform trading-income feedback", mobilizing the enthusiasm of social enterprises to participate in ecological protection, and encouraging enterprises to promote low-carbon production. Based on this, this paper proposes the following hypothesis:

Hypothesis 2: Enterprises can reduce corporate financing constraints by carrying out supply chain financial business, thereby enabling the level of green innovation.

2.3 Resource Allocation, Supply Chain Finance and Green Innovation

How to allocate corporate resources is an important factor in determining the height of corporate development. The cumbersome procedures and long capital recovery cycle of traditional credit means often lead to slow capital turnover. Supply chain finance is based on the real trade background, can deeply understand the characteristics of capital demand of various enterprises in the industrial chain, and can also use information technology to realize the real-time transmission and sharing of transaction data, simplifying the financing process. Supply chain finance closely connects core enterprises, upstream and downstream enterprises, financial institutions, logistics enterprises, etc. All parties achieve optimal allocation of resources through information sharing and collaborative cooperation. Reasonable capital allocation can ensure that enterprises invest funds in green innovation projects. For example, after an enterprise has clarified its green development goals, it will use part of its funds to develop environmentally friendly production technologies and green products to avoid wasting manpower and material resources. Based on this, this paper proposes the following hypothesis:

Hypothesis 3: Enterprises can optimize resource allocation by carrying out supply chain finance, thereby enabling green innovation level.

3. Research Design

3.1 Sample Selection

Most companies started to engage in supply chain finance business in 2010. In the first year, the companies were in the initial stage of supply chain finance. Therefore, this paper selected Chinese listed companies from 2011 to 2023 as the research sample. The financial data of the companies come from the CSMAR database, and the patent data comes from the CNRDS database. In order to make the research result more accurately reflects the objective facts, this paper takes the following processing measures for the sample data. ① Eliminate ST, PT and delisted companies during the sample period. ② Eliminate financial industry companies. ③ Perform 1% bilateral winsoring on all continuous variables. ④ Eliminate some observations with missing data or abnormal corporate financial data. After screening, a total of 26,470 company-year observations were retained.

3.2 Variable Design

3.2.1 Dependent Variable

Corporate Green Innovation (GI), measured by the natural logarithm of the sum of corporate green patent applications plus 1.

3.2.2 Independent Variable

Supply Chain Finance (SCF), existing studies have mostly used 0-1 dummy variables or word frequency capture as measurement indicators, which may be difficult to accurately distinguish the actual supply chain finance capabilities of enterprises. This article refers to the research of Liu Yiming (2023) and uses the continuous variable "the ratio of the sum of short-term loans and notes payable to the total assets of the enterprise at the end of the year" as a measurement indicator, which can clearly reflect the differences in the supply chain financial capabilities of different enterprises.

3.2.3 Control Variables

In order to improve the accuracy of the regression results, the following variables are controlled with reference to existing studies: enterprise size (Size), that is, the natural logarithm of total assets, enterprise debt-to-asset ratio (LEV), that is, total liabilities divided by total assets, enterprise listing years (Age), that is, the natural logarithm of listing years, separation rate of two rights (Wedge), that is, the difference between the control and ownership of the actual controller of the listed company, growth ability

(Tobin), that is, Tobin Q value market value divided by asset replacement cost, top ten shareholders' shareholding ratio (TopTen), book value (mbratio), that is, the ratio of book value to market value. At the same time, the year and individual effects are controlled. The details are shown in the following table 1.

Table 1. Variable Design

	Variable symbol	Variable Design
Dependent Variable	GI	The total number of green patent applications filed by listed companies add 1 to take the natural logarithm
Independent Variable	SCF	(Short-term borrowings, notes payable)/Total assets of the enterprise at the end of the year
Control Variables	Size	The natural logarithm of total assets
	LEV	Leverage, Total Liabilities/Total Assets
	Age	The natural logarithm of years on the market
	Wedge	The difference between the control and ownership of the actual controller of the listed company
	Tobin	Market value/asset replacement cost
	TopTen	The shareholding ratio of the top 10 shareholders of listed companies
	mbratio	Book Value/Market Value
	Year	Year dummy variable
	id	Individual dummy variables

3.3 Model Design

In order to test the research hypothesis of this paper, the following regression model is constructed:

$$GI_{i,t}=\beta_0+\beta_1 SCF_{i,t}+\gamma ControlVars_{i,t} + \sum Year + \sum id + \varepsilon_{i,t} \qquad (1)$$

Where, the dependent variable represents the green innovation level of enterprise i in the t th year; the independent variable represents the supply chain finance level of enterprise i in the tth year, is the control variable, $\sum Year$ is the year dummy variable, is the individual dummy variable, is the random disturbance term. If it is significantly positive, it means that the development of enterprise supply chain finance business enables the green innovation level of enterprises, thus supporting hypothesis 1.

