WEP Warwick Evans Publishing

Transactions on Social Science, Education and Humanities Research
ISSN: 2960-1770, eISSN: 2960-2262 | Volume 9
SSMI 2024

A study on the impact of supply chain finance on the innovation of small and medium-sized enterprises - mediated by the intermediary effect of financing constraints

Tianyuan Liu

Harvard Extension School, 51 Brattle St, Cambridge, MA 02138, USA

liutianyuan20@gmail.com

Abstract. Based on a detailed analysis of viewpoints proposed in relevant literature both domestically and internationally, this paper empirically investigates the impact of supply chain finance on the innovation of small and medium-sized enterprises (SMEs), utilizing financial data from listed companies on China's SME board from 2012 to 2022. Additionally, it explores whether the alleviation of financing constraints plays an intermediary effect in this pathway. The findings reveal that: (1) The development of supply chain finance can enhance the innovation capability of SMEs, and its significance level is correlated with the nature of the enterprise's equity; (2) Most SMEs face financing difficulties, and implementing supply chain finance can effectively alleviate these financing constraints. Furthermore, compared to state-owned enterprises, this alleviation effect is more pronounced for non-state-owned enterprises; (3) There exists a significant intermediary effect of financing constraints, indicating that supply chain finance can ease financing constraints, thereby facilitating the improvement of enterprise innovation capabilities. Finally, based on the research findings, this paper presents relevant recommendations from the perspectives of the government, financial institutions, and SMEs.

Keywords: Supply Chain Finance; Financing Constraints; SME Innovation; Intermediary Effect.

1. Chapter One: Introduction

In the context of economic globalization, innovation stands as a pivotal element for a nation to elevate its productivity and overall competitiveness. China, in its modernization journey, has persistently adhered to innovation as a focal point, emphasizing the primacy of enterprises and encouraging them to augment their investment in research and development. Small and medium-sized enterprises (SMEs), which constitute the bulk of the enterprise population, are gradually increasing their impetus for research and development innovation, thereby playing a significant role in enhancing China's technological innovation capability. However, this process is not without its challenges for SMEs.

Financing constraints represent a substantial hurdle that restricts the mobility of talent and innovation capability within enterprises. Given the small scale, inadequate risk-bearing capacity, and less-than-ideal credit status of SMEs, financial institutions are less willing to engage in lending activities with them, as a precautionary measure to reduce the risk of non-recoverable loans. Furthermore, state-funded projects are more prevalent among large state-owned enterprises, leaving SMEs with fewer opportunities to participate, which imposes certain constraints on their product research, development, and production. Additionally, the uniqueness of research and development investment exacerbates the financing constraints faced by SMEs. Firstly, enterprises bear a higher risk in research and development investment, as there is no guarantee of achieving the expected output. Secondly, enterprises tend to withhold information related to investment projects concerning core technologies. This uncertainty, coupled with the information asymmetry between Chinese SMEs and the capital market, poses difficulties for investors during investment evaluation and decision-making. The limited sources of funding for enterprise research and development investment further intensify financing constraints.

Supply chain finance emerges as a solution that caters to the needs of SMEs, offering a novel financing model for Chinese enterprises. It is based on the actual transaction situation between SMEs

Content from this work may be used under the terms of CC BY-NC 4.0 licence (https://creativecommons.org/licenses/by-nc/4.0/).
Published by Warwick Evans Publishing.

and core enterprises. On one hand, it provides funds for the production and operation of enterprises. On the other hand, due to the stability of trade within the chain, the funds obtained through supply chain finance exhibit sustainability, meeting the long-term capital requirements of enterprises. The application of supply chain finance has strengthened trade exchanges among industrial chain enterprises and expanded the financing methods of financial institutions. This not only resolves the financing constraints faced by enterprises but also significantly reduces financing costs.

2. Chapter Two: Literature Review

2.1. Studies on Financing Constraints

Despite the significant role played by small and medium-sized enterprises (SMEs) in economic development, financing constraints have always been an obstacle to their innovative development. The government has attached great importance to this issue and implemented relevant measures to help SMEs solve financing problems. The academic community has also conducted in-depth discussions. Regarding the connotation and causes of financing constraints, Wang Jianbin (2019) [1] argued that investors' insufficient understanding of corporate risks and returns prevents enterprises from timely obtaining development funds at market costs, thus forming financing constraints. Guo Chunsong (2019) [2] believed that the financing difficulties of private enterprises are caused by complex factors, including subjective factors such as enterprise scale and operating philosophy, as well as objective factors such as national policies and credit policies of financial institutions.

Currently, most research on the influencing factors of corporate financing constraints explores both internal and external factors. The study by Geng Chengxu and Li Meng (2018) [3] indicated that when the level of economic and financial development is higher, the external financing foundation of enterprises will be better, financing channels will be richer, and the degree of information asymmetry will be lower, making it easier to obtain funds and less susceptible to financing constraints. Feng Zhanbin and Li Guomin (2022) [4] suggested that there are significant differences in the degree of financing constraints among enterprises with different property rights. The state-owned property right reduces the impact of financing constraints on cash dividend policies due to its background advantages. Scholars often use proxy variables to study the degree of corporate financing constraints, mainly in the form of questionnaires, indices, and models. While questionnaire forms are now less frequently used, Liu Lin and Wang Jinfeng (2022) [5] constructed the KZ index and WW index to measure the magnitude of corporate financing constraints. Although various indices have their own characteristics, they generally have endogenous issues. There are mainly two types of model forms, and currently, scholars mostly use the cash-cash flow model proposed by Almeida et al. [6] to study financing constraints. Liu Zhongren and Du Jingxiu (2022) [7] utilized the cash-cash flow model to investigate the relationship between corporate financing constraints and government subsidies. Enterprises convey favorable information through government subsidies, thereby facilitating access to social resources and alleviating their financing constraints.

