

Digital Transformation and Corporate Leverage: A Panel Study of Capital Structure Dynamics

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Abstract: With the rapid development of the global digital economy (DE), Digital Transformation (DX) has become an important means for enterprises to enhance competitiveness and optimize capital structure. Based on annual report data from 5,639 listed companies in China from 1999 to 2023, this study examines the impact of DX on corporate capital structure. The research finds that DX significantly increases the level of the debt-to-asset ratio, primarily driven by increased investments in research and development and technological infrastructure during the DX process, enhanced market opportunity identification capabilities, and rising demand for technology talent, which collectively lead enterprises to rely more on debt financing. Fixed-effect regression analysis confirms the positive impact of DX on the corporate debt-to-asset ratio, and robustness tests validate the stability of the research results under different indicators of DX, providing practical references for enterprises on how to steadily promote DX and reasonably optimize capital structure in the context of the DE. The study indicates that although DX offers enterprises opportunities for innovation and growth, excessively high leverage may pose potential financial risks. Therefore, while advancing digital strategies, enterprises should reasonably control their debt levels to ensure financial stability.

Keywords: Digital Transformation, Debt-to-Asset Ratio, Corporate Finance, Digital Economy.

1. Introduction

1.1. Background

With the vigorous development of the DE and its increasing share in the GDP of many countries year by year, corporate DX has become an important force in enhancing competitive advantages and reshaping global value chains. The Global Digital Economy White Paper (2024) shows that in 2023, the total DE of the United States, China, Germany, Japan, and South Korea exceeded 33 trillion USD, with a year-on-year growth of over 8%. Among these, the added value of China's core DE industries is estimated to exceed 12 trillion yuan, accounting for about 10% of the annual GDP. The rapid development of the DE has provided new growth points for the global economy.

In the context of the continuous development of the digital economy, accelerating the digitalization process of enterprises and promoting the deep integration of digital technology with the real economy

is strategically significant for facilitating economic structure adjustment and enhancing national competitiveness [1]. The 14th Five-Year Plan for Digital Economy Development pointed out in 2022 that DX is an important way to promote the deep integration of digital technology and the real economy, driving continuous changes in production modes, lifestyles, and governance methods.

How enterprises utilize these technologies for innovation and transformation is not only related to their own competitiveness and market position but also has a significant impact on resource allocation, capital flow, and risk management within the entire economic system. Therefore, studying the impact of corporate digital transformation on corporate finance helps reveal how enterprises can optimize their financial structures, improve capital efficiency, and ultimately achieve sustainable development through technological innovation in the DE era. To this end, this paper focuses on examining the impact and mechanisms of DX on corporate finance from the perspective of capital structure, specifically investigating the effect of DX on the debt-to-asset ratio of enterprises [2].

The debt-to-asset ratio is closely related to the high-quality development of enterprises. Within a certain threshold, an increase in the debt-to-asset ratio can enable enterprises to enhance shareholder equity through financial financing methods, promoting the healthy operation of corporate finance. However, once the debt-to-asset ratio exceeds a certain threshold, further increases may lead enterprises to bear excessive financial burdens and debt risks, weakening their investment potential and capital turnover efficiency, thus constraining their development [3]. In real corporate operational decisions, occurrences of excessively high or low debt-to-asset ratios are common, making it an important topic in the decision-making process of enterprises to research how to control the debt-to-asset ratio and keep it within a reasonable range. Therefore, examining the impact of DX on the debt-to-asset ratio can help enterprises further understand the mechanisms of the debt-to-asset ratio's influence, which is of great significance.

1.2. Literature Review

In the existing research on the factors influencing capital structure, scholars have primarily focused on two main aspects: First, the impact of internal environment on corporate capital structure, including factors such as company size [4], ownership structure [5], trade models [6], executive incentive levels [7], non-debt tax shields [8], earnings management [9], profitability [10-11], accounts receivable securitization [12], and enterprise life cycles [13]. Second, the external environment's influence on corporate capital structure includes factors such as interest rates [14], corporate taxation (foreign-invested enterprises and domestic enterprises) [15], credit policies and bank-enterprise relationships [16-17], industry differences [18], and the impact of adopting accelerated depreciation policies on the debt-to-asset ratio [19].

On the other hand, as a micro-level component of the macro economy, enterprises play a key role in promoting the development and transformation of the DE, with DX gradually reflected in the specific production activities of enterprises [20]. Consequently, scholars have conducted extensive discussions on the impacts of digital transformation on enterprises. Existing studies indicate that DX is beneficial for enhancing corporate investment efficiency [2], improving total factor productivity [21-22], significantly alleviating financial distress [23], increasing organizational flexibility [24], enhancing the level of specialized division of labor [25], promoting green transformation [26], improving ESG performance [27], boosting innovation levels [28], increasing labor income share [29], advancing the degree of supply chain integration [30], and facilitating sustainable development [31].