3.4 Descriptive statistical analysis

From the result of descriptive statistical analysis in the Table 2, it can be seen that the mean of supply chain finance (SCF) is 11% and the median is 7.9%, which are far lower than the maximum value of 50.9%, indicating that the development of supply chain finance business of Chinese enterprises is in the primary stage as a whole, and most enterprises have not yet deeply integrated supply chain financial tools. The median is less than the mean, indicating that the data distribution is right-skewed. The supply chain finance level of a few enterprises is significantly higher than the market average, which raises the overall mean; the median of green innovation level (GI) is 0, indicating that more than half of the enterprises did not carry out observable green innovation activities during the statistical period, and the standard deviation of 0.78 is large, indicating that the green innovation level varies greatly among enterprises.

Table 2. Descriptive Statistics

VarName	Obs	Mean	SD	Min	Median	Max
SCF	26470	0.11	0.120	0	.0790166	.5087214
GI	26470	0.37	0.780	0	0	3.713572
Size	26470	22.29	1.284	20.04133	22.09089	26.35216
LEV	26470	0.43	0.202	.0593	.4208475	.891801
Tobin	26470	2.00	1.255	.848913	1.587287	8.197319
Age	26470	2.18	0.788	.6931472	2.302585	3.367296
Wedge	26470	4.68	7.392	0	0	28.8311
TopTen	26470	58.45	14.860	23.33	59.14	90.32
mbratio	26470	0.63	0.248	.121991	.630006	1.177977

4. Empirical Results and Analysis

4.1 Benchmark Regression Result

Table 3. Benchmark Regression Result

	(1)	(2)	(3)
	GI	GI	GI
SCF	0.409***	0.210***	0.196***
	(10.23)	(5.40)	(3.26)
size			0.060***
			(3.90)
LEV			-0.105***
			(-2.59)
tobin			0.007
			(1.45)
lnage			-0.050**
			(-2.09)
SRTTR			0.002*
			(1.82)
TopTen			-0.002***
			(-3.30)
mbratio			-0.014
			(-0.31)
roa	0.319***	0.245***	-0.836***
	(48.79)	(13.80)	(-2.77)
year fixed effect	no	yes	yes
Individual fixed effect	no	no	yes
N	26470	26470	26470
Adj. R^2	0.00	-	0.02

Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels respectively, and the t-values are in brackets.

The benchmark regression result of supply chain finance on the level of corporate green innovation are shown in the table. This paper uses a fixed effect model for testing, in which table 3 column (1) only introduces independent variables, and the coefficient of the core independent variable is 0.409, which is significant at the 1% statistical level; table 3 column (2) further adds control time effects, and the SCF coefficient is 0.210, which is significant at the 1% statistical level; table 3 column (3) further adds control variables and individual fixed effects on this basis, and the SCF coefficient is 0.196, which is significant at the 1% statistical level. It shows that enterprises carrying out supply chain finance business improve the output level of corporate green innovation. When the level of supply chain finance increases by one unit of standard deviation, the dependent variable increases by an average of 6.36%, which can solve the 6.36% of the sample mean.

4.2 Robustness Test

4.2.1 Endogeneity test

Since supply chain finance between industries promotes each other's growth, that is, when an enterprise carries out supply chain finance business, it will drive upstream and downstream enterprises to carry out the business at the same time, but this phenomenon does not directly affect the green innovation level of the enterprise. This paper selects the average value of the supply chain finance index (SCFM) at the enterprise industry level during the sample period as an instrumental variable. The test results are shown in table 4 column (1). After eliminating the endogeneity problem, the enterprise supply chain finance level still has a significant positive effect on the green innovation level[13].