2.2. Studies on Supply Chain Finance

Supply chain finance is a new financing method based on core enterprises, providing credit guarantees for upstream suppliers and downstream distributors in the supply chain. Regarding the connotation of supply chain finance, Qin Jiangbo (2021) [8] believed that it involves commercial banks and other financial institutions integrating the capital flow in the chain, forming a risk-controllable overall supply chain, and providing risk-minimized financing services for core enterprises and vulnerable enterprises. In terms of the application of supply chain finance models, Ge Lin (2022) [9] studied the integration model of digital supply chain finance and the rural e-commerce industry, proposing a macro and micro approach to form a complete and closed industrial chain for agriculture and rural e-commerce, enhancing product competitiveness, and enabling the long-term development of the rural e-commerce model. In the risk research aspect of supply chain finance, Wang Dingxiang and He Lepei (2021) [10] selected the accounts receivable financing model of supply chain finance as an

example and used the intensity model to measure its credit risk. The study found that the probability of credit risk occurrence in supply chain finance is positively correlated with its transmission among enterprises.

SMEs generally face financing difficulties due to their weak development capabilities. Many scholars have conducted research on the impact of the supply chain on these enterprises. Gu Qun (2016) [11] selected technology-based SMEs to explore how supply chain finance can address their financing constraints. The study found that the degree of financialization and property rights play a moderating role between the two, and it clarified that economically developed regions have a more significant mitigating effect. Wang Liqing et al. (2018) [12] integrated the theories of industry-finance integration and strategic commitment from information economics into the research framework of supply chain finance and financing constraints. Empirical analysis showed that corporate financing constraints have been improved, and diversified solutions were proposed. Liu Jingji et al. (2019) [13] analyzed the impact mechanism of supply chain finance on financing and concluded that supply chain finance can alleviate financing constraints by reducing information asymmetry.

2.3. Studies on Enterprise Innovation

Scholars mainly divide enterprise innovation into macro and micro-level studies. The macro aspect primarily includes policy systems, business environments, and cultural diversity. Liqun et al. (2019) [14] pointed out that environmental regulations promote enterprises' investment in innovative research and development. However, this promotion is often characterized by low-tech patents, and the innovation effect needs further improvement. Xia Houxue et al. (2019) [15] analyzed relevant data from the World Bank and explored the relationship between enterprise innovation and the business environment under a binary choice model. Empirical research found that improving the business environment will facilitate the development of enterprise innovation activities. Regarding sociocultural perspectives, Pan Yue et al. (2017) [16] selected the number of patent applications as a measure of innovation and found a positive correlation between the number of patent applications and dialect diversity in a region. This promoting effect is more pronounced in private enterprises and high-tech industries.

The micro aspect mainly includes ownership structure and financing constraints. Wang Yuze et al. (2019) [17] found that there is a critical value for the role of enterprise leverage in promoting innovation. When leverage exceeds this critical value, an increase in leverage will elevate the risk of enterprise innovation, thereby hindering it. Regarding the impact of financing constraints on enterprise innovation capabilities, Li Shubin et al. (2017) [18] conducted an empirical analysis using small and medium-sized listed enterprises as research objects. They found a negative correlation between financing constraints and enterprise R&D investment. Sun Bo et al. (2019) [19] believed that appropriate financing constraints can promote enterprise innovation to a certain extent. This is mainly because, with other conditions remaining unchanged, human capital plays a key role in enterprise innovation, thus mitigating the obstacles posed by financing constraints to enterprise innovation.

2.4. Literature Review

Scholars have primarily delved into the implications, causes, influencing factors, and measurement methods of financing constraints faced by small and medium-sized enterprises. The theoretical examination of supply chain finance has been comprehensive, covering its connotation, mode application, and risk measurement. Empirical analyses of supply chain finance have predominantly focused on its relationship with financing constraints, revealing its positive impact on alleviating the financing difficulties of enterprises. Comprehensive studies on enterprise innovation have been conducted from both macro and micro perspectives, with attention also paid to the influence of financing constraints on enterprise innovation, which indicates that financing constraints can somewhat hinder technological innovation in enterprises. However, there is limited research directly exploring the relationship between supply chain finance and technological innovation in small and medium-sized enterprises, as well as the underlying mechanisms. Based on the current research status,

this paper aims to investigate how supply chain finance directly affects enterprise innovation and examine whether financing constraints play an intermediary role in this process. Finally, based on the empirical regression results, corresponding suggestions are provided for vigorously developing supply chain finance.

3. Chapter Three: Research Design

3.1. Research Hypotheses

3.1.1. The Impact of Supply Chain Finance on Innovation in SMEs

On one hand, due to the large investment and long cycles characteristic of innovation activities in small and medium-sized enterprises (SMEs), the upfront investments cannot guarantee expected outcomes, posing significant financial risks. On the other hand, to ensure that core technologies are not plagiarized, companies tend to withhold certain information related to their invested projects, hindering investors from accessing the latest updates. This information asymmetry between enterprises and fund providers prevents the latter from accurately evaluating investment projects and making informed decisions, ultimately leading to inadequate funding for technological innovations in SMEs.

Supply chain finance reorganizes the logistics, capital, and trade information of all enterprises and institutions in the supply chain through core enterprise guarantees and repurchase commitments. This approach mitigates the recovery risks for financial institutions, alleviates information asymmetry, and enhances cooperation among SMEs, core enterprises, and other supply chain entities. Based on this financing model, SMEs can apply for loans from financial institutions using their accounts receivable, inventory, and prepaid accounts, among other assets, to obtain corresponding financing. Additionally, as supply chain finance is established based on transactions between SMEs and core enterprises, continuous real transaction information within the chain provides sustained financial support to enterprises. In summary, supply chain finance emerges as a new financing pathway for SMEs and an external financing method for technological innovations.

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

H1: The development of supply chain finance can foster innovation capabilities in enterprises.