From the above, it is evident that there is currently no literature that discusses the factors influencing corporate capital structure from the perspective of DX. Therefore, this paper selects the annual report data of 5,639 listed companies in China from 1999 to 2023 as the sample to study the impact of DX on corporate capital structure and its mechanisms.

2. Theoretical Analysis

Digital transformation, as a core strategy for enterprises to respond to global competition and enhance innovation capabilities, is gradually becoming an important driving force for corporate development. However, in the process of implementing DX, enterprises must not only cope with the challenges posed by technological innovation but also face pressure for capital structure adjustment. Digital transformation often prompts enterprises to utilize debt financing more frequently, increasing their debt-to-asset ratio. This paper analyzes the promoting effect of DX on the debt-to-asset ratio of enterprises from multiple perspectives.

2.1. Digital Transformation Requires Enterprises to Increase R&D and Maintenance Investment, Increasing Demand for External Financing

Digital transformation typically entails substantial investments in technology research and development as well as infrastructure, requiring enterprises to continuously allocate significant funds for the construction of information systems, the development of data analysis technologies, and the introduction of automated equipment. Given that these investments yield long-term returns, cash flow in the short term often cannot fully support such a massive capital requirement. Consequently, enterprises frequently opt for external financing to ensure the smooth implementation of their DX plans. Furthermore, the sustainability and technological reliance of DX mean that enterprises will face long-term technology update demands in the future. With the rapid iteration of technology, companies must continually update their information systems and equipment to maintain a competitive advantage in the market. This ongoing technological investment creates long-term capital pressure, forcing enterprises to rely on external financing to support their technology upgrades and maintenance activities. This dynamic process illustrates that DX not only increases capital demand in the initial stages but also compels enterprises to continue accumulating debt due to subsequent technological updates, further exacerbating the rise in leverage.

2.2. Digital Transformation Enhances Enterprises' Internal Control and Market Perception Abilities, Enabling Them to Capture and Identify More Market Information and Investment Opportunities, Further Expanding Their Financing Needs

Digital transformation is not only a technological change but also an innovation in enterprise management practices. Digital technologies such as big data, cloud computing, and the Internet of Things greatly enhance a company's ability to process information, allowing it to more efficiently integrate and analyze internal operational data. This significantly improves the company's sensitivity to market changes and its ability to identify investment opportunities, enabling it to more accurately predict demand fluctuations, recognize potential high-return projects, and make more informed investment decisions. In the face of these new growth opportunities, enterprises often choose to increase investments to gain future market share and profit growth. However, additional investments typically require substantial funding support, especially in the short term, where internal funds may often fall short of meeting such needs. Therefore, to seize key investment opportunities, companies frequently rely on external financing, particularly debt financing, to swiftly obtain capital and execute expansion strategies.

2.3. Digital Transformation Intensifies the Demand for Technological Talent, Increases Operational Costs, and Subsequently Raises Debt Financing Pressure for Enterprises

The successful implementation of DX relies heavily on the support of technological talent, especially in key fields such as information technology, data analysis, and artificial intelligence, where high-

quality professionals are crucial for driving technological innovation. As DX deepens, the demand for technological talent within enterprises continues to rise. The recruitment of technological personnel entails high salary expenditures and ongoing training costs, significantly increasing operational costs for enterprises. To maintain competitiveness in DX, ongoing investment in technological talent is often required, which places enormous pressure on the company's cash flow. To address these additional labor costs, enterprises typically resort to debt financing to maintain a balance between daily operations and strategic investments. Therefore, digital transformation not only enhances the technological competitiveness of enterprises but also compels them to increase external financing due to rising talent costs, further elevating their leverage ratio.

3. Research Design

3.1. Sample Selection and Data Sources

Considering the integrity of corporate digital data and panel data, this paper selects the annual report data of listed companies from 1999 to 2023 as the sample for study. The core variable "degree of DX," control variables including "company size," "managerial incentives," "proportion of intangible assets," and "operating cash flow ratio," among others, are sourced from the organized statistics of the original report texts of each company's annual reports.

