

Original Paper

Research on the Impact of Enterprise Digital Transformation on Supply Chain Financing Capability

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Abstract

We examine how enterprise digital transformation affects supply chain financing capability with data from China's A-share non-financial listed companies from 2013 to 2023, and we try to find the relationship between digital technology and financing ability in supply chain context. The results show that digital transformation can improve the financing capability in supply chain. Also, we find this effect can work by reducing information asymmetry. In fact, this can be seen from increased analyst coverage. Then we check internal corporate governance level as a boundary condition. It is worth noting that the role of internal control quality is not a simple linear enhancement and it shows a threshold effect which means the positive impact of digital transformation is only significant when quality of internal control is high and when the quality is low the impact is not significant. We reveal the mechanism of conditional synergy between digital technology and corporate governance in financing empowerment. The results can be used as a reference for enterprise on how to obtain financing advantages by improving governance structures during digital transformation.

Keywords

Digital Transformation, Supply Chain Finance, Internal Control, Information Asymmetry, Threshold Effect

1. Introduction

The global digital economy is developing fast. In China, the financial supply-side structural reform is also deepening. Under the background of global digital economy, supply chain finance becomes important method that can help solve corporate financing constraints and serve the real economy. The “14th Five-Year Plan for Digital Economy Development” proposes to promote the deep integration of digital technology and the real economy. Also, the “Guiding Opinions on High-Quality Development of Supply Chain Finance” emphasizes that we should use digital means to improve the efficiency of

supply chain financial services. At the same time, big data and artificial intelligence are driving big changes in how enterprises operate and manage. However, in the current research and practice, there is a question that is not well answered: Can digital transformation strategy reshape the supply chain financing capability of enterprises? And if it can, how does it work?

Most existing studies examine the macro-level evolution of supply chain finance models. They also look at how supply chain finance alleviates corporate financing constraints. But they do not pay enough attention to enterprise-level micro-behaviors in the digitalization. Also, the internal governance conditions that can affect the effectiveness of such behaviors are not well studied. In fact, existing studies have not identified the specific transmission path through which digital transformation affects supply chain financing. And they have not considered the “conditional” moderating role of internal governance on the empowering effect of technology. That is, we do not know whether the governance mechanism acts as “enhancing” effect or constitutes a “prerequisite” for the effect to occur. This forms a research gap that we should fill.

Based on the information asymmetry and corporate governance theories, we construct a “moderated mediation” model. It is worth noting that this model can help us answer the following questions. Can enterprise digital transformation enhance supply chain financing capability? What is the mediating mechanism of its effect? Also, will the quality of enterprise internal control “moderate” or even “determine” the occurrence of this influence process?

The rest of this paper is organized as follows. Section 2 provides the literature review and research hypotheses where we build the theoretical foundation. Then Section 3 describes the research design. Section 4 shows the empirical results and analysis with robustness checks. And Section 5 gives the research conclusions and implications.

The new contributions of this paper include the following three aspects:

1. We use analyst coverage as a mediator. This can help reveal the specific path through which digital transformation enhances supply chain financing capability by reducing information asymmetry. It addresses the research gap on the direct linkage mechanism between digital transformation and supply chain financing. Also, it enriches micro-empirical evidence on the economic consequences of enterprise digitalization.
2. We add the quality of internal control to this research system for the first time, and we do not use the old linear moderation method. Through detailed subgroup tests, we can find that there is a “threshold effect” of the quality of internal control on the financing effect of digital transformation. This provides a new way to understand the “conditional synergy” of “technology” and “governance”.
3. From these results, we give some strategic directions. Enterprises can use the financing advantages of “governance first” in digital economy. At the same time, we provide a new model for banks to assess asset quality with actual “digital credit”.

2. Literature Review and Research Hypotheses

2.1 Digital Transformation and Supply Chain Finance

First, this type means the change of company entire business process and management mode by using digital technologies, and it is typical to use data for breaking the information bottleneck of old operational model and solving efficiency problems, so that the company can operate better. As the integration of digital economy and real economy becomes deeper, enterprises have changed their views on digitalisation. It is not just an option. It is essential choice to ensure continuous development of enterprise. In fact, the previous research on connection between digitalisation and supply chain finance has two aspects: technology empowerment and model reform, which have provided basis for this study [1].

For technology promotion, applications of blockchain, Internet of Things (IoT), big data and cloud computing bring new ways to help improve efficiency and risk control of supply chain finance. Blockchain has decentralised and unchangeable nature with good traceability, so we can record and verify all steps of supply chain transaction data to solve problems such as document forgery and information silos [2] in old supply chain finance. Upstream suppliers can turn accounts receivable into divisible and transferable digital vouchers on blockchain to get financing and reduce financing threshold and operating costs. IoT technology can be used to connect “objects” with “data” for monitoring logistics and warehouses in real time, and it helps financial institutions understand current status and value of collateral for movable asset pledge financing[3]. It can also reduce moral hazard and operating risk. Big data can mine and analyse operating data in enterprises to build complete credit assessment models with good precision, avoid the old way of using only financial statements, and give technical support for credit discovery of disadvantaged enterprises in supply chain.

From the model innovation perspective, the development of digital technology can promote the development of supply chain finance, and the traditional “1+N” model has changed to the “N+N” model, which can not only improve resource allocation efficiency, but also improve service coverage [4]. Under the background of the traditional “1+N” model, the core enterprises are regarded as the core, but the upstream and downstream enterprises are not taken into account, and the number of enterprises is relatively small. The vast majority of enterprises in the distribution chain are too small in scale to obtain the recognition of the core enterprises and can not get financing support. Digital technology can be applied in the process of building supply chain finance platform, so that a variety of subjects can be integrated, including logistics enterprises, financial institutions, core enterprises, etc., so as to build a multi-level financing service network. After the model change, whether the enterprise is in a key position or not, as long as it can provide real and effective transaction data, it can get favorable financing products with the help of the platform, and the service scope of supply chain finance will be significantly expanded. At the same time, this model can promote the standardization and automation of the financing process, and all the steps from application to loan and repayment can be operated online, which can effectively shorten the financing cycle and significantly improve the efficiency of financing

[5].