3.1.2. The Impact of Supply Chain Finance on Financing Constraints in SMEs

Enterprises typically consider financing options internally before seeking external sources. Given the relatively weak profitability of SMEs, relying solely on internal fund reserves is often insufficient to meet financing needs, necessitating external financing methods. For SMEs, the thresholds for issuing bonds and stocks are considerably high. Therefore, at this stage, loans remain a crucial means of obtaining financing for these enterprises. However, SMEs face a series of challenges in the financing process, primarily related to information asymmetry and transaction costs. Additionally, financial institutions often consider multiple factors and exhibit certain biases when providing credit to SMEs, reducing their willingness to lend to these enterprises.

Throughout the financing process, enterprise financing costs may increase due to information asymmetry. Nevertheless, with the continuous development of information technology, big data processing has facilitated easier access to information. Within the supply chain, enterprises can share information, utilizing industrial core enterprises and internet enterprises to compensate for deficiencies in information circulation. Simultaneously, the entire supply chain enables real-time monitoring of enterprise operational risks. The communal relationship within the supply chain ensures that core enterprises provide credit guarantees for SMEs. To maintain long-term partnerships, core enterprises integrate information flows and select the most suitable partners to provide loans, thereby reducing the risk of default. Thanks to the guarantee role, if SMEs lose credibility, core enterprises have the capability to compensate financial institutions for partial economic losses. Meanwhile, services provided by third-party logistics companies effectively reduce the regulatory

costs of financial institutions. By reducing information asymmetry, supply chain finance constructs complex principal-agent relationships, alleviates enterprise financing constraints, and provides smoother loan access.

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

H2: Supply chain finance can alleviate financing constraints for SMEs.

3.1.3. The Mediating Effect of Financing Constraints

During their development, SMEs cannot rely solely on internal financing methods to meet their capital turnover, expansion, and technological innovation funding needs. Due to their insufficient qualifications, SMEs face considerable financing resistance in both direct markets such as stocks and bonds, as well as indirect markets dominated by banks. From the perspective of SMEs, factors like relatively small asset sizes, inadequate collateral assets, and low information transparency make it difficult for them to meet the requirements of direct and indirect financing. From the fund providers' viewpoint, SMEs with limited development potential simultaneously exhibit significant information asymmetry, posing recovery risks to funds. Considering the characteristics of innovation activities, their inherent uniqueness further exacerbates the financing constraints of SMEs.

Supply chain finance, backed by the credit of core enterprises and integrated with third-party logistics services, effectively alleviates the financing constraints of SMEs. On the one hand, core enterprises, with their excellent business achievements and high credibility, reduce the moral hazard of credit to a certain extent through their credit endorsements. Simultaneously, as the ultimate risk bearers, core enterprises also enhance their supervision over SMEs. On the other hand, to better integrate into the supply chain and establish long-term partnerships with other enterprises, SMEs share authentic information and continuously improve their capabilities and competitiveness, which helps address information asymmetry issues. Supply chain finance not only resolves various problems faced by the traditional financial system but also successfully reduces transaction costs, elevates the credit level of the entire supply chain, and provides diversified financing pathways for SMEs. This, in turn, addresses the financing constraints they encounter during technological innovation processes.

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

H3: Supply chain finance enhances the technological innovation level of SMEs by alleviating their financing constraints.

3.2. Sample Source and Data Processing

Based on the empirical testing requirements of this paper, relevant data from small and medium-sized listed enterprises from 2012 to 2022 were selected and processed as follows: (1) Eliminate the financial industry; (2) Exclude sample companies with ST and *ST status; (3) Remove sample years with missing patent application quantities; (4) Exclude sample years with incomplete financial data; (5) To eliminate the influence of extreme values, perform a 1% Winsorize treatment on the data.

Ultimately, this paper collected unbalanced panel data from 1,218 small and medium-sized enterprises listed on the SME board, totaling 7,392 valid observations. Among them, there are 389 state-owned enterprises with 2,286 observations and 829 non-state-owned enterprises with 5,106 observations. The data in this paper are sourced from the CSMAR database, and the data processing software includes Excel and Stata 16.

3.3. Variable Design

3.3.1. Dependent Variable

Currently, enterprise innovation is primarily measured by either research and development (R&D) investment, referring to a company's expenditure or intensity of investment in R&D, or innovation output, which includes metrics such as the number of patent applications or the increment in intangible assets. In this paper, we adopt innovation output as the yardstick for gauging a company's

level of innovation, specifically utilizing the number of patent applications as a proxy, drawing inspiration from the research of Li Shunchao (2020) [22].

3.3.2. Independent Variable

There is no unified metric for supply chain finance in China, with two primary approaches emerging. One is a macro indicator, which involves calculations based on national short-term loan origination, national commercial bill amounts, and national discount amounts (Zhang Weibin, 2012) [23]. The other method relies on micro-variable indicators, computed mainly through either the number of times a company accepts guarantees from related enterprises (Zhao Yueli, 2017) [24], or the sum of a company's short-term borrowings and notes payable (Yao Wangxin, 2017) [25]. Therefore, this paper references the measurement index adopted by Yao Wangxin et al. (2017) as a proxy variable for the level of supply chain finance among Chinese SMEs.

3.3.3. Mediating Variable

Scholars have traditionally relied on model estimations or indices for measurement, with representative indices including the KZ index, WW index, and SA index. All three indices are derived from weighted financial indicators, but the financial metrics used in the KZ and WW indices have a bidirectional causal relationship with financing constraints. The SA index, proposed by Hadlock (2010) [26], resolves the issue of endogeneity. Hence, we utilize the SA index to gauge a company's level of financing constraints, calculated as follows:

$$SAi,t=-0.737*Sizei,t+0.043*Sizei,t2-0.04*Agei,t \quad (1)$$

Where Age represents the number of years since the company went public. The SA index yields negative values, with smaller numbers indicating greater financing constraints.

3.3.4. Control Variables

The control variables in this study are primarily selected based on factors that could potentially influence innovation in small and medium-sized enterprises. These variables encompass enterprise size, asset-liability ratio, profitability, fixed asset ratio, growth potential, and enterprise nature.

(1) Enterprise Size: Defined as the natural logarithm of total assets calculated in millions. A larger value of this indicator signifies a larger enterprise size.