3.2. Variable Definition

3.2.1. Explanatory Variable: Digital Transformation (std_digit)

Wu Fei et al. argue that keyword information in annual reports can effectively reflect the degree of a company's DX and the internal emphasis on DX within the company [20]. In this paper, we refer to the improved method by Zhen Hongxian [32], utilizing Python web scraping and other techniques to obtain annual report data of listed companies. We statistically analyze the frequency of 139 digital-related keywords under categories such as technology classification, organizational empowerment, and digital applications. Furthermore, we adopt the corporate DX index calculation method used in the CSMAR database for research on the digital transformation of Chinese listed companies, using the computed corporate DX index as a proxy variable to reflect the level of DX of the enterprise. To eliminate the impact of dimensionality, the corporate digital transformation index is standardized.

3.2.2. Explained Variable: Capital Structure (Lev)

This paper uses the debt ratio as an indicator to measure the capital structure of listed companies. The debt ratio is calculated using a formula

$$\text{Debt} - \text{to} - \text{Asset Ratio} = (\text{Total Liabilities at Year} - \text{End} / \text{Total Assets at Year} - \text{End}) \times 100\% \quad (1)$$

that describes the extent to which the company's total assets are financed through debt within a year, reflecting the risk of credit funds provided by creditors and the company's ability to operate with borrowed funds.

3.2.3. Control Variables

Referring to the research by Chen Dan et al. [7], this paper includes other variables that may influence the level of corporate capital structure (Table 1), including company size (Size), which is the natural logarithm of total assets; managerial incentives (Motiv), which represents the proportion of total executive compensation; the proportion of intangible assets (Cflow), calculated as the net cash flow generated from operating activities divided by total assets; and operating cash flow ratio (Itang),

calculated as the net amount of intangible assets divided by total assets. The analysis also incorporates practical and individual fixed effects and applies tail trimming to all continuous variables at the 1% and 99% percentiles.

Table 1: The specific variable definitions.

Variable Name	Variable Meaning	Calculation Method
digit	Degree of corporate digital transformation	Annual report keyword frequency statistics
Oper	Operating cash flow ratio	Net cash flow generated from operating activities / Total liabilities
Lev	Debt ratio	Total liabilities at year-end / Total assets at year-end
Itang	Proportion of intangible assets	Net amount of intangible assets / Total assets
Cflow	Operating cash flow	Net cash flow generated from operating activities / Total assets
Size	Company size	Natural logarithm of total assets
Motiv	Managerial incentives	Proportion of total executive compensation

3.3. Measurement Model

This paper employs a fixed-effects regression model to study the impact of DX on corporate capital structure. The specified panel regression model is as follows:

$$\log_Lev_{it} = \beta_0 + \beta_1 \times std_digit_c_{it} + \beta_2 \times Size_{it} + \beta_3 \times Motiv_{it} + \beta_4 \times Itang_{it} + \beta_5 \times Cflow_{it} + \alpha_i + \delta_t + \epsilon_{it} \quad (2)$$

where i represents the company number; t represents the year; α_i indicates the individual fixed effect, β_t denotes the time fixed effect, and ϵ_{it} is the random error. If $std_digit_c_{it}$ is significantly positive, it indicates that DX leads to an increase in the company's debt ratio.

4. Empirical Results and Analysis

4.1. Descriptive Statistics

The descriptive statistics of the variables are shown in Table 2. As can be seen from Table 1, the mean of Lev is 0.398, indicating that the average debt level of the companies is close to 40%. The mean of digital transformation is 23.030, with a minimum value of 0.000 and a maximum value of 299.000, reflecting significant differences in the degree of DX among different companies. This also suggests that, in the current context of the DE, some companies have yet to engage in DX, indicating substantial potential for both the depth and breadth of DX. Table 1 shows that there are certain variations in Size, Motiv, Cflow, and Itang across the data from various companies, and the selection of sample objects is quite comprehensive.

Table 2: Summary Statistics.

VarName	Obs	Mean	SD	Min	Median	Max
Lev	21283	0.398	0.198	0.051	0.386	0.862
digit_a	21283	23.030	49.406	0.000	4.000	299.000
Size	21283	21.980	1.136	19.973	21.819	25.685
Motiv	16180	0.274	0.324	0.005	0.168	1.924
Cflow	21283	0.050	0.068	-0.142	0.048	0.242
Itang	21283	0.045	0.044	0.000	0.034	0.276

4.2. Benchmark Regression Analysis

The empirical test results of this study are presented in Table 3. In column (1), without including control variables, log_Lev is significantly positively correlated with std_digit_a at the 1% level ($\beta_1 = 0.085$). Column (2) adds fixed effects for the years, while column (3) further includes fixed effects for stock codes. Column (4) incorporates some control variables, and in all cases, the coefficient of the explanatory variable std_digit_a remains significant.