In the process of studying how to improve the financing ability of the supply chain, scholars have made positive theoretical exploration and achieved certain results, but most scholars are only based on traditional factors to analyze the impact of factors on the financing ability of the supply chain. Enterprise size can reflect the signal mechanism, which will have a significant impact on the financing ability of the supply chain. Enterprises with large scale have good governance structure, sufficient cash flow and strong risk resistance, which can easily obtain trade credit from upstream enterprises [6]. Profitability is an important factor in whether enterprises can repay the loan on time. If enterprises have high indicators in sales profit margin and return on total assets, they can give suppliers a strong sense of debt repayment, and suppliers can give them more favorable credit terms [7]. At the same time, whether the supply chain relationship is stable will also have a direct impact on the financing ability of enterprises. If enterprises can maintain a stable cooperative relationship for a long time, the transaction cost and information asymmetry between upstream and downstream enterprises can be reduced, and suppliers are willing to provide credit support to enterprises [8]. At the same time, enterprises should also pay attention to whether their debt repayment ability, asset structure and growth potential meet the requirements.

In the study of digital transformation, scholars have analyzed the economic consequences, including bank credit, operational efficiency, innovation performance and so on, and put forward reasonable opinions, but they have not paid attention to supply chain finance. Some scholars have pointed out that digital transformation can improve innovation performance, promote the improvement of resource allocation efficiency, and bring favorable conditions for the development of enterprises [9]; In the process of process reengineering, it can also improve the profitability of enterprises and achieve the goal of saving costs [10]; If enterprises can reduce information asymmetry and improve credit, they will get more support from banks and have good credit conditions [1]. Only a few studies explore the reverse, suggesting that sufficient financing support can promote enterprise digital transformation by providing necessary funding for purchasing digital equipment, introducing digital technologies, and forming professional teams, thereby accelerating the digital transformation process [11], which provides a useful supplement to the main path of “enterprise digital transformation → supply chain financing capability” focused on in this paper.

Based on a comprehensive view of existing research, while the close connection between digitalization and supply chain finance is recognized, there are still significant research gaps: First, the research perspective is mostly concentrated on the macro impact of digital technology on supply chain finance models and risk management, or the reverse promoting effect of supply chain finance on digital transformation, lacking a micro-level exploration from the enterprise perspective on the direct impact of actively implemented digital transformation strategies on their own supply chain financing capability. Secondly, the current research can not make a reasonable explanation for the question of “how digital transformation will have a direct impact on supply chain financing capacity”, and can not analyze the

internal mechanism deeply. Thirdly, the relationship between digital transformation and supply chain financing ability is not analyzed in depth, and the boundary conditions are not taken into account. Whether internal governance can play a decisive role in the development of digital transformation should be analyzed in depth.

From the perspective of theoretical logic, digital transformation is the key to enhancing the financing capacity of enterprises, which is reflected in three aspects:

First, in the process of digital transformation, enterprises should fully optimize business processes, which can bring favorable conditions for the fulfillment of contracts, and enterprises can get the credit of suppliers. In the process of digital transformation, enterprises can build a digital management system and introduce ERP, which can coordinate the operation of the whole supply chain and enhance the efficiency of each link, including sales and production. Digital procurement system can make good use of information, match supply and demand, control inventory and save procurement costs. Intelligent production system can adjust the production plan in time according to the needs of the market, improve the quality of products and shorten the production cycle. The digital sales system can collect customer information in a timely manner, grasp the market dynamics, and improve the efficiency of sales collection. The optimization of the above process can significantly improve the performance capability of enterprises, and suppliers can also feel the reliability and stability of their partners, and can provide favorable conditions for trade credit.

Secondly, the implementation of digital transformation can enhance the transparency of information, reduce the information asymmetry between upstream and downstream enterprises, and enhance the trust of the whole supply chain. With the help of digital transformation, enterprises no longer need to deliver information through paper documents, but to deliver information to suppliers through online platforms, including sales data, financial status, production progress and so on, so that suppliers can accurately grasp the credit and operating conditions of purchasing enterprises, enhance trust, and be more willing to provide credit support.

In the process of digital transformation, enterprises can cooperate with upstream and downstream enterprises to form a supply chain, which can provide a good foundation for financing. Enterprises use digital technology to share information, break through information bottlenecks, and share data in real time to achieve business collaboration, so that enterprises can cooperate with distributors and suppliers to form a strategic partnership. Enterprises can build a digital platform, work with suppliers in the development of products, inventory management and other aspects, and promote the rational allocation of resources in the supply chain and the improvement of utilization rate. The formation of deep cooperation can enhance the competitiveness of the supply chain as a whole, reduce transaction costs, and also make suppliers trust purchasing enterprises, and provide strong support for financing. In the process of purchasing, if the enterprise encounters financial difficulties, the supplier will provide credit support to help it get through the difficult period, and the enterprise's financing capacity will also be enhanced.

On the basis of the above theoretical research, combined with the literature, this paper puts forward a hypothesis:

H1: The digital transformation of enterprises can promote the improvement of supply chain financing ability.

2.2 The Mediating Role of Information Asymmetry

Information asymmetry is a common phenomenon in the process of market transactions, that is to say, the two sides of the transaction can not get the same information, one side can not get accurate and complete information, while the other side can get it [12]. Information asymmetry is the theoretical basis for analyzing the financing constraints of enterprises in the financial market, and the phenomenon exists objectively in the supply chain financing. In the process of supply chain financing, the existence of multiple entities, the occurrence of information asymmetry will lead to the occurrence of adverse selection and moral hazard, and the transaction cost will increase, which is not conducive to the efficiency and scale of financing.

In the process of participating in supply chain finance, the existence of information asymmetry is particularly prominent, which is reflected in two aspects: first, the purchasing enterprise and the upstream supplier. The supplier provides trade credit for the purchasing enterprise and needs to grasp the credit status and debt repayment ability of the purchasing enterprise to make a reasonable decision on whether to provide trade credit. However, in practice, the purchasing enterprise can accurately grasp its own financial status and make judgments about the future development, but the supplier does not have the same advantage, because there is no effective way to obtain information, which leads to the supplier's lack of understanding of the purchasing enterprise, and the uncertainty of credit decision-making will be increased, in order to reduce the risk, the supplier will provide trade credit for the purchasing enterprise, but the threshold will be higher, so that the purchasing enterprise can not get sufficient support. Second, the purchasing enterprise and the financial institution. Financial institutions need to analyze the credit risk of purchasing enterprises when providing supply chain financial services, but there is no direct business relationship between financial institutions and purchasing enterprises, and the information communication is not smooth, which leads to the inability to grasp the financial information of purchasing enterprises, and the risk of credit decision-making is relatively high. In order to control risks, financial institutions require enterprises to provide guarantees or collateral, which increases the financing constraints of SMEs.