(2) Asset-Liability Ratio: Represents the ratio of total liabilities to total assets. A higher value indicates a greater proportion of liabilities in the total assets.

(3) Profitability: Measured by the return on assets, which is the ratio of net profit to total assets. A higher value denotes stronger profitability of the enterprise.

(4) Fixed Asset Ratio: Reflects the proportion of fixed assets in total assets. A lower value is preferable, indicating a higher proportion of current assets in the enterprise.

(5) Growth Potential: Assessed by the growth rate of total assets. A higher value signifies better growth potential of the company.

(6) Enterprise Nature: Previous research has indicated differences in financing constraints between state-owned and private enterprises, with state-owned enterprises often receiving more financial support due to their inherent advantages. Therefore, this variable is included as a control variable, represented as a 0-1 dummy variable. If the enterprise is state-owned, it is assigned a value of 1; otherwise, it is 0.

Table 1. Variable Definitions

Category	Name	Symbol	Description
Dependent variable	Number of patent applications	Pat	ln(Number of patent applications + 1)
Independent variable	Supply chain finance index	SCF	(Short-term borrowings + Notes payable) / Total assets
Mediator variable	Financing constraints	SA	SAi,t = -0.737 * Sizei,t + 0.043 * Sizei,t2 - 0.04 * Agei,t
Control variables	Enterprise scale	Size	Size = ln(Total assets / 1 million)
	Profitability	Roa	Net profit / Total assets
	Asset-liability ratio	Lev	Year-end liabilities / Total assets
	Fixed asset ratio	Far	Year-end fixed assets / Year-end total assets
	Growth potential	Growth	Total asset growth rate

3.4. Model Construction

To validate the hypotheses proposed earlier, the following models are established in this paper. Herein, α0, β0, and λ0 represent constant terms, while α1-α6, β1-β6, and λ1-λ6 denote the coefficients of various variables. The subscript i signifies the company, t denotes the year, and ε represents the random residual term.

3.4.1. The Relationship Between Supply Chain Finance and Innovation in SMEs

Model 1:

$$Pat_{i,t}=\alpha_0+\alpha_1 SCF_{i,t}+\alpha_2 Size_{i,t}+\alpha_3 Roa_{i,t}+\alpha_4 Lev_{i,t}+\alpha_5 Far_{i,t}+\alpha_6 Growth_{i,t}+\varepsilon_{i,t} \quad (2)$$

In this model, the explanatory variable is supply chain finance, while the dependent variable is the innovation capability of enterprises, measured by the natural logarithm of the number of patent applications plus one. The control variables include enterprise size, asset-liability ratio, profitability, fixed asset ratio, and growth potential. Following the first step of the stepwise regression method, a regression model is established to verify Hypothesis 1 by examining the relationship between supply chain finance and the number of patent applications.

3.4.2. The Relationship Between Supply Chain Finance and Financing Constraints in SMEs

Model 2:

$$SAi,t=\beta0+\beta1SCFi,t+\beta2Sizei,t+\beta3Roai,t+\beta4Levi,t+\beta5Fari,t+\beta6Growthi,t+\varepsilon i,t \quad (3)$$

According to the second step of the stepwise regression method, the explanatory variable is supply chain finance, while the dependent variable is financing constraints, measured using the SA index. The control variables remain the same as in Model 1. This regression model aims to validate Hypothesis 2.

3.4.3. The Mediating Effect Model of Financing Constraints

Model 3:

$$Pat_{i,t}=\lambda_0+\lambda_1 SA_{i,t}+\alpha_1' SCF_{i,t}+\lambda_2 Size_{i,t}+\lambda_3 Roa_{i,t}+\lambda_4 Lev_{i,t}+\lambda_5 Far_{i,t}+\lambda_6 Growth_{\ i,t}+\varepsilon_{i,t} \quad (4)$$

The models are constructed based on the mediation effect testing procedure. Model 1 examines the relationship between supply chain finance and enterprise innovation capability, while Model 2 explores the relationship between supply chain finance and financing constraints. Following the mediation effect testing steps, Model 3 integrates the explanatory variable, dependent variable, and mediating variable into a regression model to analyze the focal point of this study and verify Hypothesis H3.

In summary, the mediation effect testing procedure in this paper primarily refers to the method proposed by scholars such as Wen Zhonglin et al. (2004) [27]. Firstly, the existence of the main effect between variables is verified, specifically examining the total effect between the explanatory variable

of supply chain finance and the dependent variable of SMEs' innovation capability. In this study, if the coefficient α1 in Model 1 is significant, the next step of testing proceeds; otherwise, it stops.

Secondly, the coefficients β1 and λ1 in Models 2 and 3 are tested sequentially. If both are significant, it indicates that part of the effect of X on Y is mediated by the mediating variable M. If at least one of them is not significant, a Sobel test is required.

Thirdly, a complete mediation test is conducted to examine the coefficient α1' in Formula (3-3). If α1' is not significant, it suggests that X's influence on Y is entirely mediated by M, indicating a complete mediation process. If α1' is significant, it indicates that only a portion of X's effect on Y is mediated by M, representing a partial mediation process.

Finally, a Sobel test is performed. A significant result indicates a significant mediation effect, while a non-significant result suggests the opposite. This concludes the testing procedure.

4. Chapter Four: Empirical Analysis

4.1. Descriptive Statistics

The sample comprises 1,218 small and medium-sized enterprises, yielding a total of 7,392 valid observations. As illustrated in Table 2, the mean value of patent applications (Pat) among enterprises is 2.465. However, there exists a significant disparity between the maximum and minimum values, ranging from a high of 6.85 to a low of zero, indicating substantial variations in the innovative development capabilities among different enterprises.

The standard deviation of supply chain financing (SCF) is 4.751, reflecting a relative instability in its development level, with extremes of 23.81 and 0. The financing constraint (SA) exhibits a smaller standard deviation of 0.255, suggesting a narrow dispersion and hence a minimal overall difference in the degree of financing constraints faced by the sampled companies. This implies that they encounter similar financing constraint issues.

