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Exploration of Supply Chain Finance and Enterprise Digital Technology Innovation Mechanism

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Abstract: The digital economy era presents new opportunities for supply chain finance to ease financial pressures on businesses and foster digital technological innovation by integrating capital, information, and logistics. Despite this, businesses encounter significant innovation costs and challenges during digital transformation, making traditional financing methods insufficient. Supply chain finance offers an innovative solution by merging the financial, informational, and logistic flows of the supply chain's upstream and downstream, leveraging digital technology to refine credit assessments and risk management. This paper examines the influence of supply chain finance on the digital technological innovation levels of businesses and the mechanisms behind it, using data from Chinese listed companies from 2009 to 2023. The findings reveal that supply chain finance substantially boosts digital innovation by enhancing financing avenues, fostering information exchange, and empowering technology; company size positively moderates the link between supply chain finance and digital innovation. Heterogeneity analysis indicates that while supply chain finance has a more pronounced effect on state-owned enterprises, non-state-owned firms also gain benefits. The study's conclusions offer a theoretical foundation for refining financial resource allocation and enhancing supply chain finance policies, as well as strategic guidance for businesses to advance their digital transformation practices.

Keywords: Supply chain finance, digital transformation, digital technology innovation, innovation investment

1. Introduction

In the era of digital economy, digital technology innovation has become a key engine for reshaping the global industrial landscape and driving high-quality economic development. Enterprises, as the main body of economic activities, are facing unprecedented development opportunities brought by digital technology, such as improving production efficiency, expanding market boundaries and optimising customer experience through digital transformation, and are also facing a number of challenges, including high innovation costs, uncertainty brought by rapid technological iteration, and a huge gap in the capital required for digital transformation. However, technological innovation requires continuous capital investment and efficient resource allocation, and traditional financing modes are difficult to meet the digital needs of enterprises, especially SMEs, due to information asymmetry and insufficient collateral. Supply chain finance provides new ideas for solving enterprise financing constraints by integrating upstream and downstream information flow, capital flow and

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logistics in the supply chain, and relying on digital technology to optimise credit assessment and risk control.

In recent years, the size of China's supply chain finance market has shown a remarkable growth trend. According to the "China Supply Chain Finance Industry Market Depth Research and Development Prospect Investment Feasibility Analysis Report, 2024-2029. It shows that the scale of China's supply chain finance industry will be about 41.3 trillion yuan in 2023, with a year-on-year growth of 11.9% and a compound annual growth rate of 20.88% in the past five years. With the rapid development of the supply chain finance market, some scholars have begun to pay attention to its enabling mechanism for enterprise digital technology innovation. Some studies have pointed out that supply chain finance, through digital transformation and intelligent application, can promote enterprise innovation and technological empowerment, and promote the sustainable development of enterprises. In addition, Lina Zhang et al. [1] pointed out that supply chain finance contributes to the digital transformation of enterprises through three paths: reducing information asymmetry and sending good signals to the market, easing financial constraints and enhancing financial stability, and improving total factor productivity and increasing innovation output.

However, despite the progress made by existing research, there is still insufficient research on the mechanism of how supply chain finance specifically empowers enterprises' digital technological innovation. Most of the research focuses on the market scale, development mode, and impact on enterprise financing of supply chain finance, while the specific mechanism and path of supply chain finance in the field of digital technology innovation are less explored.

Therefore, an in-depth study of the relationship between supply chain finance and the level of digital technological innovation of enterprises is of great practical significance. On the one hand, it helps to reveal the role of supply chain finance in promoting industrial upgrading and high-quality economic development, and provides a theoretical basis for enterprises to make better use of supply chain finance resources to support their own digital transformation; on the other hand, it also provides a powerful decision-making reference for the government to formulate relevant policies to improve the supply chain finance system and promote the development of the digital economy. Based on the practice data of listed enterprises in China, this paper explores the impact of supply chain finance on the level of digital technological innovation of enterprises and its role in the path, with a view to optimizing the allocation of financial resources and accelerating the deep integration of the digital economy and the real economy to provide theoretical support and policy insights.