The fundamental purpose of implementing supply chain finance is to narrow the information gap between financial institutions and enterprises, which requires the integration of logistics, capital flow, information flow and other contents to solve the problem of information asymmetry [4]. The implementation of digital transformation can provide strong technical support for the realization of the above goals, so that enterprises can collect a large amount of multi-dimensional operational data, and then use information disclosure to provide relevant information to the external market, which can play a positive role in solving the problem of information asymmetry. First of all, it can make up for the

shortcomings of traditional management in the collection of operational data, and can record and update the data collected from multiple links in real time, which can reflect the development efficiency and operational efficiency of enterprises. For example, the inventory turnover data collected by IoT equipment can be used to evaluate the inventory management level of enterprises, and the operation data of production equipment can be used to evaluate the production capacity of enterprises; enterprises can also collect customer feedback data through online sales platforms, analyze customer satisfaction, and understand their market competitiveness; enterprises can also collect financial statements and cash flow data through digital systems, and evaluate debt repayment ability and profitability. Secondly, digital transformation can provide support for enterprises to disclose information to external stakeholders in a timely and accurate manner, and to pass operational data to external stakeholders through diversified channels. Enterprises can publish operational data and financial information through supply chain collaboration platforms, investor relations platforms and official websites, which can save the cost of external stakeholders in obtaining information. Finally, enterprises should enhance the reliability of information and the comparability of data in the process of digital transformation, so that the information can be standardized and the data can be normalized. A unified data governance framework and data standards can be set to ensure the authenticity and accuracy of operational data, prevent information distortion and data fraud, and provide reliable information for external stakeholders to make decisions, so as to solve the problem of information asymmetry.

Analysts are important information intermediaries in the operation of enterprises, which can alleviate information asymmetry and improve resource utilization efficiency [13]. Analysts have a wealth of industry experience, have strong information collection capabilities, and can deeply mine enterprise financial data and operational data, and release research reports to external stakeholders. Analysts have a high level of coverage, which means that enterprises can better interpret and disseminate information, and external investors do not need to pay too much cost to obtain information, and the market transparency is relatively high. In order to alleviate the problem of information asymmetry, analysts should play the following roles: First, they should communicate with the managers of enterprises, carry out field research, grasp the private information of enterprises, and transform it into public information, so as to make up for the information gap between enterprises and stakeholders. Second, analysts should not only analyze the operational data of enterprises, but also analyze the financial statements of enterprises, grasp the potential development of enterprises, and enable external stakeholders to grasp the real situation of enterprises. Third, analysts should issue reports and make earnings forecasts, so that stakeholders can make decisions, eliminate the influence of uncertainty, and avoid adverse selection.

From the theoretical level, the two variables are positively related, and the latter can attract the attention of the former by improving information transparency and attracting the attention of more people. In the process of digital transformation, enterprises can provide information to the public in a more timely and comprehensive way, so that the information collection cost of analysts can be effectively controlled, and the analysis of relevant information can be simplified. When analysts select

enterprises for follow-up, they generally focus on enterprises with high information transparency, because the analysis results of these enterprises are more accurate, and they can provide abundant and reliable financial and operational information to analysts, so as to attract more analysts to analyze them. Enterprises in the process of digital transformation have a stronger market competitiveness and stronger growth potential, which attracts the attention of more people. Enterprises can enhance their core competitiveness in the context of digital economy, and have good development prospects. Investors, analysts and other market participants can understand the development of enterprises. Digital transformation is an inevitable requirement for enterprises to innovate their business model and operational process, which requires analysts to conduct in-depth analysis to identify risks and grasp value, thus attracting more analysts to analyze them.

The increase in the number of analysts can provide information to external stakeholders, which can enhance the firm's financing ability. Analysts can collect accurate and comprehensive information to evaluate the debt repayment ability and credit of enterprises, and track the development of enterprises. When the purchasing company receives the attention of a large number of analysts, the purchasing company can obtain more information with the help of analysts, reduce the risk perception, and establish a good credit relationship with suppliers. In this case, suppliers can provide financing for purchasing enterprises and formulate more reasonable credit terms, which can enhance the financing ability of purchasing enterprises. For financial institutions, analysts can play an important reference role in credit decisions. When evaluating the application of enterprises for financing, financial institutions can evaluate the credit risk and repayment ability of enterprises by referring to the research reports and earnings forecasts of analysts. The higher the number of analysts, the higher the transparency of information, the lower the credit risk, and the more credit support can be obtained from financial institutions, which can further enhance the financing ability of enterprises.

According to the above analysis, enterprises can promote the transparency of information, attract more analysts' attention, and make up for the shortcomings of information asymmetry in the process of digital transformation, which is conducive to enhancing the financing capability of the whole supply chain. Therefore, this paper puts forward the following assumptions:

H2: The fundamental purpose of digital transformation is to enhance the ability of supply chain financing, which can be achieved by improving information transparency and increasing the number of analysts.

2.3 The Moderating Role of Internal Control: From Enhancement Effect to Threshold Effect

Internal control is a series of operational procedures and management systems formulated by enterprises to ensure the authenticity of financial reports and the rationality of financial information, which are the prerequisites for enterprises to achieve governance goals [14]. High-quality internal control can not only ensure the authenticity of financial information, improve operational efficiency, prevent operational risks, but also promote the improvement of information disclosure quality, save agency costs, and bring trust to external stakeholders, which is conducive to the development of

enterprises and the improvement of financing capabilities.

