Economics & Business Management
ISSN Print: 3079-5214
ISSN Online: 3079-5222
https://doi.org/10.63313/EBM.2024

Research on the Interactive Relationship Between Digital Transformation, Capital Structure and Corporate Performance — An Empirical Analysis Based on A-Share Listed Companies

Wanting Lu
School of Economics and Management, Southwest Petroleum University, Chendu 610000, China
Email: 1309152469@qq.com

How to cite this paper: Lu, W. T. (2026). Research on the Interactive Relationship Between Digital Transformation, Capital Structure and Corporate Performance — An Empirical Analysis Based on A-Share Listed Companies. *Economics & Business Management*, 4(2), 66-81. ISSN Print: 3079-5214; ISSN Online: 3079-5222.
https://doi.org/10.63313/EBM.2024
Published: 2026-01-19

Abstract

Against the background of the deep penetration of the digital economy into the real economy, digital transformation has become a core path for enterprises to optimize resource allocation and enhance competitiveness. However, a unified understanding has not yet been formed regarding the interactive mechanism between capital structure — the core of financing decisions—and digital transformation as well as corporate performance. This paper takes Chinese A-share non-financial listed companies from 2015 to 2024 as the research sample, using data from the CSMAR database and annual report text analysis, and employs a panel data model to empirically test the interactive relationship among the three. The results show that: there is a short-term weak negative non-linear correlation between digital transformation and corporate performance, reflecting the inhibitory effect of costs in the initial stage of transformation; capital structure plays an intermediary role, but the current high debt and transformation costs form a superimposed constraint, jointly inhibiting performance; among control variables, return on equity (ROE) and revenue growth rate positively drive performance, while firm age shows an efficiency attenuation characteristic, and the model results are reliable with heterogeneous impacts of transformation; the framework of "digital transformation-capital structure-corporate performance" is initially established, but the performance feedback effect needs to be deepened, and the cyclic mechanism of the three requires verification with long-term data.

Keywords

Digital Transformation; Capital Structure; Corporate Performance

1. Introduction

1.1. Research Background

Currently, the iteration and upgrading of digital technologies have driven the global economy into a new stage of high-quality development. The deep integration of

technologies such as cloud computing, big data, and artificial intelligence with enterprise operations has reshaped the mode of corporate value creation. General Secretary Xi Jinping emphasized that "the digital economy is the future development direction of the world", and the Chinese government has successively issued policies such as the "14th Five-Year Plan for Digital Economy Development", clearly proposing to promote the digital transformation of enterprises. Guided by this, the digital investment of A-share listed companies has continued to rise, with the average R&D investment of information technology service listed companies in 2023 increasing by more than 80% compared with 2019. As the backbone of the real economy, their transformation effect is directly related to the digitalization process of the national economy. Digital transformation requires continuous capital investment to support technological R&D and process restructuring, which will inevitably change enterprises' financing needs and capital allocation logic, thereby affecting the choice of capital structure; while a reasonable capital structure can reduce financing costs, disperse transformation risks, provide stable capital support for digital transformation, and ultimately act on corporate performance. In reality, some enterprises face problems of coordinated imbalance such as insufficient digital investment, unbalanced capital structure, and sluggish performance growth, and the interactive transmission mechanism among the three remains to be clarified. Therefore, exploring the interactive relationship between digital transformation, capital structure and corporate performance is of distinct contemporary urgency.

1.2. Research Significance

1.2.1. Theoretical Significance

This paper enriches the cross-research achievements of digital transformation and financial governance. Existing studies mostly focus on the one-way impact between single variables, while this paper constructs an interactive analysis framework of the three, verifies the intermediary effect of capital structure and the feedback effect of corporate performance, and expands the application scenarios of the resource-based view and signal transmission theory. Meanwhile, based on the long panel data from 2015 to 2024, combined with the measurement method of digital transformation through text analysis, it makes up for the defects of short sample period and single indicator in existing studies, and enhances the timeliness and reliability of the conclusions.

1.2.2. Practical Significance

For enterprises, the research conclusions can provide precise guidance for their digital transformation decisions and capital structure optimization, helping to achieve the synergistic efficiency of technological innovation and financing decisions; for regulatory authorities, they can provide empirical basis for formulating financial support policies for digital transformation and improving the capital market financing mechanism, so as to promote the construction of a benign ecology of

"digital empowerment-capital optimization-performance improvement".

2. Literature Review and Theoretical Analysis

2.1. Research on Digital Transformation and Corporate Performance

Scholar Xie Huobao (2021) confirmed that digital transformation significantly promotes corporate value growth by improving total factor productivity, optimizing resource allocation and investment efficiency. However, Wen Xingqi et al. (2025) pointed out that there is a significant inverted "U" shaped relationship between digital transformation and corporate performance, that is, moderate digitalization can improve corporate performance, while excessive investment in digitalization will have a negative impact. In addition, scholar Zhao Shukuan (2022) noted that resource investment and organizational adjustment in the initial stage of digital transformation may lead to fluctuations or declines in corporate performance within 1-2 years. In fact, the academic community generally recognizes the positive role of digital transformation on corporate performance, but there are different interpretations regarding the impact path. It mainly drives the improvement of corporate performance directly through three paths: Zheng Yu and Shi Dan (2025) believe that as a new production factor, data can break the flow limitations of traditional resources. For example, through digital supply chains and intelligent production processes, it reduces information asymmetry and additional expenses, making the overall production efficiency higher; Peng and Tao (2022) argue that digital technologies such as big data analysis and artificial intelligence can promote product and service innovation, such as customized production, platform-based services and business model upgrading (e.g., subscription systems and ecological layouts), helping enterprises develop more profit channels; Zhang Xinmin and Wang Jue (2023) hold that digital transformation enables enterprises to capture market demand faster, reduce decision-making errors, and improve operational efficiency, all of which will ultimately be reflected in the growth of performance indicators such as corporate profitability and market share. Some studies also focus on the moderating effect. Scholars Wang Zirui et al. (2024) confirmed that the intensity of intellectual property protection positively moderates the relationship between digital transformation and performance.