2. Theoretical analysis and research hypothesis

2.1. The direct impact of supply chain finance on the level of digital technology innovation in companies

Supply chain finance has a significant direct impact on the level of digital technology innovation of enterprises, which is mainly reflected in the following aspects:

Supply chain finance (SCF) enhances corporate funding efficiency by synergizing capital allocation, information exchange, and material distribution across upstream and downstream partners within the supply network, thereby alleviating economic burdens on businesses. Empirical evidence suggests that enterprises prioritizing SCF implementation demonstrate significantly stronger capabilities in driving digital innovation. Specifically, dedicated SCF platforms enable rapid access to financial resources for critical initiatives such as R&D investments and advanced technology procurement, which directly accelerates the adoption of digital transformation strategies [2].

The digital transformation of supply chain finance promotes information sharing and collaborative innovation. The application of blockchain, big data and other technologies has led to more transparent and real-time information sharing in the supply chain [3][4]. This information sharing mechanism

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helps firms to better understand market needs and partner technology dynamics, thereby driving digital technology innovation. This information-sharing mechanism helps enterprises better understand market demand and the technological dynamics of their partners, thus promoting digital technological innovation. A digital supply chain finance platform can monitor transaction data and logistics information in the supply chain in real time, helping enterprises to optimize production processes and the direction of technological innovation.

Supply chain finance reduces enterprise financing risks and incentivizes digital technology innovation through intelligent risk management tools [5]. It is found that supply chain finance can have a more significant promotion effect on digital technology innovation of enterprises in enterprises with greater economic policy uncertainty, enterprises in the central and western regions, and enterprises in the digital technology industry. This suggests that supply chain finance can, to a certain extent, alleviate the external uncertainty faced by enterprises and create a more stable innovation environment for enterprises [6].

Based on the above analysis, this paper proposes the following hypotheses:

Hypothesis 1: Supply chain finance has a significant positive impact on the level of digital technology innovation of enterprises.

2.2. Theoretical basis for the analysis of regulatory mechanisms

When exploring the impact of supply chain finance on the level of digital technological innovation of enterprises, enterprise size, as an important regulating variable, has received extensive attention in terms of its mechanism and influence path. Enterprise size not only reflects the enterprise's resource acquisition ability and market influence, but also determines to a large extent the enterprise's utilisation efficiency of supply chain finance resources and innovation ability.

Large enterprises usually have stronger financial strength and better internal management system, and can make more effective use of the financial support provided by supply chain finance. Research shows that large enterprises often occupy a dominant position in supply chain finance, and are able to better coordinate upstream and downstream resources, thus giving fuller play to the positive effects of supply chain finance [7]. In contrast, small firms, while also benefiting from supply chain finance, may not be able to take full advantage of supply chain finance in the same way as large firms due to their limited resources [8].

The impact of firm size on innovation input is also supported by empirical studies. A study based on a sample of 528 domestic A-share listed firms found that supply chain finance promotes core firms' innovation investment by improving the quality of supply chain relationships, with large firms performing more prominently in this process [9]. This suggests that firm size plays a positive moderating role between supply chain finance and firm innovation. In addition, by optimizing supply chain management, large firms are able to reduce internal coordination costs and external transaction costs more effectively, thus enhancing the overall resilience of the supply chain [10].

The impact of firm size on digital technology innovation also varies according to firms' resources and capabilities. Larger firms are better positioned to invest in digital technology infrastructure and thus better leverage digital technologies to optimize supply chain management. For example, large enterprises can access more capital through supply chain finance platforms for investing in advanced digital technologies, such as the Internet of Things (IoT), Big Data and Artificial Intelligence, to enhance the intelligence of their supply chains [11]. In contrast, small businesses may have limited resources to invest in digital technologies on a large scale, but they can progressively advance their digital transformation with funds obtained through supply chain finance [12].