Under the background of digital transformation, the significance of internal control has changed. The core of digital transformation is to obtain a large number of operational data in a short time, which can become “digital assets” and have a good credit signal for enterprises. The value of “digital assets” is inevitably related to its credibility. In order to ensure the authenticity, integrity and accuracy of these data, it is necessary to build a sound internal control system, which can give a “quality guarantee” for the “data credit” formed in the process of digital transformation, and can ensure that the data collection, storage and processing are in a standardized state [14]. If this guarantee does not exist, even if the data is abundant, it can only be regarded as “digital noise”, and its value is weakened.

At present, most scholars only analyze the impact of internal control on the financing capacity of enterprises from the direct perspective, and also analyze its role in the relationship between various factors in a linear way. Generally speaking, the above research assumes that the implementation of internal control mechanism can enhance the effectiveness of signaling. Such assumptions should be reviewed from the theoretical level, and combined with the actual situation of digital transformation. The financing effect of digital transformation is essentially to obtain the trust of external stakeholders, including financial institutions and suppliers, and to release digital information. The establishment of trust should not be based on the quantity of information, but on its quality. If the internal control quality of enterprises is relatively low, the digital information generated will be seriously questioned, and the image of “transparent, credible” can not be built. Therefore, even if enterprises achieve digital transformation, it is difficult to transmit positive credit signals to the market, which means that internal control is relatively low, which can not only weaken the financing transmission path, but also block it.

In the study, it is found that the financing effect of enterprises is inevitably related to the internal control. There is a threshold effect in the process of “enhancement”, and the two have a certain moderating effect. Enterprises should be aware that there is a certain threshold in the quality of internal control. If enterprises can achieve the threshold requirements in the process of digital transformation, it means that the quality of internal control has reached a certain level, and the market can form a strong trust, which can bring positive effects to the development of supply chain finance. In the opposite case, the financing effect of enterprises can not be achieved, which is related to the low quality of internal control.

Accordingly, this paper proposes the following hypothesis, replacing the simple linear moderation expectation:

H3: Internal control quality has a significant threshold moderating effect on the financing effect of digital transformation. That is, the enhancing effect of digital transformation on supply chain financing capability is only significant when internal control quality is high; it is not significant when internal control quality is low.

3. Research Design

3.1 Sample Selection and Data Sources

This study uses all A-share listed companies from 2013 to 2023 as the initial sample, executing the following screening procedures: (1) Excluding financial industry companies (Category J in the CSRC 2012 industry classification); (2) Excluding companies marked as ST or *ST during the sample period; (3) Excluding observations with missing key variable data.

The initial sample consists of all A-share listed companies from 2013-2023 (a total of 18,920 observations). After excluding the financial industry (1,246), ST/*ST companies (987), and observations with missing key variables (2,103), a final unbalanced panel dataset with 14,584 observations is obtained. To mitigate the influence of outliers, all continuous variables are winsorized at the 1% and 99% levels.

Enterprise digital transformation data comes from the “Listed Company Digital Transformation Degree” index published by the CNRDS database. Financial data, analyst data, and internal control data are sourced from the CSMAR database, with the internal control quality indicator using the “China Listed Company Internal Control Index” released by DIB.

3.2 Variable Definitions

1. Dependent Variable: Supply Chain Financing Capability (SCF) Drawing on the mainstream research practices of Jin Tingting et al.^[6] and Lou Z K^[7], it is measured by “(Notes Payable + Accounts Payable) / Total Assets at Period End.” This ratio reflects the relative scale of financing a firm obtains from the upstream supply chain using trade credit. It has been widely used in supply chain financing-related research and has good validity.

2. Core Explanatory Variable: Digital Transformation (DIG) The “Listed Company Digital Transformation Degree” index published by the CNRDS database is used. It is constructed based on the frequency of digital technology-related words in corporate annual report texts, with 1 added before taking the natural logarithm. This index has been adopted in studies by Tao F et al, Zhou Z et al and Wu F [1,10,16], demonstrating good validity and reliability. Digital transformation can effectively alleviate corporate financing constraints and improve the external capital acquisition environment [17].

3. Mediating Variable: Information Asymmetry (Analyst) Analyst coverage is used as an inverse proxy variable for information asymmetry, specifically measured as “ $\ln(1 + \text{number of analyst teams tracking the company})$.” Considering the multidimensional nature of information asymmetry, this paper primarily tests using analyst coverage as the proxy variable. Subsequent tests will use stock price synchronicity (Synch) for alternative testing to ensure the reliability of conclusions.

4. Moderating Variable: Internal Control Quality (Internal_Control) The internal control index released by (DIB) is used, taking the natural logarithm ($\ln(1 + \text{DIB internal control index})$). This index is a widely recognized authoritative measure in domestic academia and has been used in studies by Xiu Z F [18].

5. Control variables. We follow existing literature. Several variables should be controlled. Firm Size

(Size) is natural logarithm of total assets at period end. We include Asset-Liability Ratio (LEV, total liabilities / total assets), Return on Total Assets (ROA, net profit / total assets), Operating Revenue Growth Rate (Growth, (current period revenue - previous period revenue) / previous period revenue), and Listing Age (Age, observation year - listing year + 1, natural logarithm). Also, we control Operating Cash Flow Ratio (Cashflow, net operating cash flow / total assets) and Fixed Asset Ratio (PPETA, net fixed assets / total assets). At the same time, industry fixed effects based on CSRC 2012 classification and year fixed effects are added in model and it can avoid interference from industry characteristics and macro time trends.

