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The Impact of Digital Transformation on Corporate Financing Constraints: Based on the Mediating Effect of Internal Control

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Abstract: Based on an empirical model, this paper examines the impact mechanism of digital transformation on corporate financing constraints, with a focus on testing the mediating role of internal control. The results show that digital transformation can significantly alleviate corporate financing constraints, where internal control plays a critical mediating and bridging role. Specifically, digital transformation indirectly eases corporate financing pressure by improving the quality of internal control. Further heterogeneity analysis reveals that the above alleviation effect is more pronounced in non-state-owned enterprises and enterprises in the eastern region of China. In contrast, no significant short-term effect is observed in high-tech enterprises, due to the high investment and uncertainty associated with their transformation process. Based on the findings, the government should further improve the policy environment to promote the coordinated development of corporate digital transformation and internal control. Enterprises also need to strengthen the construction of internal control to fully capture the financing convenience brought by digital transformation.

Keywords: Digital transformation; Corporate financing constraints; Internal control

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1. Introduction

Against the backdrop of the vigorous development of the digital economy, digital transformation has increasingly become a critical path for enterprises to break away from traditional business models and reshape their core competitiveness. According to the *China Digital Economy Development Report (2024)*, the digital economy provides solid support for the expansion of new quality productive forces in China and has emerged as a key driving force. As enterprises continue to increase investment in innovation activities, financing constraints have imposed an increasingly significant limit on their innovation capacity. In a market with widespread information asymmetry, whether enterprises can rely on digital transformation to solve financing difficulties has become a vital research topic.

Existing studies generally agree that digital tools can improve information transparency and reduce external

financing costs. Meanwhile, by reconfiguring the value chain through data factors, enterprises are expected to enhance the trust of the capital market [1]. Many scholars have also focused on the strategic significance of alleviating financing constraints for the sustainable development of enterprises. Using a mediating effect model, Sheng *et al.* (2022) verified that digital transformation can alleviate financing constraints through "information manifestation" and "resource allocation" [2]. Whether the technological dividend of digital transformation can be translated into a substantive alleviation of financing constraints depends not only on the introduction of digital tools, but also on the simultaneous upgrading of enterprises' internal governance capabilities. This paper systematically explores the impact of digital transformation on financing constraints and its mediating mechanism through internal control. The findings can provide decision-making references for the government to guide enterprises' intelligent digital transformation and for financial institutions to innovate risk assessment models.

2. Theoretical analysis and research hypotheses

2.1. Digital transformation alleviates corporate financing constraints

In the operation of modern enterprises, financing constraints are widely regarded as a key barrier to sustainable growth, which profoundly affects enterprises' strategic layout in investment decision-making, scale expansion, talent attraction and other aspects. As a management reform relying on digital technology, digital transformation provides a new approach for enterprises to address financing restrictions.

Under the traditional management model, a large amount of valuable internal information of enterprises fails to be systematically mined and effectively transmitted to the investment market, which aggravates information asymmetry between enterprises and external stakeholders [3]. With the help of digital technology, digital transformation can convert non-standard internal information into standardized structured information, thereby improving the quality and scale of information. This process not only strengthens the disclosure effect of enterprises' business information, but also improves the clarity and readability of documents such as annual reports.

Digital transformation also has a "governance effect". In terms of internal governance, digital transformation promotes the reform of enterprise management, accelerates cross-departmental collaboration, restricts the discretionary power of management, and reduces the space for self-serving behavior [4]. It improves enterprises' data processing capacity, increases business transparency, optimizes the internal control system, enhances the quality of internal control, and sends a signal of low enterprise risk to investors [5]. Based on the above analysis, this paper proposes hypothesis H1:

H1: Ceteris paribus, corporate digital transformation alleviates financing constraints.

2.2. Digital transformation, internal control and financing constraints

Information and communication, as key elements, penetrate the entire process of all internal control activities of enterprises and play a core role in improving the quality of internal control [6]. Digital transformation has a significant enabling effect on improving the level of corporate internal control. The key reason is that digital technology greatly improves the efficiency of enterprises in the whole process of information collection, processing and transmission. By effectively alleviating information barriers, digital transformation helps to suppress internal agency costs, thereby enhancing the effectiveness and reliability of the internal control system [7]. Specifically, relying on digital technologies such as big data and artificial intelligence, digital transformation enables management to gain a more timely and comprehensive insight into the operation of all links of the enterprise, reducing decision-

making bias. This not only improves the efficiency of cross-departmental collaboration, but also enhances the operational efficiency of the internal control system, laying a solid foundation for the stability and development of the enterprise.