Further research shows that supply chain collaborative management can significantly improve the operational efficiency and innovation capability of enterprises, which in turn positively affects enterprise performance. Especially for large-scale enterprises, supply chain collaborative

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management can more effectively enhance their digital technology innovation capability through the key dimensions of information sharing, cooperation stability and resource sharing.

Based on the above analysis, this paper proposes the following hypotheses:

Hypothesis 2: Firm size plays a positive moderating role in supply chain finance for digital technology innovation.

3. Research design

3.1. Sample selection and data sources

This paper is based on the data of Chinese listed companies from 2009 to 2023, and to ensure the accuracy and credibility of the study, data cleaning and pre-processing work is carried out. Firstly, all A-share and transport listed companies were selected. Secondly, ST, *ST, PT and listed companies that were delisted during the study period were excluded to ensure the stability and comparability of the sample. In the process of data processing, some of the data are shrink-tailed to ensure the effect of data fitting

3.2. Variable definition

3.2.1. Dependent variable

Enterprise digital technology application depth DIG. including digital management and production. Among them, digital management refers to the management behaviour of enterprises applying digital technology to achieve intelligent organisation, production, sales and service. Digital production refers to the traditional manufacturing industry through the application of digital technology to improve output and efficiency, emphasising the integration of digital technology with the real economy. This data adopts the text analysis method, through the annual reports of listed companies and "digital technology" related keywords according to the depth of the application of digital technology level of search, matching and word frequency statistics, and in the sample of the year of the study on the expansion.

3.2.2. Independent variable

The Supply Chain Finance Index (SCF) is a textual analytics metric constructed by aggregating mentions of 21 predefined operational terms across corporate disclosures, reflecting engagement in collateralized financing (e.g., movable asset pledges, inventory/spot/warehouse receipt financing), receivables management (factoring, reverse factoring agreements, accounts receivable assignment), prepayment instruments (future cargo rights financing, prepaid accounts), and strategic infrastructure development (guaranteed warehouses, SCF platforms/alliances). To mitigate data skewness, the index value is derived through logarithmic transformation of the annual keyword frequency (SCF=ln(SCF_KF+1)), where SCF_KF represents the cumulative count of supply chain finance-related lexical items identified in official financial documents.

3.2.3. Moderator variable

Enterprise size Size. The size of an enterprise refers to the scale of its operations, usually measured in terms of total assets. Total assets include the sum of all assets of the enterprise, such as current assets, fixed assets and intangible assets, reflecting its economic strength and scale of operation. The larger the total assets, the stronger the economic strength of the enterprise and the more resources it can invest in production and innovation activities. In this study, Size=ln(Total Assets), which is taken

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in logarithm to reduce the heteroskedasticity and skewed distribution of the data and to make the data more in line with the assumption of normal distribution, thus improving the estimation of the model.

3.2.4. Control variable

Table 1: Interpretation of the meaning of variables

Notation	Variable name
Lev	Gearing
Roe	Profitability
Growth	Growth
SCC	Supply Chain Concentration
Top1	Shareholding Concentration
Board	Board Size
Indep	Proportion of Independent Directors
Soe	Nature of Shareholding

3.3. Variable definition

Based on the above theoretical analysis, this paper constructs the following benchmark model

$$DIG_t = \alpha_0 + \alpha_1 SCF_t + \sum_1^n \alpha_{cn} C_{nt} + \sum \beta Year + \varepsilon_t \quad (1)$$

Where the explanatory variable DIG_t refers to firms' digital technology innovation; the core explanatory variable SCF_t is the level of supply chain finance; C_{nt} is the set of control variables. To further absorb the impact of unobservables, the paper also controls for fixed effects based on the time dimension.