In terms of enterprise size (Size), the maximum value reaches 11.88, while the minimum is 6.274. The standard deviation of 1.169 signifies diversity in the scale of small and medium-sized enterprises within the sample. Asset composition varies among different enterprises, with the asset-liability ratio (Lev) fluctuating between a maximum of 0.856 and a minimum of 0.0563, averaging at 0.431.

The mean asset return rate (Roa) stands at 0.0391, ranging from -0.184 to 0.188, indicating minimal variation among different enterprises. Conversely, the fixed asset ratio (Far) demonstrates greater diversity, averaging at 0.223, with extremes of 0.008 and 0.656. Growth potential differs among enterprises, as evidenced by the total asset growth rate, which spans from a minimum of -0.237 to a maximum of 2.115, averaging at 0.207.

Table 2. Descriptive Statistics

VARIABLES	N	mean	sd	min	max
Pat	7,392	2.465	1.295	0.693	6.850
SCF	7,392	19.02	4.751	0	23.81
SA	7,392	-3.665	0.255	-4.229	-3.151
Size	7,392	8.380	1.169	6.274	11.88
Lev	7,392	0.431	0.191	0.0563	0.856
Roa	7,392	0.0391	0.0528	-0.184	0.188
Far	7,392	0.223	0.142	0.00842	0.656
Growth	7,392	0.207	0.356	-0.237	2.115

4.2. Correlation Analysis

The correlation coefficients among variables are presented in Table 3, revealing that the key variables have achieved a certain level of significance. Through an initial examination of these correlations, it was discovered that the correlation coefficients among the variables are all less than 0.5. This finding

suggests a relatively low level of correlation among the variables. Furthermore, the variance inflation factor (VIF) is significantly less than 10, indicating the absence of notable multicollinearity.

The analysis results reveal a significant positive correlation between patent applications of sampled enterprises and supply chain financing, which is statistically significant at the 1% level. This provides preliminary validation for Hypothesis 1. Additionally, there is a significant negative correlation between supply chain financing and the financing constraint SA index. This suggests that supply chain financing can alleviate financing constraints faced by enterprises, thus providing initial support for Hypothesis 2. A pronounced negative correlation exists between patent applications and financing constraint indicators, indicating that financing constraints have become an impediment to technological innovation. Based on these findings, further investigation into the relevant variables is warranted to explore their intricate relationships.

Table 3. Correlation Analysis

	Pat	SA	SCF	Size	Lev	Roa	Far	Growth
Pat	1							
SA	-0.019***	1						
SCF	0.221***	-0.143***	1					
Size	0.391***	-0.274***	0.359***	1				
Lev	0.126***	-0.287***	0.405***	0.526***	1			
Roa	0.057***	0.098***	-0.168***	-0.050***	-0.395***	1		
Far	-0.079***	-0.094***	0.099***	0.063***	0.099***	-0.135***	1	
Growth	-0.00900	0.155***	-0.059***	-0.055***	-0.136***	0.228***	-0.224***	1
VIF	1.740	1.140	1.250	1.690	1.850	2.940	1.080	1.130

Note: *, **, *** represent significance at the 10%, 5%, and 1% levels, respectively.

4.3. Hausman Test

In this paper, the regression effect is selected through the Hausman test. Based on the test result of Prob>chi2 = 0.0000 from the regression model of the main effect, the null hypothesis is rejected at the 1% significance level. Consequently, the fixed effects model is chosen. The specific results are presented in Table 4 below.

Table 4. Hausman Test Results

VARIABLES	(Fe) Pat	(Re) Pat
SCF	0.038*** (0.003)	0.037*** (0.003)
Size	0.572*** (0.019)	0.497*** (0.016)
Lev	-0.599*** (0.111)	-0.741*** (0.099)
Roa	0.137 (0.393)	0.271 (0.375)
Far	-0.244 (0.149)	-0.581*** (0.124)
Growth	-0.112*** (0.030)	-0.120*** (0.029)
Prob>chi2	0.0000	

Note: *, **, *** represent significance at the 10%, 5%, and 1% levels, respectively.

4.4. Regression Results Analysis

4.4.1. Exploring the Correlation Between Supply Chain Finance and Innovation Capability

In accordance with the mediation effect testing procedure, we first ascertain the primary effect among variables. By utilizing Model 1, we conducted a verification analysis on the relationship between supply chain finance and the innovation capabilities of small and medium-sized enterprises. The

outcomes are presented in Table 5. Additionally, during the testing process, enterprise data was categorized based on different equity properties, allowing for a comparison of results between state-owned and non-state-owned enterprises.

Table 5 exhibits the regression outcomes between supply chain finance and enterprise innovation. Upon analysis, the following observations can be made: The first column reveals that the coefficient between the number of patent applications filed by enterprises and supply chain finance in the full sample is 0.038, which is statistically significant at the 1% confidence level. This indicates that supply chain finance can significantly increase the number of patent applications filed by enterprises, thereby fostering innovation capabilities among small and medium-sized enterprises. The second and third columns present the results of sample categorization and verification. Notably, in the third column, the coefficient of supply chain finance stands at 0.042, significant at the 1% level, implying that supply chain finance can augment the number of patent applications for non-state-owned enterprises. The second column elucidates that the empirical results for state-owned enterprises are not significant. This may be attributed to their fixed mechanisms and rigid models for innovation activities, coupled with the rarity of funding shortages, rendering supply chain finance less impactful on their innovation processes. In summary, within the full sample, supply chain finance demonstrates a significant increase in patent applications filed by enterprises, thereby validating Hypothesis H1.