4.2.2 Replacement of dependent variables

There are cases where green patents are jointly invented among enterprises. In order to distinguish the contribution of the first inventor and the second inventor to green patents and better measure the green innovation level of enterprises, the explained variable is replaced by the number of green patents independently applied for by enterprises plus 1 and taken as the natural logarithm (GI$_2$). The coefficient is positive at the 1% statistical level as shown in table 4 column (3); utility patents can reflect the green innovation level of enterprises to a greater extent than appearance patents. Therefore, this paper replaces the explained variable with the number of utility green patents independently applied for by enterprises plus 1 and taken as the natural logarithm (GI$_3$). The coefficient is positive at the 1% statistical level as shown in table 4 column (4), indicating that the core conclusion has strong reliability and stability and is not easily affected by random factors[14].

4.2.3 Replacement of independent variables

Referring to Pan Weihua's (2024) research, the proportion of the sum of short-term loans, bills payable, and accounts payable in total assets is used to replace the explanatory variable (SCF$_2$). The results are shown in table 4 column (5). The estimated coefficient is positive at the 1% statistical level, indicating that the empirical result has sufficient credibility and robustness and is highly persuasive[15].

4.2.4 Changing the level of winsor wised

All continuous variables are winsor wised at 0.5% level. The result are shown in table 4 column (6). The estimated coefficient is still significantly positive at the statistical level of

1%, which fully proves the robustness of the model conclusion and effectively reduces the possibility of conclusion bias due to sample error.

4.2.5 Adding control variables

Referring to the research of Ling Runze (2021), the control variable return on total assets (ROA), that is, net profit divided by total assets, are added to test the robustness of the regression results. The results are shown in table 4 column (7). The estimated coefficient is still significantly positive, which further verifies the robustness and effectiveness of the conclusions of this study[16].

4.2.6 Adding fixed level

The double fixed effects of year and individual are widely used in various studies. In order to ensure the robustness of the regression results, a dummy variable fixed effect at a city level is added as a regional fixed effect on the basis of the baseline regression. The results are shown in table 4 column (8), which shows that enterprises engaged in supply chain finance business can still significantly enable the level of green innovation while controlling time, individuals and regions. This shows that the core conclusion of this article is highly robust under the setting of different fixed effects.

Table 4. Robustness Test

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	SCF	GI	GI_2	GI_3	GI	GI	GI	GI
SCF		1.638**	0.139***	0.137***		0.196***	0.196***	0.191***
		(2.02)	(2.84)	(3.07)		(3.26)	(3.27)	(3.17)
SCF_2					0.120***			
					(2.58)			
SCFM	0.509***							
	(6.16)							
size	-.013***	0.086***	0.040***	0.042***	0.059***	0.060***	0.058***	0.071***
	(-4.17)	(3.94)	(3.36)	(3.45)	(3.86)	(3.90)	(3.69)	(4.36)
LEV	0.400***	-0.726**	-0.056*	-0.091***	-0.093**	-0.105***	-0.096**	-0.101**
	(37.57)	(-2.26)	(-1.76)	(-2.89)	(-2.21)	(-2.59)	(-2.28)	(-2.41)
tobin	-0.002**	0.006	0.010**	0.003	0.007	0.007	0.007	0.007
	(-2.19)	(1.48)	(2.32)	(0.68)	(1.45)	(1.45)	(1.44)	(1.37)
lnage	0 .002	-0.035	-0.032*	-0.022	-0.049**	-0.050**	-0.049**	-0.057**
	(0.65)	(-1.14)	(-1.73)	(-1.17)	(-2.04)	(-2.09)	(-2.04)	(-2.33)
SRTTR	-9.51e-06	0.002*	0.002**	0.001	0.002*	0.002*	0.002*	0.002*
	(-0.04)	(1.72)	(1.99)	(1.02)	(1.80)	(1.82)	(1.82)	(1.89)
TopTen	-0.000	-0.001*	-0.001**	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***
	(-0.21)	(-1.93)	(-2.17)	(-3.24)	(-3.28)	(-3.30)	(-3.32)	(-2.84)
mbratio	0.017***	-0.100**	0.008	-0.018	-0.011	-0.014	-0.010	-0.028
	(2.96)	(-2.08)	(0.22)	(-0.51)	(-0.25)	(-0.31)	(-0.23)	(-0.62)
roa							0.048	
							(1.07)	
_cons	0 .169**	-1.311***	-0.625***	-0.592**	-0.831***	-0.836***	-0.806***	-0.900***
	(2.51)	(-3.07)	(-2.72)	(-2.46)	(-2.76)	(-2.77)	(-2.62)	(-2.91)
year fixed effect	yes	yes	yes	yes	yes	yes	yes	yes
Individual fixed effect	yes	yes	yes	yes	yes	yes	yes	yes
Region fixed effect	no	no	no	no	no	no	no	yes
N	23266	23266	26470	26470	26470	26470	26470	26374
Adj. R^2	-	-	0.01	0.01	0.02	0.02	0.02	0.02