Under the traditional management model, information transmission often suffers from lags, incompleteness and even distortion, which not only increases the decision-making difficulty of management, but also leads to the rise of internal agency costs. By building an efficient information system, digital transformation breaks down information barriers between departments and realizes rapid information sharing and transparency. Meanwhile, internal control can alleviate corporate financing constraints by improving information processing efficiency, optimizing information circulation channels and reducing information asymmetry [8]. The optimization of information circulation not only reduces information asymmetry between management and employees, but also cuts internal supervision costs caused by information opacity, further improving the quality of corporate internal control. Based on the above analysis, this paper proposes hypothesis H2:

H2: Ceteris paribus, corporate digital transformation alleviates financing constraints by strengthening internal control.

3. Research design

3.1. Data sources and processing

This paper selects China's Shanghai and Shenzhen A-share listed companies from 2017 to 2023 as the research sample, and screens the samples according to the following criteria:

(1) Excluding ST, *ST, and financial and insurance listed enterprises;
(2) Excluding samples with missing relevant data;
(3) Winsorizing all continuous variables at the upper and lower 1% levels.

Finally, 14,585 observations are obtained. The data used in this paper comes from the China Stock Market & Accounting Research (CSMAR) Database, and Stata is used as the statistical analysis software for the data.

3.2. Variable definition

3.2.1. Explained variable

Corporate financing constraints (FC), measured by the FC index, which is widely used to evaluate the degree of corporate financing constraints. Relevant variables such as firm size, age and cash dividend payout ratio are standardized, and the sample listed companies are sorted according to the mean value of the standardized variables. On this basis, the fitted probability value is defined as the financing constraint index (FC). The higher the index value, the more severe the financing constraints faced by the enterprise.

3.2.2. Explanatory variable

Degree of digital transformation (DIG), drawing on the method of Wu *et al.* (2021), this paper constructs a proxy variable for the degree of corporate digital transformation using the frequency of keywords related to digital transformation in the annual reports of listed companies. In the specific processing, Python text analysis technology is used to automatically capture specific feature words in the annual reports. To measure the degree of digitalization more accurately, the occurrence times of each feature word are counted first, then 1 is added to the frequency to eliminate the zero value problem, and finally the natural logarithm of the frequency after adding 1 is taken as the measurement indicator of digital transformation.

3.2.3. Mediating variable

Internal control (INCON), measured by the Dibo Internal Control Index as the proxy variable for internal control quality. The index is generated based on a systematic internal control evaluation framework. The higher the index value, the better the quality and effectiveness of the enterprise's internal control; conversely, it indicates a lower level of internal control and weaker corresponding governance efficiency.

3.2.4. Control variables

Drawing on the practice of Chen (2023), this paper controls for equity multiplier, quick ratio, management expense ratio (agency cost), accounts receivable ratio, fixed asset ratio, and also controls for industry and year fixed effects [9]. The specific definition of each variable is shown in **Table 1**.

Table 1. Variable definition

Variable type	Variable name	Variable symbol	Calculation method
Explained Variable	Financing Constraints	FC	Absolute value of the FC index; the larger the value, the stronger the corporate financing constraints
Explanatory Variable	Degree of Digital Transformation	DIG	Natural logarithm of (total frequency of digital transformation keywords + 1)
Mediating Variable	Internal Control	INCON	Natural logarithm of (Dibo Internal Control Index + 1)
Control Variables	Equity Multiplier	EM	1/(1 - asset-liability ratio)
	Quick Ratio	QUICK	(Current assets - Inventory)/Current liabilities
	Management Expense Ratio (Agency Cost)	FIR	Administrative expenses/Operating income
	Accounts Receivable Ratio	Rec	Accounts receivable/Total assets
	Fixed Asset Ratio	FAR	Fixed assets/Total assets

Note: A typo in the original Chinese manuscript regarding the calculation method of FAR is corrected here to align with the variable name and academic norms.

3.3. Model specification

To verify hypothesis H1, **Model (1)** is constructed, with the expected coefficient β_1 to be significantly negative.

$$FC_{i,t} = \beta_0 + \beta_1 dig_{i,t} + \beta_2 Controls_{i,t} + \sum year + \sum industry + \rho_{i,t} \quad (1)$$

In **Model (1)**, $dig_{i,t}$ is the explanatory variable representing the degree of digitalization of the enterprise. If hypothesis H1 holds, the coefficient β_1 in **Model (1)** should be significantly negative, indicating that corporate digital transformation has a mitigating effect on financing constraints.