Table 5. Supply Chain Finance and Enterprise Innovation Capability

VARIABLES	Full Sample Pat	State-Owned Enterprises Pat	Non-State-Owned Enterprises Pat
SCF	0.038*** (0.003)	0.004 (0.007)	0.042*** (0.003)
Size	0.572*** (0.019)	0.889*** (0.033)	0.483*** (0.023)
Lev	-0.599*** (0.111)	-0.151 (0.199)	-0.626*** (0.134)
Roa	0.137 (0.393)	1.781** (0.697)	-0.135 (0.480)
Far	-0.244 (0.149)	0.107 (0.230)	-0.273 (0.190)
Growth	-0.112*** (0.030)	-0.235*** (0.066)	-0.111*** (0.034)
_cons	-2.725*** (0.161)	-5.203*** (0.310)	-2.041*** (0.188)
N	7392	2286	5107
R2	0.182	0.316	0.153
Company FE	Control	Control	Control
Year FE	Control	Control	Control

Note: *, **, *** represent significance at the 10%, 5%, and 1% levels, respectively.

4.4.2. The relationship between supply chain finance and financing constraints

Based on the mediation test process, the next step is to examine the relationship between supply chain finance and financing constraints. Simultaneously, the data was classified and verified according to the nature of equity, and the results are shown in Table 6.

Table 6 presents the empirical results of the relationship between supply chain finance and corporate financing constraints. Analysis reveals that: The full-sample empirical results indicate that the coefficient of SCF is -0.011, which is statistically significant. This suggests that the more credit and guarantees provided by core enterprises in the supply chain, the more it can alleviate the financing constraints faced by enterprises. After classifying the samples, the second and third columns display the empirical results for state-owned and non-state-owned enterprises, respectively. From the results, it can be observed that: In the third column, the coefficient of the variable SCF is -0.011, which is significant. This indicates a negative correlation between supply chain finance and corporate financing constraints, implying that supply chain finance business can ease the financing constraints

of non-state-owned small and medium-sized enterprises. This is because, compared to state-owned enterprises, non-state-owned enterprises face more difficulties and constraints in external financing, and developing supply chain finance can effectively reduce their financing costs and alleviate financing problems. In the second column, the SCF coefficient is 0.010, which is not significant. This suggests that supply chain finance has no significant impact on the financing constraints of state-owned enterprises in the sample. By contrast, non-state-owned enterprises are subject to factors such as scale and national policies, and face credit discrimination when seeking external financing, resulting in higher external financing costs compared to state-owned enterprises. Therefore, the results show that supply chain finance has a more pronounced effect on alleviating financing constraints in non-state-owned enterprises than in state-owned enterprises. In summary, the results of this step can verify Hypothesis 2.

Table 6. Supply Chain Finance and Financing Constraints

VARIABLES	Full Sample SA	State-Owned Enterprises SA	Non-State-Owned Enterprises SA
SCF	-0.011*** (0.003)	-0.010 (0.003)	-0.011*** (0.003)
Size	-0.006*** (0.001)	0.026*** (0.002)	-0.018*** (0.001)
Lev	-0.041*** (0.006)	-0.010 (0.014)	-0.028*** (0.007)
Roa	-0.069*** (0.022)	-0.130*** (0.048)	-0.010 (0.024)
Far	0.032*** (0.008)	0.043*** (0.016)	0.034*** (0.010)
Growth	-0.007*** (0.002)	-0.014*** (0.005)	-0.005*** (0.002)
_cons	-3.593*** (0.009)	-4.080*** (0.021)	-3.422*** (0.009)
N	7392	2286	5106
R2	0.037	0.098	0.112
Company FE	Control	Control	Control
Year FE	Control	Control	Control

Note: *, **, *** represent significance at the 10%, 5%, and 1% levels, respectively.

4.4.3. Examination of the Mediating Effect of Financing Constraints

The significance of the main effect has been previously verified, and empirical analysis has demonstrated that supply chain finance can effectively alleviate the financing constraints faced by small and medium-sized enterprises (SMEs). The next step involves establishing a regression equation between supply chain finance, SME innovation, and financing constraints. The significance of regression coefficients λ1 and α1' will be used to validate whether financing constraints play a mediating role in the pathway of the main effect. This will elucidate whether supply chain finance can enhance the innovation capability of SMEs by easing their financing constraints.

Table 7 unveils the regression results of the mediating effect of financing constraints in the mechanism of supply chain finance on corporate innovation. In comparison to the previous two test results, the coefficient of SA in the third column is -1.903, which is significant at the 1% confidence level, indicating a significant mediating effect. SCF is significant at the 1% level with a coefficient of 0.039. This suggests that in supply chain finance, core enterprises provide credit guarantees for the financing of downstream enterprises, significantly enhancing their innovation capability by alleviating financing constraints. Therefore, it can be inferred that supply chain finance can improve corporate innovation capability by ameliorating financing constraints, thus validating Hypothesis H3.

Table 7. The Mediating Effect of Financing Constraints

VARIABLES	Pat	SA	Pat
SCF	0.038***	-0.011***	0.039***
	(0.003)	(0.003)	(0.003)
SA			-1.903***
			(0.223)
Size	0.572***	-0.006***	0.584***
	(0.019)	(0.001)	(0.019)
Lev	-0.599***	-0.041***	-0.523***
	(0.111)	(0.006)	(0.111)
Roa	0.137	-0.069***	0.267
	(0.393)	(0.022)	(0.391)
Far	-0.244	0.032***	-0.305**
	(0.149)	(0.008)	(0.148)
Growth	-0.112***	-0.007***	-0.099***
	(0.030)	(0.002)	(0.030)
_cons	-2.725***	-3.593***	4.111***
	(0.161)	(0.009)	(0.816)
N	7392	7392	7392
R2	0.182	0.037	0.192
Company FE	Control	Control	Control
Year FE	Control	Control	Control

Note: *, **, *** represent significance at the 10%, 5%, and 1% levels, respectively.

4.5. Robustness Testing

4.5.1. Examination of Different Effects

Regression tests were conducted on the number of patent applications filed by enterprises and variables such as supply chain finance using mixed effects, fixed effects, and random effects, as presented in Table 8. The results indicate that under different effects, the coefficients of SCF are 0.038, 0.038, and 0.037, respectively. This suggests that in all three effects, supply chain finance can enhance the innovation capability of small and medium-sized enterprises, and all are significant at the 1% confidence level. This provides evidence that the previous test results are relatively accurate.