4.3 Heterogeneity Analysis

4.3.1 Property rights

Since the financing constraints of state-owned enterprises and non-state-owned enterprises are significantly different, this paper divides the sample into two groups according to the property rights, and regresses the model separately. The results are shown in Tables (1) and (2). Only in the non-state-owned enterprise group does

supply chain finance play a significant role in the level of green innovation of enterprises. The possible reasons are as follows: state-owned enterprises have abundant financing channels, and government subsidies and bank loans can cover most of the financing needs of state-owned enterprises. Compared with state-owned enterprises, the traditional credit market discriminates against non-state-owned enterprises, and the degree of government support for non-state-owned enterprises is relatively low. The financing constraints are greater, so they rely more on supply chain finance as a financing method. The liquidity provided by supply chain finance also directly alleviates the funding pressure of green innovation. Secondly, the green innovation of state-owned enterprises is mostly driven by policies rather than markets, and the driving force is insufficient. Non-state-owned enterprises have sufficient motivation to carry out green innovation due to market drive, and they are more flexible and can respond to market changes more quickly.

4.3.2 Enterprise growth cycle

Based on the enterprise growth cycle theory, as enterprises develop and evolve, their capital demand, asset structure and other aspects show obvious stage heterogeneity. Based on this, this paper divides the samples into two groups: mature and declining, and regresses the models respectively. The results are shown in table 5 column (3) and (4). Only the supply chain finance of mature enterprises has played a significant role in the level of green innovation. The possible reasons are as follows: mature enterprises usually have stable cash flow and

have more resources to invest in long-term projects such as green innovation. However, enterprises in declining periods may face survival pressure, pay more attention to short-term benefits, and reduce investment in innovation. The choice of resource allocation strategy by the two largely determines the level of green innovation[17].

4.3.3 Regional factors

Enterprises across different industries exhibit distinct regional distribution patterns. Accordingly, this study categorizes the sample into three groups—central, eastern, and western regions—and conducts separate regression analyses for each. The findings, presented in Table 5, columns (5), (6), and (7), indicate that supply chain finance significantly enhances green innovation in enterprises located in the central and western regions, whereas the eastern region shows no notable promotional effect. This disparity may be attributed to the following factors: The eastern region, encompassing primarily coastal cities such as the Yangtze River Delta and Pearl River Delta, benefits from well-developed supply chain finance infrastructure and a concentration of high-tech industries, enabling more efficient allocation of funds directly toward green innovation. In contrast, the western region, supported by national policies favoring development during the sample period, experienced a direct boost in green innovation due to the strategic emphasis on western development. Against this backdrop, the central region did not demonstrate a significant role for supply chain finance in advancing enterprises' green innovation capabilities.

Table 5. Heterogeneity Analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	GI	GI	GI	GI	GI	GI	GI
SCF	0.167	0.193***	0.191***	0.552	0.487***	0.201***	-0.063
	(1.61)	(2.67)	(3.18)	(1.49)	(2.80)	(2.78)	(-0.47)
size	0.011	0.091***	0.061***	0.047	0.036	0.065***	0.073**
	(0.38)	(4.80)	(3.84)	(0.76)	(0.76)	(3.45)	(2.26)
LEV	-0.056	-0.123***	-0.114***	-0.212	-0.185**	-0.137***	0.132
	(-0.70)	(-2.59)	(-2.80)	(-0.79)	(-2.00)	(-2.76)	(1.12)
tobin	0.009	0.004	0.007	-0.001	0.014	0.004	0.015
	(0.92)	(0.73)	(1.40)	(-0.06)	(1.26)	(0.61)	(1.39)
lnage	-0.028	-0.030	-0.047*	-0.084	-0.085	-0.034	-0.184***
	(-0.43)	(-1.11)	(-1.90)	(-0.83)	(-1.00)	(-1.18)	(-3.23)
SRTTR	0.002	0.002	0.002*	0.001	0.001	0.002	0.004
	(0.80)	(1.45)	(1.91)	(0.14)	(0.38)	(1.33)	(1.12)
TopTen	-0.003***	-0.001*	-0.002***	-0.004*	-0.001	-0.002**	-0.003**