For the test of the action mechanism, this paper adopts the mediating effect test framework. Drawing on Jiang (2022), we focus on testing the effect of the explanatory variable on the mediating variable in **Equation (2)**, while the relationship between the mediating variable (internal control) and the explained variable (financing constraints) is mainly analyzed through the above theoretical mechanism [10].

$$ICQ_{i,t+1} = \alpha_0 + \alpha_1 dig_{i,t} + \alpha_2 Controls_{i,t} + \sum year + \sum industry + \mu_{i,t} \quad (2)$$

Note: The variable symbol of the mediating variable in the original manuscript is unified as INCON here to ensure consistency in the full text.

4. Empirical analysis

4.1. Benchmark regression analysis

Based on the above theoretical research on the impact of digital transformation on corporate financing constraints, a two-way fixed effects regression model is constructed (**Table 2**). (1) shows the benchmark regression result of the impact of digital transformation on financing constraints without control variables, and (2) shows the benchmark regression result with the corresponding enterprise characteristic control variables added.

From the results in **Table 2**, (1) proves that digital transformation significantly reduces corporate financing constraints without adding control variables. Meanwhile, $R^2 = 0.139$ indicates that the current model can explain 14% of the variation in the financing constraint variable, confirming that digital transformation is an important influencing factor of financing constraints.

After adding control variables (Regression (2)), the regression results further verify the alleviating effect of digital transformation on financing constraints, with the alleviation degree rising to 0.4%. The explanatory power of the model is significantly enhanced (R^2 jumps from 0.139 to 0.401), indicating that the control variables capture 26.2% of additional variation. The industry and year fixed effects continue to control for confounding factors, systematically strengthening the reliability of the core hypothesis and further verifying hypothesis H1.

Table 2. Benchmark regression and mediating mechanism test results

Aspects	(1)	(2)	(3)	(4)
VARIABLES	FC Index	FC Index	Internal Control Index	Internal Control Index
Digital Transformation	-0.003***	-0.004***	0.060***	0.056***
	(-9.15)	(-12.64)	(4.83)	(4.48)
Equity Multiplier		-0.942***		-4.810***
		(-46.97)		(-5.48)
Quick Ratio		0.311***		0.014
		(26.62)		(0.03)
Management Expense Ratio (Agency Cost)		6.726***		-288.244***
		(21.49)		(-21.05)
Accounts Receivable Ratio		7.099***		-54.998***
		(33.85)		(-5.99)
Fixed Asset Ratio		-0.051		-43.480***
		(-0.34)		(-6.55)
Constant	5.214***	5.339***	630.735***	688.641***
	(27.51)	(30.20)	(89.65)	(89.02)
Observations	14,585	14,585	14,585	14,585
R-squared	0.139	0.401	0.011	0.044
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively. The same applies below.

4.2. Mechanism test

For the analysis of the mechanism of the impact of digital transformation on financing constraints. Based on the above theoretical analysis and benchmark regression results, a significant negative correlation between the

two has been confirmed. Following that, for the relationship between digital transformation and the mediating variable internal control, (3) and (4) in **Table 2** show the benchmark regression results of digital transformation on internal control after adopting two-way fixed effects, and the regression results after adding control variables. Both (3) and (4) are significant at the 1% statistical level, indicating that digital transformation has a significant positive effect on internal control. Finally, the previous section elaborates on the relationship between internal control and financing constraints: internal control can alleviate corporate financing constraints by improving information processing efficiency, optimizing information circulation channels, and reducing information asymmetry. The above results collectively verify hypothesis H2.

4.3. Robustness tests

4.3.1. Endogeneity test

Considering the potential endogeneity problem caused by omitted variables, which may lead to large deviations in the results, the Propensity Score Matching (PSM) method is adopted to solve this problem. Taking financing constraints as the outcome variable and the aforementioned control variables as covariates, one-to-one nearest neighbor matching is performed. Based on the further matched sample, the relationship between the variables is re-tested. The results are shown in (4) of **Table 3**: the regression coefficient of digital transformation on financing constraints is -0.0143, which is significant at the 1% statistical level, proving that the research conclusions are credible.

4.3.2. Replacement of the explained variable

To verify the reliability of the regression results, this paper replaces the explained variable for robustness testing. The FC index is replaced with the KZ index, which is also a common measure of corporate financing constraints, with the control variables unchanged, and the benchmark regression is re-conducted. The results are shown in (1) of **Table 3**: the regression coefficient between the two is -0.0004, which is significant at the 5% statistical level, supporting the benchmark results of this study, consistent with the previous conclusions, and passing the robustness test.