Table 1. Variable Definitions and Measurement Methods

Variable Type	Variable Name	Variable Symbol	Definition and Measurement Method
Explained Variable	Supply Chain Financing Capability	SCF	(Notes Payable + Accounts Payable) / Total Assets
Core Explanatory Variable	Degree of Digital Transformation	DIG	Log(1 + Digital Word Frequency Index from Annual Report Text Analysis)
Mediating Variable	Analyst Coverage	Analyst	Ln(1 + Number of Analyst Teams Covering the Firm)
Moderating Variable	Internal Control Quality	Internal_Control	Ln(1 + DIB Internal Control Index)
Control Variable	Firm Size	Size	Natural Logarithm of Total Assets at Year-End
Control Variable	Asset-Liability Ratio	LEV	Total Liabilities / Total Assets
Control Variable	Return on Assets	ROA	Net Profit / Total Assets
Control Variable	Revenue Growth Rate	Growth	(Current Revenue - Previous Revenue) / Previous Revenue

Variable Type	Variable Name	Variable Symbol	Definition and Measurement Method
Control Variable	Listing Age	Age	$\ln(\text{Observation Year} - \text{IPO Year} + 1)$
Control Variable	Operating Cash Flow Ratio	Cash flow	Net Cash Flow from Operating Activities / Total Assets
Control Variable	Fixed Asset Ratio	PPETA	Net Fixed Assets / Total Assets
Control Variable	Industry Fixed Effect	Industry	Industry Dummy Variables (CSRC 2012 Classification)
Control Variable	Year Fixed Effect	Year	Year Dummy Variables (2013–2023)

3.3 Model Construction

1. Baseline Regression Model (Testing Main Effect H1)

First, we examine direct effect of digital transformation on supply chain financing capability. It is worth noting that Hausman test gives $\chi^2 = 128.34$ and $p < 0.01$, which means random effects model assumption can be rejected here and the fixed effects model should be more suitable. Then we construct a two-way fixed effects model with both individual and time fixed effects:

$$SCF_{i,t} = \alpha_0 + \alpha_1 \text{Digital}_{i,t} + \gamma \text{Controls}_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t}$$
 where i is firm, t is the year. $SCF_{i,t}$ is dependent variable. $\text{Digital}_{i,t}$ is core explanatory variable. $\text{Controls}_{i,t}$ is control variables including other factors that can affect supply chain finance and we should control them in regression so that the estimated coefficient can be more accurate and reliable in empirical analysis. μ_i and λ_t are individual and time fixed effects and they can control for unobserved heterogeneity that may bias our results. $\varepsilon_{i,t}$ is random disturbance term. It is worth noting that if α_1 is positive and significant, H1 can be supported.

2. Mediation Effect Model (we test H2 via information asymmetry path)

It should be noted that two kinds of methods are used in this study, which are Bootstrap method and stepwise regression. In the first step, the main effect is tested, which is the same as the baseline regression model, including the core explanatory variable, but not including the control variable and mediator. In the second step, it is necessary to clarify the relationship between digital transformation and mediating variables:

$$\ln \text{Analyst}_{i,t} = \beta_0 + \beta_1 \text{Digital}_{i,t} + \gamma \text{Controls}_{i,t} + \mu_i + \lambda_t + \epsilon_{i,t}$$

In Step 3, we include both core explanatory variable and mediating variable for testing the direct effect and the mediating effect:

$$\text{SCF}_{i,t} = \phi_0 + \phi_1 \text{Digital}_{i,t} + \phi_2 \ln \text{Analyst}_{i,t} + \gamma \text{Controls}_{i,t} + \mu_i + \lambda_t + \eta_{i,t}$$

The testing logic is as follows. First, we check if β_1 is significant. We examine whether ϕ_2 is significant, and then we compare ϕ_1 with α_1 in baseline model. The result can show the direct effect. At the same time, Bootstrap method is used with 5000 re-samplings to check the indirect effect $\beta_1 \times \phi_2$. If confidence interval does not include 0, the mediation effect can be established.

3. Moderation Effect Model (Testing H3: threshold role of internal control quality)

In order to test hypothesis H3, two methods are used. Firstly, an interaction term is introduced into the model to build a moderate model, and it should be emphasized that the interaction term and the moderate variable should be put into the model to solve the problem of multicollinearity, so that the estimation results are more credible:

$$\text{SCF}_{i,t} = \delta_0 + \delta_1 \text{Digital}_{i,t} + \delta_2 \text{IC}_{i,t} + \delta_3 (\text{Digital}_{i,t} \times \text{IC}_{i,t}) + \gamma \text{Controls}_{i,t} + \mu_i + \lambda_t + \nu_{i,t}$$

where $\text{IC}_{i,t}$ is moderating variable, internal control quality. If coefficient δ_3 is positive, this means internal control quality can moderate the relationship between digital transformation and supply chain financing capability. Second, to test the “threshold effect”, we divide sample into high and low groups based on internal control quality because we want to check if the effect changes across different levels, and we run the baseline regression model separately in each subsample. By comparing the significance and magnitude of the digital transformation coefficients in different groups, we can determine whether internal control is a prerequisite for digital transformation to take effect.

4. Empirical Results and Analysis

4.1 Descriptive Statistics

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Median	Max
SCF	14584	0.1466	0.0968	0.0087	0.1238	0.4482
DIG	14584	1.6577	1.4175	0.0000	1.3863	5.2364
Analyst	14584	2.0262	0.9018	0.6931	2.0794	3.8712

Variable	Obs	Mean	Std. Dev.	Min	Median	Max
Internal_Control	14584	6.4877	0.1335	5.7096	6.5080	6.7207
Size	14584	22.271	1.299	19.876	22.097	26.091
LEV	14584	0.424	0.203	0.049	0.419	0.892
ROA	14584	0.039	0.064	-0.197	0.036	0.198
Growth	14584	0.176	0.314	-0.397	0.121	1.695
Age	14584	9.408	6.959	1.000	7.000	27.000
Cash flow	14584	0.045	0.070	-0.155	0.044	0.243
PPRAT	14584	0.216	0.160	0.002	0.182	0.697

We use 14,584 observations in this study. It is worth noting that mean of Supply Chain Financing Capability (SCF) is 0.1466 and standard deviation is 0.0968, while the minimum is 0.0087 and maximum reaches 0.4482, which means the sample includes firms with very different supply chain finance situations and we can use this variation to test the effect. This indicates enterprises can have different development levels. Also, the mean of Digital Transformation (DIG) is 1.6577 with standard deviation 1.4175, so the distribution is dispersed and can be used for effect testing. Then, the mean of Internal Control Quality (Internal_Control) is 6.4877 with standard deviation 0.1335 and the sample has good internal control. In fact, we can see some variations exist in sample firms.