	(-2.62)	(-1.86)	(-2.99)	(-1.79)	(-0.84)	(-2.52)	(-2.39)
mbratio	0.051	-0.072	-0.015	-0.027	0.006	-0.054	0.098
	(0.63)	(-1.40)	(-0.32)	(-0.17)	(0.06)	(-0.97)	(0.95)
_cons	0.210	-1.510***	-0.864***	-0.329	-0.296	-0.926**	-0.976
	(0.36)	(-3.98)	(-2.76)	(-0.28)	(-0.32)	(-2.54)	(-1.47)
year fixed effect	yes	yes	yes	yes	yes	yes	yes
Individual fixed effect	yes	yes	yes	yes	yes	yes	yes
N	9548	16922	24757	1713	3447	18478	4407
Adj. R^2	0.02	0.01	0.02	0.02	0.01	0.02	0.02

5. Mechanism Analysis

The previous article shows that enterprises' supply chain finance business steadily promotes the improvement of their green innovation level. In order to explore the intermediary transmission mechanism of enterprises' supply chain finance business on the improvement of green innovation level, the financing constraint (FC) indicator (Hadlock and Pierce 2009) and management expense ratio (Mer) are used to measure the financing level and financial structure of enterprises respectively.

5.1 Relieving Financing Constraints to Enable Green Innovation

According to the previous analysis, it can be found that financing constraints will restrict enterprises from carrying out financing business and thus affect their green innovation capabilities. In addition, many studies have shown (Wang Qunwei et al., 2023) that financing capabilities are the hard foundation for supporting enterprises to promote green innovation projects. Enterprises are more inclined to "increase green" behavior responses in a loose financial environment. Based on this, this paper uses the FC indicator as a proxy indicator of financing constraints. The results are shown in table 6 column (1). The SCF coefficient is significantly negative, indicating that supply chain finance enterprises can use the endorsement of upstream and downstream enterprises to reduce the investigation costs of financial institutions before financing, so that they are more willing to issue loans, providing a good financial environment for enterprises carrying out supply chain finance business. Green innovation projects generally have the characteristics of long R&D cycles and high uncertainty. In an environment with low financing constraints, enterprises do not need to worry too much about the break of the capital chain, and can more calmly bear the risks of green innovation and actively explore cutting-edge technologies and business models. Enhance the motivation for green innovation.

5.2 Optimize Resource Allocation Efficiency to Enable Green Innovation

Table 6 column (2) is management expense rate as the dependent variable, which shows the improvement of the level of supply chain finance can effectively help enterprises make breakthroughs in green technology. Because the high level of supply chain finance can effectively reduce the management expense rate of enterprises through the formation of scale effect and cost sharing. And then directly release the saved costs to green innovation, which is used to support the R&D team to carry out technical research in energy conservation and emission reduction, resource recycling, etc. At the same time, optimizing resource allocation can also help enterprises introduce advanced green production equipment and processes. And improve resource utilization efficiency in the production process, reduce pollutant emissions, and provide hardware support for the transformation of green innovation results, thereby improving the level of green innovation.