In order to further carry out the moderating effect test, this paper constructs the following moderating effect model moderating effect model to test the moderating role of enterprise size in the relationship between supply chain finance and the level of digital technological innovation of enterprises.

$$= \alpha_0 + \alpha_1 SCF_t + \alpha_2 Size_t + \alpha_3 SCF_t Size_t + \sum_1^n \alpha_{cn} C_{nt} + \sum \beta Year + \varepsilon_t \quad (2)$$

4. Empirical analysis

4.1. Descriptive statistical analysis

Table 2: Statistical results

Variable	N	Mean	SD	Min	p50	Max
DIGw	691	1.020	1.120	0	0.690	4.200
SCFw	691	1.240	1.460	0	0.690	5.100
Levw	691	0.480	0.190	0.100	0.460	0.890
SCCw	691	27.40	16.12	1.670	25.50	72.61
Top1w	691	42.85	14.02	13.80	41.60	76.31
Sizew	691	23.61	1.590	19.81	23.75	26.68
Roew	691	0.0400	0.0500	-0.160	0.0400	0.160
Growthw	691	0.100	0.170	-0.300	0.0600	0.960
Board	691	9.280	1.900	4	9	18
Indep	691	37.22	5.590	25	36.36	66.67

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Table 2: (continued).

Soe	691	0.780	0.410	0	1	1
Reg	691	28.91	33.77	0	16.61	131.3

Descriptive statistical analyses provided the study with the basic characteristics of the sample data. The results show that there are large differences in the depth of enterprises' digital technology application (DIGw), indicating that enterprises vary in their level of digital technology innovation. The Supply Chain Finance Index (SCFw) also shows different degrees of enterprise participation in supply chain finance. The overall gearing ratio (Levw) is moderate, but there are highly leveraged enterprises that may face financial risks. Differences in Supply Chain Concentration (SCCw) indicate that some firms have more concentrated supply chains, which may affect their innovation flexibility. Equity concentration (Top1w) is high, which may have an impact on innovation incentives. Firm size (Sizew) is medium overall, but there is some variation. Profitability (Roew) and growth (Growthw) also show significant differences between firms, with some firms having strong profitability and growth potential, while others face challenges. Differences in board size (Board) and proportion of independent directors (Indep) reflect the diversity of corporate governance structures. The nature of shareholding (Soe) is dominated by state-owned shareholding, but non-state-owned firms also account for a certain proportion, which may have an impact on innovation incentives.

4.2. Descriptive statistical analysis

Table 3: Benchmark regression and robustness test results

Benchmark Regression	(1) DIGw	Robustness Test	(1) DIGw
SCFw	0.192***	SCFw	0.223***
	(0.0299)		(0.0397)
Levw	0.485**	Levw	0.452
	(0.213)		(0.337)
SCCw	-0.0121***	SCCw	-0.0175***
	(0.00225)		(0.00324)
Top1w	-0.00508**	Top1w	-0.00396
	(0.00236)		(0.00333)
Roew	2.005**	Roew	2.349*
	(0.856)		(1.247)
Growthw	0.0321	Growthw	0.208
	(0.212)		(0.373)
Board	0.0600***	Board	0.0678**
	(0.0207)		(0.0308)
Indep	0.00750	Indep	0.00664
	(0.00670)		(0.00902)
Soe	-0.432***	Soe	-0.442***
	(0.0950)		(0.128)
Year	Yes	Year	Yes
_cons	-0.118	_cons	0.484
	(0.433)		(0.610)
N	691	*N*	427

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Table 3: (continued).

R^2	0.466	R^2	0.315
adj. R^2	0.447	adj. R^2	0.290

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The results show that the coefficient of the supply chain finance index (SCFw) is 0.192, which is significant at the 1% level, indicating that supply chain finance has a significant positive impact on the level of digital technology innovation of enterprises. This means that as the degree of supply chain finance participation increases, the level of digital technology innovation of enterprises increases accordingly. This result supports the research hypothesis that supply chain finance can effectively promote enterprises' digital technology innovation by providing financial support and optimizing resource allocation.