4.3.3. Adjustment for abnormal years

During the sample period, considering the exogenous shock of the COVID-19 pandemic, enterprises may have been greatly affected after 2020. To reasonably exclude the interference of uncertain results, this paper excludes the data from 2020 to 2022 and conducts the regression again. As shown in (2) of **Table 3**, the coefficient of digital transformation is significant at the 1% statistical level, which is also consistent with the previous conclusions and passes the robustness test.

4.3.4. Exclusion of special cities

Municipalities directly under the central government and major provincial capital cities in China often have special status in the national economic layout. To reduce the impact of the above cities on the research results, the sample enterprises in the 4 municipalities directly under the central government (Beijing, Shanghai, Tianjin, Chongqing) and 27 provincial capital cities are excluded, and the regression is conducted. From the regression results in (3) of **Table 3**, digital transformation is significantly negative at the 1% level, indicating that the degree of corporate digital transformation can effectively alleviate financing constraints in all regions of China, and the aforementioned conclusions still hold.

Table 3. Robustness test results

Aspects	(1)	(2)	(3)	(4)
VARIABLES	KZ Index	Excluding Abnormal Years	Excluding Special Cities	Propensity Score Matching
Digital Transformation	-0.0004**	-0.0042***	-0.0040***	-0.0143***
	(-2.1329)	(-8.5425)	(-9.7985)	(-15.3805)
Equity Multiplier	0.7471***	-0.9886***	-0.9511***	-0.9271***
	(42.2493)	(-28.7285)	(-33.6477)	(-36.6193)
Quick Ratio	-0.3367***	0.3251***	0.3464***	0.3070***
	(-27.5936)	(20.6042)	(23.8217)	(22.3706)
Management Expense Ratio (Agency Cost)	5.6433***	4.8788***	6.9362***	6.9462***
	(22.5283)	(10.1756)	(16.2560)	(17.7859)
Accounts Receivable Ratio	4.4185***	6.2683***	6.4431***	7.0926***
	(30.1031)	(19.9592)	(24.7754)	(29.0250)
Fixed Asset Ratio	0.4880***	0.5511**	0.5325***	-0.2403
	(4.6764)	(2.4231)	(2.9334)	(-1.4983)
Constant	-0.8661***	5.1063***	4.5147***	5.5388***
	(-4.5809)	(12.6520)	(13.4951)	(29.3018)
Observations	14,585	8,151	11,493	12,683
R-squared	0.4964	0.4355	0.4378	0.415
Industry FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

4.4. Heterogeneity analysis

This paper conducts group regression according to three dimensions as follows:

(1) Ownership nature, divided into state-owned enterprises (SOEs) and non-state-owned enterprises (non-SOEs) based on the property right nature of the top ten shareholders;

(2) Geographical location, divided into enterprises in the eastern region and enterprises in non-eastern regions;

(3) Industry attribute, divided into high-tech enterprises and non-high-tech enterprises [11].

The results are shown in **Table 4**.

Table 4. Heterogeneity analysis results

Aspects	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	SOEs	Non-SOEs	Eastern Region	Non-Eastern Regions	High-Tech Enterprises	Non-High-Tech Enterprises
DIG	-0.001	-0.003***	-0.004***	-0.001	0.004***	-0.001*
	(-0.82)	(-9.66)	(-10.16)	(-1.35)	(2.59)	(-1.91)
Constant	4.292***	5.495***	5.042***	5.418***	7.245***	5.092***
	(10.95)	(25.66)	(20.39)	(18.67)	(7.33)	(25.84)
Observations	1,837	12,728	10,459	4,126	6,255	8,330
R-squared	0.204	0.136	0.163	0.130	0.137	0.132
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

The effect of digital transformation on alleviating corporate financing constraints is more significant in non-SOEs, while it fails to pass the significance test in SOEs. This difference reflects the moderating role of ownership nature in the effectiveness of digital transformation. Under China's economic system and social environment, SOEs may be less motivated to prove their value to the market through digital transformation due to institutional factors. On the contrary, non-SOEs usually face stronger financing restrictions, and the information transparency and process optimization achieved through digitalization are more easily translated into financing advantages. In addition, the higher constant term of the non-SOE group also supports that they face a more severe overall financing constraint situation.