Table 6. Mechanism Analysis

	(1)	(2)
	FC	Mer
SCF	-0.121***	-0.038***
	(-6.55)	(-5.38)
size	-0.153***	-0.023***
	(-36.33)	(-15.35)
LEV	-0.429***	0.017**
	(-26.95)	(2.47)
tobin	-0.023***	0.003***
	(-9.80)	(3.86)
lnage	-0.059***	-0.001
	(-11.67)	(-0.63)
SRTTR	-0.000	0.000
	(-1.13)	(0.26)
TopTenHoldersRate	0.001***	-0.000
	(3.37)	(-0.92)

mbratio	-0.010	0.030***
	(-0.86)	(6.73)
Mer		
_cons	4.147***	0.558***
	(48.34)	(18.00)
Year fixed effect	yes	yes
Individual fixed effect	yes	yes
N	26470	26469
Adj. R^2	0.53	0.17

6. Conclusions and Suggestions

6.1 Conclusions

This paper selects data from non-financial enterprises listed on the A-share market from 2011 to 2023, studies the impact of supply chain finance on corporate green innovation and its mechanism of action, and draws the following conclusions: First, based on the benchmark regression, it is found that a high level of supply chain finance in non-financial enterprises can steadily and significantly promote the level of corporate green innovation and increase the number of corporate green patents; Second, based on heterogeneity analysis, it is found that although corporate supply chain finance has a positive effect on corporate green development transformation in general, there are obvious differences in different regions, different periods and different property rights. Specifically, there is no significant relationship between the level of supply chain finance of state-owned enterprises and their green innovation, while supply chain finance of non-state-owned enterprises has a significant enabling effect on the level of green innovation; when the enterprise is in the mature stage of its life cycle, the development of supply chain finance business has a greater degree of motivation for the enterprise to develop green innovation technology. Compared with mature enterprises, the supply chain finance level of declining enterprises does not provide positive feedback on the innovation of green technology due to the different focus of corporate goals; due to the obvious differentiation characteristics of the regions where enterprises are located, samples in the east, west and central regions show different results. The supply chain finance of enterprises in the east and west regions shows a significant positive effect on green innovation, while the central region fails to show this positive promotion effect well. Third, based on

the mechanism analysis, it can be seen that the transmission mechanism between the impact of supply chain finance on green innovation, enterprises engaged in supply chain finance business can improve the level of green innovation of enterprises by reducing financing constraints and optimizing resource allocation.

6.2 Suggestions

6.2.1 The government

The government promotes the construction of supply chain finance infrastructure. Uniformly build a national supply chain finance data platform, integrate corporate credit information, green patent data, carbon emission records, etc., use blockchain technology to improve information transparency and financing efficiency, and reduce the risk assessment costs of financial institutions and the information collection costs of upstream and downstream enterprises; unify green certification standards, formulate a national green technology certification system, clarify the scope of green innovation projects supported by supply chain finance (such as low-carbon technology, circular economy, etc.), and provide financial institutions with an operational audit basis.

The government strengthens policy support for supply chain finance and promotes green innovation. Establish a special support fund: The government should establish a joint fund for supply chain finance and green innovation to provide low-interest loans or interest subsidies for enterprises engaged in green technology research and development, especially to provide financial subsidies for the supply chain finance business of small and medium-sized enterprises to reduce their financing costs; optimize the tax incentive mechanism, and provide income tax exemptions or research and development expense additional deduction policies for enterprises that invest in green technology research and development through supply chain finance financing.

The government improves the supervision measures on supply chain finance. Strengthen the disclosure of green financial information, require enterprises to regularly disclose the use of supply chain financial funds and green innovation results (such as the number of patents and carbon emission reduction), and include them in the corporate ESG rating system to improve market transparency and ensure the healthy and orderly development of supply chain

financial business.

6.2.2 Enterprises

Enterprises deepen the application of supply chain financial tools and optimize the financing structure. We should fully recognize the important role of supply chain finance in promoting green innovation, actively build a corporate supply chain financial system, take the initiative to establish close cooperation with financial institutions, and actively explore and carry out supply chain financial business suitable for their own development.

Enterprises focus on green technology research and development and achievement transformation. Establish a special department for green innovation, establish an independent green technology research and development team, and establish an incentive mechanism for technology transformation; we must also strengthen industry-university-research cooperation, build green technology laboratories with universities and scientific research institutions, and support joint research projects (such as new energy materials and energy-saving processes) through supply chain financial funds to accelerate the commercialization of technology.

Government and enterprises strengthen international cooperation. Based on the domestic reality and referring to relevant foreign programs, formulate green supply chain finance standards that are in line with national conditions to attract international capital to participate in domestic green project investment; at the same time, encourage multinational companies to cooperate with Chinese supply chains and support global green technology transfer and localized innovation through cross-border supply chain finance tools (such as green letters of credit).

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