Table 8. Examination of Different Effects

VARIABLES	(Ols) Pat	(Fe) Pat	(Re) Pat
SCF	0.038***	0.038***	0.037***
	(0.003)	(0.003)	(0.003)
Size	0.461***	0.572***	0.497***
	(0.015)	(0.019)	(0.016)
Lev	-0.829***	-0.599***	-0.741***
	(0.096)	(0.111)	(0.099)
Roa	1.345***	0.137	0.271
	(0.440)	(0.393)	(0.375)
Far	-0.988***	-0.244	-0.581***
	(0.100)	(0.149)	(0.124)
Growth	-0.102**	-0.112***	-0.120***
	(0.040)	(0.030)	(0.029)
_cons	-1.559***	-2.725***	-2.060***
	(0.113)	(0.161)	(0.135)
N	7392	7392	7392
R2	0.188	0.182	
R2_a	0.187	0.036	

Note: *, **, *** represent significance at the 10%, 5%, and 1% levels, respectively.

4.5.2. Sobel Test

Based on the analytical steps of the step-by-step testing method, the total effect of supply chain finance on the innovation capability of enterprises is found to be 0.038, with a significant impact. The direct effect of supply chain finance on enterprise innovation stands at 0.039, which is also significant. The indirect effect, or mediating effect, of supply chain finance exerted through financing constraints amounts to 0.0209 (=-0.011*(-1.903)). This mediating effect accounts for 55.09% (=-0.011*(-1.903)/0.038) of the total effect. Given the surrounding the traditional step-by-step regression testing method, the Sobel test is conducted to verify the mediating effect of supply chain finance on enterprise innovation, following the mediation effect testing procedure outlined earlier.

Table 9 presents the results of the Sobel test, specifically focusing on the regression of supply chain finance on innovation capability. The data reveals that the Z-value of the Sobel test is significant (with a P-value less than 0.05), and the proportion of the mediating effect is 0.716. The coefficient of the mediator variable SA is -1.903, which is significant at the 1% confidence level. This suggests that supply chain finance can reduce financing constraints for enterprises and significantly enhance the innovation capability of small and medium-sized enterprises through transmission mechanisms. In this pathway, financing constraints play a partial mediating role, indicating that the results obtained from the mediation effect step-by-step testing method used earlier are relatively accurate.

Table 9. Sobel Test

VARIABLES	Pat
SCF	0.039***
	(0.003)
SA	-1.903***
	(0.223)
Size	0.584***
	(0.019)
Lev	-0.523***
	(0.111)
Roa	0.267
	(0.391)
Far	-0.305**
	(0.148)
Growth	-0.099***
	(0.030)
Constant	4.111***
	(0.816)
Observations	7,392
Number of id	1,218
Company FE	Control
Year FE	Control
Sobel Z	3.77***
p-value	(0.000)
Proportion of mediating effect	0.716

Note: *, **, *** represent significance at the 10%, 5%, and 1% levels, respectively.

4.5.3. Bootstrap Method

The mediation effect is the focal point of this study, hence further examination of the mediation effect of key variables is imperative. While the Sobel test has been a traditional and typical method for examining indirect mediation effects, it possesses certain flaws. Consequently, scholars have proposed numerous alternative testing approaches, among which the Bootstrap method has gained widespread acceptance. According to the test results presented in Table 10, the confidence intervals for both the direct and indirect effects of supply chain finance on the innovation capability of enterprises do not include 0, indicating a significant mediation role. This signifies that supply chain finance significantly alleviates financing constraints, and these constraints play a partial mediating

role in the relationship between supply chain finance and innovation in small and medium-sized enterprises. These findings suggest that supply chain finance can influence enterprise innovation capability by easing financing constraints. Evidently, the test results align with those obtained through the step-by-step analysis and Sobel test. Therefore, the empirical analysis results presented in this paper possess a certain degree of credibility.

Table 10. Bootstrap Test

	Test results		[95%Conf. Interval]		Mediation effect
	Coefficient	SE	Lower limit	Upper limit	
_bs_1 r(ind_eff)	-0.021	0.045	-0.092	-0.086	Significance
_bs_2 r(dir_eff)	1.365	0.189	0.994	1.735	Significance

5. Chapter Five: Conclusion

Utilizing a sample of 1218 enterprises listed on the SME board from 2012 to 2022, this paper investigates the relationship between supply chain finance and the innovative capabilities of small and medium-sized enterprises (SMEs), as well as the mediating effect of financing constraints within this relationship. The primary research findings are summarized as follows:

(1) Supply chain finance for SMEs significantly promotes their innovation capabilities. Based on panel data from SME board companies spanning from 2010 to 2020, it is evident that supply chain finance notably enhances the profitability of these enterprises. This suggests that it provides financial support to SMEs, thereby steadily strengthening their economic power.

(2) Supply chain finance effectively alleviates financing constraints for SMEs, with varying effects depending on the equity nature of the enterprise. This variation arises from substantial differences in financing forms and characteristics among enterprises with different equity structures. Firstly, for financial institutions, collecting information on non-state-owned SMEs poses challenges due to their small size, numerous quantity, dispersion, insufficient credit, and management difficulties. Additionally, providing financial services to these enterprises can be cumbersome, resulting in generally higher financing costs for state-owned enterprises. Secondly, compared to state-owned enterprises, non-state-owned enterprises lack adequate support and strong credit endorsements. Their small scale and insufficient historical credit records to prove their strength contribute to information asymmetry from the perspective of financial institutions, posing risks and making external financing more difficult to obtain. To address the financing challenges of SMEs, financial institutions are actively exploring and innovating the new financing model of supply chain finance. Based on transactional behavior among enterprises, financial institutions can acquire more comprehensive information and conduct credit assessments. Under the credit guarantee of core enterprises, SMEs can use some of their current and fixed assets as collateral, thereby easing financing constraints. Thus, it can be concluded that the innovative financing model of supply chain finance positively promotes financing for non-state-owned enterprises, effectively reducing their financing burden.