Digital transformation of enterprises in the eastern region significantly reduces financing constraints, and this effect is significantly stronger than that of enterprises in non-eastern regions. This difference highlights the important impact of regional development level on the distribution of digital dividends. The eastern region has more fully realized the optimization of the financing environment by virtue of advanced digital infrastructure, a sound market mechanism, and a denser talent supply from universities compared with other regions. In contrast, non-eastern regions are constrained by factors such as low digital access, an imperfect financial service system, and limited industrial supporting capacity, so the effect of digital transformation on alleviating corporate financing pressure is relatively limited. In addition, the better model goodness of fit of the eastern region sample also statistically supports the strengthening effect of regional inherent advantages on the promotion of financing capacity through digital transformation.

Notably, the study finds that digital transformation has a significant positive impact on the financing constraints of high-tech enterprises, which is contrary to the general expectation, while non-high-tech enterprises show a slight alleviation effect. This finding reveals the unique situation of technology-intensive enterprises in the process of digital transformation. The digital transformation of high-tech enterprises is often accompanied by large R&D investment and rapid technological iteration risks, which may intensify rather than alleviate financing constraints in the short term. In addition, the complexity and uncertainty of their technical paths also increase the difficulty for financial institutions to evaluate the value of digital assets, thus forming the so-called "digital transformation premium". In contrast, the transformation process of non-high-tech enterprises is relatively simple with higher technology adaptability, and the improvement of information transparency through digitalization is more easily recognized by the financial market.

5. Conclusions and policy implications

5.1. Research conclusions

Taking the sample data of China's Shanghai and Shenzhen A-share listed companies as the research object, this paper deeply explores the impact mechanism of corporate digital transformation on financing constraints, and constructs a regression model to empirically test the relationship between digital transformation, internal control and financing constraints. The results show that the effective implementation of digital transformation by enterprises can significantly alleviate financing constraints, which is mainly achieved by improving information transparency and optimizing the governance structure to reduce external financing difficulties.

Meanwhile, digital transformation plays a vital mediating role by strengthening the internal control mechanism. Digital technology improves information processing efficiency and effectively controls agency costs, thereby enhancing the overall risk governance capacity of enterprises and sending positive signals to the market.

In addition, the effect of digital transformation shows structural differences. Non-SOEs are more likely to translate transformation into financing dividends in a stronger market-oriented environment; enterprises in the eastern region achieve more prominent financing optimization by virtue of a sound digital infrastructure and ecosystem; while high-tech enterprises face challenges such as high transformation investment, uncertainty of technical routes and enhanced asset specificity, so digitalization may aggravate financing pressure in the short term, reflecting the special dilemma in the transformation process of technology-intensive industries.

5.2. Policy implications

5.2.1. For the government

Efforts should be made to reduce institutional barriers and optimize the resource allocation mechanism. At present, SOEs are advancing digital transformation relatively slowly. To solve this problem, it is recommended to incorporate the effectiveness of digital transformation into the performance appraisal system of enterprise management, so as to weaken the restriction of soft budget constraints on technological upgrading activities. On the other hand, there is a significant gap in the development level of digitalization between different regions in China. To promote regional balanced development, pilot special bonds can be considered in the central and western regions to support the construction of digital infrastructure. Meanwhile, the construction of cross-regional computing power collaboration and data scheduling centers should be actively promoted. High-tech enterprises often face phased financing pressure in the transformation process. In this regard, the establishment of a risk-sharing fund for technological transformation can be promoted. The national level should also accelerate the introduction of unified valuation standards for digital assets, so as to help enterprises alleviate capital difficulties in the innovation process.

5.2.2. For enterprises

It is necessary to promote the in-depth integration of technology application and governance system, and attach importance to the bridging function of internal control. Specific measures include: strengthening the real-time monitoring capability of data flow, improving the interpretability of algorithms, and taking the effectiveness of internal control as an important credit condition for enterprises to obtain digital financing. In addition, enterprises can cooperate with universities and research institutions to build a training platform for digital governance talents, focusing on cultivating interdisciplinary talents who master both blockchain technology and risk management. For high-tech enterprises, a step-by-step digital transformation strategy is appropriate, giving priority to the implementation of digital tools with quick results such as supply chain visualization, so as to reduce the financing pressure caused by the improvement of asset specificity.

5.2.3. For financial institutions

The innovation of risk management mechanisms should be accelerated, and an evaluation system suitable for technological value identification should be constructed. Specifically, a dynamic evaluation model can be developed with the maturity of technical routes and the mortgage rate of digital patents as the core indicators, replacing the traditional fixed asset-based mortgage model. Financial institutions can also cooperate with the government to launch “digital transformation effectiveness-linked bills” relying on the risk compensation fund, sharing part of the risks while enjoying the long-term benefits brought by the digital transformation of enterprises.

Disclosure statement

The authors declare no conflict of interest.

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