4.2 Baseline regression and robustness test

Variable	Coefficient	Std. Err.	t-value
DIG	0.0022***	0.0006	3.4434
Size	-0.0011	0.0013	-0.873
LEV	-0.0321***	0.0071	-4.521
ROA	0.0412**	0.0196	2.103
Growth	0.0190***	0.0022	8.723
Age	0.0007***	0.0001	6.163

Variable	Coefficient	Std. Err.	t-value
Cash flow	0.0178	0.0125	1.421
PPETA	-0.0211*	0.0112	-1.891
_cons	0.1892***	0.0448	4.225
Industry / Year Effects	Controlled	Controlled	Controlled
Observations	14,584	14,584	14,584
Adjusted R ²	0.3301	0.3301	0.3301

*Note. *p<0.01, **p<0.05, ***p<0.1; we control industry and year fixed effects.

First, we examine the baseline regression. The coefficient for Digital Transformation (DIG) is 0.0022 and it is positive at 1% level ($t=3.4434$). For economic significance, if other conditions keep unchanged, when digital transformation degree increases one unit, the Supply Chain Financing Capability (SCF) can increase by 0.0022 on average, which is equivalent to 1.5% of the sample mean (0.1466) and has certain economic significance. This result suggests that when enterprise digitalization level is improved, it can promote supply chain financing capability. So hypothesis H1 is supported.

Then we examine control variables. The coefficient for Operating Revenue Growth Rate (Growth) is 0.0190 ($p<0.01$). This means higher growth firms can have stronger supply chain financing capability because high-growth firms have better market prospects and upstream suppliers are willing to provide trade credit to them. The coefficient for Asset-Liability Ratio (LEV) is -0.0321 ($p<0.01$). High debt levels can reduce supply chain financing capability. This is due to higher credit risk. Also, the coefficient for Return on Total Assets (ROA) is 0.0412 ($p<0.05$). It shows that more profitable firms have stronger supply chain financing capability. This is consistent with basic logic of trade credit financing. However, the effect of Firm Size (Size) is not significant. This possibly indicates that after controlling for other factors, size itself is not decisive factor for supply chain financing capability. In fact, the “soft information” and credit quality brought by digitalization can be more critical.

We do several robustness tests to check the reliability of conclusions. First, we re-estimate with the Tobit model because SCF values are between 0-1. The DIG coefficient is 0.0038 ($t=4.12$, $p<0.01$) and consistent with baseline results. Second, we adjust the sample period by excluding the pandemic-impacted year 2020 and the sample size becomes 13,218. The DIG coefficient is 0.0020 ($t=3.27$, $p<0.01$). The core conclusion keeps robust. Third, we replace the core explanatory variable with “Digital Investment Ratio” (digital technology investment amount / operating revenue) instead of the DIG index. Regression results show the coefficient for digital investment ratio is 0.0213 ($t=3.15$,

$p < 0.01$). It is still positive. Finally, we replace the dependent variable with “(Notes Payable + Accounts Payable + Advances from Customers) / Total Assets” to measure supply chain financing capability. The DIG coefficient is 0.0025 ($t = 3.58$, $p < 0.01$). The conclusion remains robust.

Table 4. Robustness Test Results

Test Method	Core Explanatory Variable	Coefficient	t-value	Observations	Adjusted R ²
Benchmark Regression	DIG	0.0022***	3.4434	14,584	0.3301
Tobit Model	DIG	0.0038***	4.1200	14,584	-
Excluding Year 2020 Sample	DIG	0.0020***	3.2700	13,218	0.3285
Replacing Explanatory Variable (Digital Investment Ratio)	Digital Investment Ratio	0.0213***	3.1500	13,862	0.3298
Replacing Explained Variable (Extended SCF)	DIG	0.0025***	3.5800	14,584	0.3356

**Note.* * $p < 0.01$, $p < 0.05$, $p < 0.1$; we control industry and year fixed effects, and control variables are also included.

4.3 Endogeneity Treatment

Endogeneity problems can exist in our study, and for example reverse causality may happen because firms with strong supply chain financing capability can have more resources to do digital transformation, which means the capability promotes transformation but transformation may also enhance capability, creating a circular relationship that OLS cannot handle well. Also, omitted variables can exist. Some unobserved factors can affect both digital transformation and supply chain financing capability, and we cannot observe them in the data, so this brings endogeneity bias to our results. It is worth noting that we use one-period lag of digital transformation (L.DIG) as instrumental variable to solve this problem. Then we run two-stage least squares (2SLS) regression.

Table 5. Instrumental Variable Regression Results

Stage	Variable	Coefficient	Std. Err.	t-value
First Stage	L.DIG	0.3097***	0.0103	30.07
	Control Variables	Controlled	Controlled	Controlled

Stage	Variable	Coefficient	Std. Err.	t-value
Second Stage	DIG	0.0079***	0.0018	4.26
	Control Variables	Controlled	Controlled	Controlled
	Anderson LM Test	1054.14*** [0.0000]		
	Cragg-Donald Wald F Statistic	904.03 {16.38}		
Observations	10,386			
R-squared	0.8900			

*Note. *p<0.01, p<0.05, p<0.1; we control industry and year fixed effects and other variables.

In first stage, coefficient of instrumental variable (L.DIG) on endogenous variable (DIG) is 0.3097 and significant at 1% level (t=30.07). The correlation is strong. It is worth noting that Anderson LM test statistic is 1054.14 (p<0.01), so we can reject the null hypothesis of under-identification. Also, Cragg-Donald Wald F statistic is 904.03, which is larger than the critical value 16.38 at 10% level in Stock-Yogo weak instrument test and the weak instrument problem can be avoided.

In second stage, after we control the endogeneity, coefficient of DIG on SCF is 0.0079 and it is positive and significant at 1% level (t=4.26). The absolute value is larger than baseline result. This can support the positive impact of digital transformation on supply chain financing capability and the causal inference is expected to be more reliable.

4.4 Mechanism Analysis: Mediating Effect of Information Asymmetry

Table 6. Mediation Effect Test Results

Variable	(1) SCF	(2) Analyst	(3) SCF
DIG	0.0022*** (3.4446)	0.0091*** (13.0707)	0.0019*** (3.0091)
Analyst			0.0029*** (3.9519)
Control Variables	Yes	Yes	Yes
Industry / Entity Fixed Effects	Yes	Yes	Yes
N	14354	14354	14354
Adj. R ²	0.2301	0.0925	0.2307

**Note.* * $p < 0.01$, $p < 0.05$, $p < 0.1$; t-values in parentheses; we control industry and year fixed effects and other control variables.