In column (5), under the condition of including all control variables and fixed effects, log_Lev is significantly positively correlated with std_digit_a at the 1% level ($\beta_1 = 0.035$). This indicates that an increase in the degree of DX of companies will, to some extent, raise their levels of leverage. Specifically, for each 1-unit increase in std_digit_a, the company's debt-to-asset ratio increases by approximately 3.5%. The findings of this study are validated, and the research conclusions exhibit a good degree of stability.

Table 3: Results of empirical regression analyses.

	(1)	(2)	(3)	(4)	(5)
	log_Lev	log_Lev	log_Lev	log_Lev	log_Lev
std_digit_a	0.085*** (0.004)	0.046*** (0.004)	0.066*** (0.011)	0.036*** (0.012)	0.035*** (0.012)
Size				0.143*** (0.016)	0.140*** (0.016)
Motiv				-0.269*** (0.044)	-0.276*** (0.044)
Itang				0.959*** (0.284)	0.961*** (0.284)
Cflow					-0.377*** (0.059)
_cons	-1.134*** (0.010)	-1.190*** (0.017)	-1.147*** (0.017)	-4.076*** (0.339)	-3.995*** (0.338)
N	21283	21283	21283	16180	16180
r2			0.092	0.166	0.170
Year		Yes	Yes	Yes	Yes
Id			Yes	Yes	Yes

4.3. Robustness Test

The results of the robustness tests are shown in Table 4. Using alternative variable measurement methods, column (1) presents the lagged dependent variable, while column (2) shows the lagged independent variable. Columns (3) and (4) replace the indicators for corporate digital transformation with different measures. Column (3) references the method of Wu Fei [20], and column (4) references the method of Zhao Chenyu [21], where related terms for corporate DX are substituted, followed by a new frequency count. The explanatory variable digit_a is replaced with digit_b and digit_c, respectively, and regression analysis is conducted again.

The regression results indicate that the coefficients for the lagged variables (columns 1 and 2) are significantly positive at the 1% level. The coefficients for the substituted dependent variable tests (columns 3 and 4) are significantly positive at the 5% level, confirming that the conclusions of this study are robust.

Table 4: Robustness test results.

	(1) F.log_Lev	(2) log_Lev	(3) log_Lev	(4) log_Lev
std_digit_a	0.042*** (0.012)			
Size	0.094*** (0.017)	0.135*** (0.018)	0.140*** (0.016)	0.142*** (0.016)
Motiv	-0.225*** (0.047)	-0.270*** (0.053)	-0.277*** (0.044)	-0.277*** (0.044)
Cflow	-0.403*** (0.065)	-0.352*** (0.065)	-0.380*** (0.060)	-0.379*** (0.060)
Itang	0.796*** (0.234)	0.846*** (0.263)	0.953*** (0.284)	0.952*** (0.284)
L.std_digit_a		0.041*** (0.012)		
std_digit_b			0.029** (0.013)	
std_digit_c				0.029** (0.012)
_cons	-2.965*** (0.363)	-3.852*** (0.397)	-3.996*** (0.346)	-4.026*** (0.338)
N	12488	12488	16180	16180
r2	0.122	0.144	0.169	0.169
Year	Yes	Yes	Yes	Yes
Id	Yes	Yes	Yes	Yes

5. Research Conclusions and Insights

While DX brings vitality and opportunities for corporate development, it also poses new challenges for businesses. This study examines the impact of digital transformation on corporate asset structure and its mechanisms. The findings reveal that DX leads to an increase in the asset-liability ratio of enterprises. Digital transformation typically involves significant investments in research and development, technological upgrades, and talent acquisition, all of which heighten financial pressure on companies, prompting them to rely more on external financing and increasing their debt risk.

Based on the research, this paper offers the following insights: during the process of advancing DX, companies should simultaneously consider the benefits brought by innovation-driven growth and the pressures on their capital structure. They should avoid excessive reliance on debt financing, which could lead to financial risks. Companies ought to set reasonable leverage targets according to their financial conditions to ensure the health and stability of their capital structure during DX.

Additionally, businesses need to optimize human resource management during digital transformation, leveraging digital technologies to improve operational efficiency, reduce operating costs, and alleviate debt burdens. At the same time, the government and financial institutions should provide diversified financing channels for enterprises, supporting them in acquiring necessary funding through innovative financing tools or policy-based financial measures to lower their financing costs. This will facilitate the smooth progress of DX and the sustainable and healthy development of enterprises.

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