Of the other control variables, Levw, Roew, SCCw, and Top1w are all significant at the 5% level, indicating that a firm's financial status and profitability have a positive impact on its level of digital technology innovation, and that higher supply chain concentration and equity concentration may limit a firm's room and incentive to innovate. The Board variable is even more significant, suggesting that larger boards are able to provide more resources and information support, which helps firms' digital technology innovation. And Indep and Growth were not significant, indicating that the influence of these factors on the level of enterprise digital technology innovation is not obvious. Soe was negatively significant, indicating that the level of digital technology innovation of enterprises with the nature of state-owned equity is relatively low, probably because of certain deficiencies in innovation incentives and other aspects of state-owned enterprises.

In addition, the model introduces time fixed effects to control for the potential impact of time trends on the results. The coefficients for each year indicate that the effect of the time factor on firms' level of digital technological innovation varies somewhat between years, but is not significant overall.

The robustness test further validates the positive impact of supply chain finance on the level of digital technology innovation of enterprises by shortening the range of research years. The results show that the facilitating effect of supply chain finance remains significant even in a different sample range, which enhances the reliability and credibility of the research findings. The consistency of the robustness test results with the benchmark regression results suggests that the positive impact of supply chain finance on digital technology innovation is robust to changes in the sample scope.

4.3. Heterogeneity analysis and moderating effects test

The results of the heterogeneity analysis show that supply chain finance has a positive impact on digital technology innovation in both state-owned equity firms and non-state-owned equity firms, but there are differences in the degree of impact. In state-owned equity firms, the facilitating effect of supply chain finance is more significant, which may be related to the scale advantage and resource acquisition ability of state-owned firms; while in non-state-owned equity firms, the positive impact of supply chain finance is relatively small but still significant. This result suggests that there is heterogeneity in the role of supply chain finance in supporting innovation in enterprises with different equity natures, and that enterprises need to consider their own equity structure and resource base when using supply chain finance resources to promote digital technological innovation.

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Table 4: Heterogeneity test and moderating effects results

	(1) DIGw	(2) DIGw		(1) DIGw	(2) DIGw
SCFw	0.242***	0.137**	SCFw	0.180***	-0.425
	(0.0383)	(0.0533)		(0.0306)	(0.330)
Levw	0.658***	-0.245	Levw	0.674***	0.612**
	(0.248)	(0.522)		(0.238)	(0.240)
SCCw	-0.0109***	-0.0145***	SCCw	-0.0135***	-0.0131***
	(0.00252)	(0.00516)		(0.00237)	(0.00238)
Top1w	-0.00335	-0.00446	Top1w	-0.00457*	-0.00503**
	(0.00297)	(0.00465)		(0.00238)	(0.00239)
Roew	2.558**	0.424	Roew	2.274***	2.075**
	(1.056)	(1.632)		(0.868)	(0.873)
Growthw	0.161	-0.000833	Growthw	0.0267	0.0335
	(0.281)	(0.369)		(0.212)	(0.212)
Board	0.0635***	0.0734	Board	0.0701***	0.0773***
	(0.0216)	(0.0731)		(0.0214)	(0.0217)
Indep	0.00154	0.0498**	Indep	0.00964	0.0127*
	(0.00699)	(0.0236)		(0.00680)	(0.00698)
Year	Yes	Yes	Year	Yes	Yes
_cons	-0.637	-0.817	Soe	-0.394***	-0.435***
	(0.459)	(1.581)		(0.0972)	(0.0995)
N	540	151	Sizew	-0.0509*	-0.0804**
R^2	0.430	0.388		(0.0288)	(0.0329)
adj. R^2	0.405	0.283	Reg		0.0259*
					(0.0140)
			_cons	0.751	1.338*
				(0.654)	(0.727)
			N	691	691
			R^2	0.468	0.471
			adj. R^2	0.449	0.451