We test the mediation effect. In Step 1, the coefficient of Digital Transformation (DIG) on Supply Chain Financing Capability (SCF) is positive and significant ($\alpha_1 = 0.0022$, $p < 0.01$). So the main effect is established. Step 2 shows the coefficient of Digital Transformation (DIG) on mediating variable Analyst Coverage (Analyst) is also positive and significant ($\beta_1 = 0.0891$, $p < 0.01$). It means digital transformation can increase analyst coverage. In Step 3, after we include both DIG and Analyst in the model, the coefficient for Analyst Coverage is still positive and significant ($\varphi_2 = 0.0029$, $p < 0.01$), and the direct effect of digital transformation on SCF becomes smaller but is still significant ($\varphi_1 = 0.0019$, $p < 0.01$).

Then we use Bootstrap method with 5000 re-samplings. The 95% confidence interval for the indirect effect ($\beta_1 \times \varphi_2 = 0.0891 \times 0.0029 \approx 0.000258$) is [0.003, 0.011]. It does not contain 0. The Sobel test also shows the mediation effect is significant ($Z = 3.62$, $p < 0.01$).

These results show that the mediating path of “Digital Transformation → Increased Analyst Coverage (Reduced Information Asymmetry) → Enhanced Supply Chain Financing Capability” can be established. In fact, hypothesis H2 is supported.

4.4 Further Analysis: Threshold Effect of Internal Control Quality

Table 7. Moderation Effect Regression Results

Variable	(1) Without Interaction	(2) With Interaction
DIG	0.0022*** (3.4434)	0.0020*** (3.1633)
Internal_Control	0.0294*** (5.7164)	0.0215*** (4.8921)
DIG × Internal_Control	-	0.0165*** (4.5764)
Control Variables	Yes	Yes
Industry / Year Fixed Effects	Yes	Yes
N	14584	14584
Adj. R ²	0.3301	0.3323

**Note:* The moderating variable in interaction term is centered; * $p < 0.01$, $p < 0.05$, $p < 0.1$; t-values in parentheses; industry and year fixed effects and all control variables are controlled.

We examine the moderation effect regression results. After adding the interaction term, the coefficient

for $DIG \times Internal_Control$ is 0.0165, which is positive at the 1% level ($t=4.5764$), and at the same time, the adjusted R^2 increases from 0.3301 to 0.3323. This means the model fit becomes better. The result can give some support to the positive moderating effect of internal control on the financing effect of digital transformation.

But the interaction term model only shows the direction of moderating effect, and it is hard to reveal its specific form, especially the “threshold effect.” To test hypothesis H3, we divide sample into low group, medium groups and high group based on internal control quality for subgroup regressions. It is worth noting that to make test more rigorous, this section adds more control variables, including property nature SOE, equity balance Balance1, board size Board, and other factors, based on the baseline model. This can help identify the inter-group differences in the digital transformation effect when we control other important firm characteristics. The subgroup regression results are in Table 8.

Table 8. Regression Results Grouped by Internal Control Quality (In-depth Test)

Variable	Low Internal Control Quality		Middle Internal Control Quality		High Internal Control Quality	
	Coefficient	t - value	Coefficient	t - value	Coefficient	t - value
DIG	0.0006	0.54	0.0002	0.21	0.0056*	4.62
SOE	0.0231***	7.31	0.0170***	5.87	0.0150***	4.30
Growth	0.0211***	5.03	0.0190***	5.20	0.0061	1.53
Top5	-0.0017	-0.20	0.0227***	2.90	0.0280***	2.99
Age	0.0004*	1.88	0.0008***	3.89	0.0006***	2.94
Balance1	-0.0071	-1.62	-0.0087**	-2.31	-0.0091**	-1.98
Board	0.0201***	2.99	0.0080	1.38	0.0223***	3.31
INV	0.1316***	8.71	0.2043***	15.21	0.1261***	8.79
_cons	0.0711***	4.59	0.0765***	5.67	0.0524***	3.26
Observations	4370	-	5832	-	4372	-
Adjusted R squared	0.2977	-	0.3213	-	0.3856	-

The results in Table 8 present a clear and theoretically meaningful pattern, providing strong evidence for hypothesis H3:

1. In the sample group with weak internal control, the coefficient of digital transformation is 0.0006, the t value is 0.54, and the p value is greater than 0.1, which is not statistically significant. This means that when the internal control ability of enterprises is relatively weak, even if the digital transformation is carried out, it is not conducive to the improvement of supply chain financing ability.
2. From the perspective of the internal control group, the DIG coefficient is -0.0002, which is 0.21, which is not significant, which shows that even if the internal control reaches the middle level, it can not provide reliable financing credit signals for digital transformation.
3. Only in the case of high internal control quality can the DIG coefficient be positive, with a significance level of 1% (coefficient=0.0056, t=4.62). It can be seen that only enterprises with perfect internal control system can get the support of the external market in digital transformation, and their efforts can be recognized by financial institutions and suppliers, so as to have a good performance in supply chain financing.

Result Interpretation and Theoretical Implications:

These subgroup regression results strongly support hypothesis H3 and reveal the “threshold” role played by internal control in the financing effect of digital transformation, rather than a simple “enhancer.” It indicates that high-quality internal control is a “necessary prerequisite” or “pass” for digital transformation to exert its financing empowerment effect. Before internal control quality reaches the relatively high level of this “threshold,” the positive effect of digital transformation remains “locked” and cannot be released. Only after crossing this governance threshold do the massive amounts of data generated by digital transformation possess credibility, and its transmission mechanism of enhancing financing capability by reducing information asymmetry can proceed unimpeded. This finding deepens our understanding of the “technology-governance” synergy: in the digital age, corporate governance (represented by internal control) is not only a supplementary enhancement but a prerequisite and foundational guarantee for technological value realization. It empirically echoes the management practice insight that “without good governance, digitalization may be just a castle in the air.”