(3) This paper introduces a mediating effect model, setting financing constraints as the mediating variable. The research findings indicate that the alleviation of financing constraints indeed plays a mediating role in the main effect. By addressing the financing constraints faced by enterprises, supply chain finance can effectively enhance the innovation level of SMEs. Therefore, it is prudent for SMEs to actively integrate into the supply chain finance system. By utilizing this model, they can obtain necessary financial support to fund research and development activities, thereby improving technological innovation capabilities, accelerating the construction of innovative technology platforms, and achieving sustainable development.

References

[1] Wang, J. (2019). Research on the Differential Impact of Monetary Policy on the Financing Constraints of Chinese Listed Companies [J]. Economic Issues, (12), 44-51.

[2] Guo, C. (2019). Financing Constraints of Private Enterprises [J]. China Finance, (23), 81-83.

[3] Geng, C., Li, M., & E, H. (2018). Financing Ecology and Financing Constraints of New Energy Enterprises - Based on the Analysis of China's A-share New Energy Listed Companies [J]. East China Economic Management, 32(01), 153-159.

[4] Feng, Z., & Li, G. (2022). Research on Cash Dividend Policy Under Differentiation Strategy [J]. Economic Longitude and Latitude, 39(02), 141-151.

[5] Liu, L., & Wang, J. (2022). Social Capital, Company Transparency and Debt Financing Costs [J]. Research World, (11), 32-43.

[6] Almeida H, Campello M, Weisbach M S. The Cash Flow Sensitivity of Cash[J]. The Journal of Finance, 2004,59(4): 1777-1804.

[7] Liu, R., & Du, J. (2022). Signaling Effect, Government Subsidies, and Financing Constraints [J]. Journal of Harbin University of Commerce (Social Science Edition), (02), 58-70.

[8] Qin, J. (2021). Current Status and Countermeasures of Supply Chain Finance Development in China [J]. Academic Exchange, (05), 103-115.

[9] Ge, L. (2022). Research on the Supply Chain Model and Innovation Development of Rural E-commerce in China [J]. Agricultural Economy, (02), 128-130.

[10] Wang, D., He, L., & Li, L. (2021). Credit Risk Transmission Mechanism and Simulation in Supply Chain Finance [J]. Financial Forum, 26(09), 15-25.

[11] Gu, Q. (2016). Research on the Effect of Supply Chain Finance on Alleviating Financing Constraints - Empirical Evidence from Technology-based SMEs [J]. Financial and Economic Forum, (05), 28-34.

[12] Wang, L., & Hu, Y. (2018). Supply Chain Finance and Improvement of Corporate Financing Constraints - Based on the Analysis of the Regulatory Role of Industry-Finance Integration and Strategic Commitment [J]. China Circulation Economy, 32(06), 122-128.

[13] Liu, J., Yang, M., & Guo, J. (2019). Can Supply Chain Finance Alleviate the Financing Constraints of Technology-Based SMEs? - Based on Experience Data from SME Board Listed Companies [J]. Friends of Accounting, (10), 116-121.

[14] Liqun Zhuge, Richard B. Freeman, Matthew T. Higgins. Regulation and innovation: Examining outcomes in Chinese pollution control policy areas[J]. Economic Modelling,2020,89.

[15] Xia, H., Tan, Q., & Bai, J. (2019). Business Environment, Corporate Rent-Seeking, and Market Innovation - Empirical Evidence from a Survey on the Business Environment of Chinese Enterprises [J]. Economic Research, 54(04), 84-98.

[16] Pan, Y., Xiao, J., & Dai, Y. (2017). Cultural Diversity and Corporate Innovation: A Study Based on the Perspective of Dialects [J]. Financial Research, (10), 146-161.

[17] Wang, Y., Luo, N., & Liu, W. (2019). What Kind of Leverage Ratio is Conducive to Corporate Innovation [J]. China Industrial Economics, (03), 138-155.

[18] Li, S., He, Y., & Guo, M. (2017). An Empirical Analysis of the Relationship Between Information Disclosure Quality, Financing Constraints, and Corporate R&D Investment [J]. Statistics and Decision Making, (23), 161-164.

[19] Sun, B., Liu, S., Jiang, J., Ge, C., & Zhou, H. (2019). Corporate Financing Constraints and Innovation Performance: A Perspective of Human Capital Social Networks [J]. Chinese Management Science, 27(04), 179-189.

[20] Zhang, Y. (2020). Research on the Impact of Information Transparency of Chinese P2P Lending Platforms on Platform Operation Efficiency [D]. Jinan University.

[21] Liu, S., Wang, Z., Cheng, Y., Han, X., & Shi, W. (2019). Cost Reduction: Survey and Analysis in 2019 [J]. Fiscal Research, (11), 3-16.

[22] Li, S. (2020). Supply Chain Finance and Corporate Innovation Performance - An Empirical Study from SMEs [J]. Investment and Entrepreneurship, 31(24), 1-8.

[23] Zhang, W., & Liu, K. (2012). Can the Development of Supply Chain Finance Reduce the Financing Constraints of SMEs? - An Empirical Analysis Based on Small and Medium-Sized Listed Companies [J]. Economic Science, (03), 108-118.

[24] Zhao, Y., Yang, Y., & Long, Z. (2017). Research on Supply Chain Finance Alleviating the Financing Constraints of GEM Listed Companies [J]. Journal of Guangxi University of Science and Technology, 28(03), 124-131.

[25] Yao, W., Xia, J., & Sun, T. (2017). Research on the Financing Constraints of Technology-Based SMEs and Their Mitigation from the Perspective of Supply Chain Finance [J]. Science and Technology Progress and Countermeasures, 34(04), 105-110.

[26] Hadlock C J, Pierce J R. New Evidence on Measuring Financial Constraints: Moving Beyond the KZ Index[J]. Review of Financial Studies, 2010, 23(5): 1909-1940.

[27] Wen, Z., Zhang, L., Hou, J., & Liu, H. (2004). Testing and Application of the Mediation Effect Examination Procedure [J]. Acta Psychologica Sinica, (05), 614-620.