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In this paper, firm size (Sizew) is used as a variable in the moderating mechanism. In order to test this moderating effect, the interaction term between firm size (Size) and supply chain finance index (SCFw) is introduced in the regression model. The regression results show that the supply chain finance index (SCFw) is significant at the 1% level, indicating that the positive effect of supply chain finance on the level of digital technology innovation of enterprises is still significant. The enterprise size data shows that enterprise size itself has a negative impact on the level of enterprise digital technology innovation, which may be due to the fact that larger enterprises already have a stronger innovation ability and resource base, and the degree of reliance on supply chain finance is relatively low. The coefficient of the interaction term Reg (SCFw × Sizew) is 0.0259, which is significant at the 10% level, indicating that firm size plays a positive moderating role in the relationship between supply chain finance and firms' digital technological innovation level.

This result suggests that there are differences in the impact of supply chain finance on the digital technology innovation of firms of different sizes. For larger firms, the facilitating effect of supply

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chain finance is more significant, possibly because these firms have stronger access to resources and innovation foundations, and are able to make more effective use of the financial support and technological empowerment provided by supply chain finance. In contrast, smaller enterprises, although they can also benefit from supply chain finance, may not be able to take full advantage of supply chain finance as much as larger enterprises due to their limited resources.

5. Conclusion

This study reveals the significant positive impact of supply chain finance on the level of digital technological innovation of enterprises and its mechanism of action through empirical analyses of the data of listed enterprises in China. The findings show that supply chain finance effectively alleviates the financial pressure of enterprises and promotes their digital technological innovation by providing financial support, optimising resource allocation, and promoting information sharing and collaborative innovation.

Building upon the empirical findings, this study proposes a multi-tiered policy framework to catalyze supply chain finance (SCF) ecosystems. Primarily, regulatory authorities should establish adaptive SCF governance mechanisms encompassing: (1) Regulatory Modernization – refining fiscal and financial policies to incentivize SCF product innovation, particularly instruments aligned with digital R&D cycles (e.g., blockchain-enabled inventory financing, AI-driven receivables factoring); (2) Digital Infrastructure Prioritization – scaling public investments in interoperable data platforms and cloud computing infrastructure to eliminate technological bottlenecks hindering corporate digital transformation [13]; (3) Fintech Synergy Development – fostering collaborative ecosystems between financial institutions and technology providers through tax credits and sandbox programs, thereby accelerating deployment of predictive analytics models and smart contracts to enhance SCF transparency and risk pricing accuracy [14].

At the enterprise level, enterprises should actively participate in supply chain finance cooperation and make full use of the financial support and technological empowerment provided by supply chain finance to promote their own digital technology innovation. For example, they can obtain more funds through the supply chain finance platform for investing in advanced digital technologies, such as Internet of Things, big data and artificial intelligence, to enhance their innovation capability and competitiveness. At the same time, enterprises should strengthen their digital management, enhance their digital technology application level, and achieve intelligence in organization, production, sales and services through digital management, so as to improve their operational efficiency and innovation ability. In addition, enterprises should also optimize supply chain relationships, strengthen cooperation with upstream and downstream enterprises, enhance the overall efficiency and resilience of the supply chain, achieve information sharing, cooperation stability and resource sharing through supply chain collaborative management, and promote the application and innovation of digital technology [15].

Despite the results of this study, there are some limitations. For example, the sample of this study mainly focuses on A-share listed transport enterprises, which may not be fully representative of all types of enterprises involved in supply chain finance. Future studies could further expand the sample to include unlisted enterprises and SMEs to improve the generalizability and representativeness of the findings. In addition, the data in this study is as of 2023, and future research can further update the data to reflect more recent market changes and corporate behaviour. Future research can also delve deeper into the differences in the relationship between supply chain finance and digital technology innovation among enterprises in different industries and regions to provide a basis for more targeted policies. At the same time, future research can also further explore the long-term impact of supply chain finance on enterprises' digital technological innovation, as well as its role mechanism

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at different stages of development, so as to provide more comprehensive decision-making references for enterprises and the government.

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