5. Research Conclusions and Implications

5.1 Research Conclusions

This study, using a sample of China’s A-share non-financial listed companies from 2013-2023, systematically examines the impact of enterprise digital transformation on supply chain financing capability, its internal mechanism, and key boundary conditions through theoretical analysis and empirical testing [19]. The main conclusions are as follows:

1. Obvious main effect: The digital transformation of enterprises will have a direct impact on the supply chain financing ability, which can play a role in promoting, and the conclusion is more robust

after taking into account the endogenous problems, which further proves that the transformation is an effective way to improve the financing ability of enterprises.

2. The existence of a clear mediating path: This is a mechanism that can effectively alleviate information asymmetry and is the key link in transmitting information. According to the above analysis, digital transformation can lead to changes in the information environment of enterprises. The reason is that it can generate a large number of operational data and disclose them, so that external stakeholders can perceive the risk of the enterprise and continuously reduce the cost of acquiring information, and the financing ability of the supply chain will continue to increase. The existence of this path can make people clearly feel the influence of digital transformation on financing ability.

3. Threshold effect: The most critical conclusion of this study is that the relationship between the two variables is closely related to the internal control of the enterprise. In the process of digital transformation, enterprises need to focus on financing empowerment, but this is a conditional process, which is inevitably related to the governance of internal control. Through in-depth analysis, it is known that there is a significant threshold effect in the internal control of enterprises. Only when the internal control quality of enterprises is relatively high can digital transformation have a positive impact on the financing capacity of the supply chain. If the internal control quality of enterprises is not high, this impact is not obvious. This conclusion further shows that enterprises must guarantee the quality of internal control, which is the foundation for the smooth development of digital transformation, can play the role of “quality cornerstone”, produce reliable data assets, and transmit credit information to the market. This requires enterprises to not only be empowered by technology, but also to be empowered by governance, and governance is the foundation for the realization of technological value.

5.2 Theoretical Contributions

1. Expand the research spectrum: This paper introduces the concept of digital transformation into the research, and compares it with traditional research, which focuses on the impact of digital transformation on innovation, credit, efficiency and other aspects, but the introduction of this concept into the real transaction network can make the supply chain finance research more targeted. This study focuses on the role of digital strategy in the process of reconstructing trade credit, which can enrich the theoretical understanding of digital strategy.

2. Revealing the internal mechanism of digital transformation to enhance financing capability: the introduction of analysts as mediating variables to test the effectiveness of eliminating information asymmetry, to clarify the key transmission path, to clarify how the “black box” of digital transformation will affect financing capability, to make up for the shortcomings in the existing research, and to deepen the understanding of how to promote the transformation of digital technology to “credit capital”.

3. Grasp the mechanism of synergy between digital technology and corporate governance: in this study, the simple linear moderation theory is broken through, and the refined subgroup regression method is used to analyze the impact of internal control on the financing effect of enterprises in the process of

digital transformation, and to understand the “threshold effect”, which re-examines the theoretical connotation of corporate governance under the background of digital technology, and deeply analyzes that internal governance mechanism is not only an “amplifier” of technological effects, but also an “initiator” and “stabilizer” to achieve technological empowerment. This conclusion puts forward a reasonable theoretical view, which is conducive to a deeper understanding of the relationship between “technological hard power” and “governance soft power”.

5.3 Practical Implications

Based on the above research conclusions, this paper provides the following implications for different market entities:

1. Implications for Enterprises: Corporate managers must completely abandon the one-sided thinking of “emphasizing technology investment while neglecting governance construction.” When formulating and implementing digital transformation strategies, the principle of “governance first” or “synchronizing governance with technological transformation” should be upheld. The primary task is to continuously consolidate the internal control system, improve the data governance framework, and ensure the authenticity, accuracy, and reliability of various data collected, processed, and disclosed during the digital transformation process. Only when internal governance solidifies the foundation for “data credit” can massive digital investments be transformed into financing advantages recognized by supply chain partners and financial markets. For enterprises with imperfect internal control, prioritizing internal control improvement should be the top agenda item in digital transformation.
2. Implications for Financial Institutions and Investors: Commercial banks, supply chain finance platforms, and other financial institutions should innovate their traditional models that overly rely on financial indicators and collateral when conducting credit approval and credit risk assessment. They should actively construct a dual-dimensional assessment model integrating “digitalization level” and “internal control quality.” They should focus on and prioritize serving those “dual-excellent” enterprises that possess both “high digital transformation degree” and “high internal control quality.” The digital credit of such enterprises is highly credible, and financing risks are relatively low. Investors should also consider the synergistic effect of combining the two as an important factor when assessing corporate value and growth potential.
3. Implications for Policymakers: Relevant government departments, while vigorously promoting industrial digital transformation and providing various fiscal, tax, and technical support, should correspondingly strengthen policy guidance, standard setting, and regulatory requirements regarding corporate internal control and data governance. Enterprises should be encouraged or required to disclose the substantive progress of digital transformation and its related internal control guarantee measures. By fostering a market environment and institutional atmosphere that advocates “credible digitalization,” resources can be guided to be allocated more effectively to enterprises with genuine sustainable development capabilities, thereby enhancing the health of the entire supply chain finance system and its efficiency in serving the real economy.

5.4 Research Limitations and Future Outlook

Although this study strives for rigor, it still has some limitations. Future research can be expanded in the following aspects [19]:

1. Sample Scope Limitation: This study focuses on A-share listed companies, whose scale, governance structure, and financing channels differ from the vast number of non-listed small, medium, and micro enterprises. The generalizability of conclusions to SMEs and even cross-border supply chain enterprises needs verification in future research.
2. Deepening Variable Measurement: Core variables like digital transformation use text analysis indices, which are widely applied. However, future research could combine structured data such as digital capital expenditure, digital patents, and digital business revenue to construct a more three-dimensional and objective measurement system. There is also room for further deepening the measurement of internal control and “data credit.”
3. Expanding Influence Mechanisms: This paper focuses on the mediating path of information asymmetry and the moderating variable of internal control. Future research could further explore whether digital transformation indirectly affects financing capability through other paths such as improving supply chain collaboration efficiency, improving working capital turnover, or enhancing corporate innovation and ESG performance, as well as the moderating effects of external contextual factors like supply chain concentration and fintech development level.
4. Endogeneity Issues and Causal Inference: Although the instrumental variable method is used, stricter causal identification (such as difference-in-differences based on exogenous policy shocks) will be a direction for deepening future research.

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