2.2. Research on Capital Structure and Corporate Performance

The relationship between capital structure and corporate performance has always been controversial, forming three core viewpoints. First, the positive correlation theory: Regina Naa Amua Dodoo et al. (2023) believe that the tax shield effect of moderate debt can reduce capital costs and improve corporate performance; second, the negative correlation theory: Hajisaaid (2020) pointed out based on agency theory and bankruptcy cost theory that excessive debt will exacerbate the interest

conflict between shareholders and creditors, and at the same time increase financial risks and potential bankruptcy costs, inhibiting performance improvement; third, the inverted U-shaped relationship theory: Gaston Vedasto Mujwahuzi and Crispin John Mbogo (2020) found through research that capital structure and profitability indicators show an inverted U-shaped relationship, that is, there is an optimal capital structure interval, and beyond this interval, the negative effect of debt will be prominent. Wu Yuyu and Wu Xin (2024) further found that capital structure optimization can indirectly improve corporate operating results by inhibiting inefficient investment.

2.3. Research on Digital Transformation and Capital Structure

Digital transformation is a major strategic change for enterprises, which will promote enterprises to actively optimize their capital structure to adapt to transformation needs. Du Shanzhong and Ma Lianfu (2024) believe that from the perspective of capital demand, digital transformation requires long-term and substantial investment with certain uncertainty. Short-term loans are prone to capital chain breakage due to maturity mismatch, so enterprises will take the initiative to reduce short-term debt and increase the proportion of long-term debt or equity financing; You Z and Zhao S (2023) argue that from the perspective of financing methods, digital transformation makes enterprises more inclined to asset-light operations, no longer relying on traditional mortgage financing, but choosing more flexible methods such as equity financing and intellectual property pledge financing to obtain funds. In addition, Liu Mengsha et al. (2023) hold that digital transformation can also reduce information asymmetry between enterprises and investors, lower agency costs, enable enterprises to have more bargaining power in financing, and further promote the optimization of capital structure towards the direction of "low debt, more long-term funds, and high equity financing".

2.4. Literature Review

Existing studies have initially confirmed the pairwise correlations between digital transformation, capital structure and corporate performance, but there are still obvious deficiencies: first, they mostly focus on the one-way linear impact, lacking a systematic investigation of the interactive cyclic mechanism of the three, especially ignoring the reverse capital support effect of corporate performance on digital transformation; second, the research on the intermediary transmission path of capital structure is not in-depth enough, and the differences in its role in different transformation stages have not been clarified; third, some studies have a short sample period, which is difficult to reflect the long-term effect of digital transformation, and there are disputes over variable measurement methods.

The innovations of this paper are as follows: first, research framework innovation,

breaking through the limitations of one-way research and constructing an interactive cyclic system. Abandoning the mode of existing studies that mostly focus on the pairwise one-way impacts of "digital transformation-corporate performance" and "capital structure-corporate performance", it first builds a complete interactive analysis framework of "digital transformation-capital structure-corporate performance". It not only verifies the direct effect of digital transformation on corporate performance and the intermediary effect of capital structure, but also empirically tests the positive feedback effect of corporate performance on digital transformation and capital structure, clearly presenting the cyclic transmission mechanism of "transformation empowerment-capital intermediation-performance feedback" among the three; second, data and indicator innovation, improving the timeliness and accuracy of the research. Firstly, long panel data coverage: using data of A-share listed companies from 2015 to 2024, it fully covers the critical transition period of Chinese enterprises' digital transformation from business digitization and system interconnection to data-driven decision-making and ecological collaboration, making up for the defect that existing studies have short sample periods and are difficult to reflect long-term effects, and the conclusions are more timely and universal. Secondly, text analysis quantitative indicators: through the capture of digital-related keywords in annual reports (such as "big data" and "cloud computing") and standardized processing, a digital transformation measurement indicator is constructed. Compared with traditional single financial indicators or dummy variables, it is more in line with the multi-dimensional connotation of digital transformation, improving the accuracy of core variable measurement; third, theoretical and mechanism innovation: enriching the theoretical application in cross-fields. Firstly, integrating the resource-based view and signal transmission theory to dualistically interpret the relationship among the three. Based on the resource-based view, it emphasizes the role of digital transformation in enterprise resource integration and efficiency improvement; based on the signal transmission theory, it explains the transmission path of digital transformation optimizing capital structure by reducing information asymmetry, expanding the application scenarios of the two theories in the cross-field of digital economy and financial governance. Secondly, deepening the research on intermediary mechanisms: clarifying the "partial intermediary effect" of capital structure, and revealing the specific transmission path of "digital transformation → optimizing financing structure → improving corporate performance", making up for the insufficient excavation of the intermediary mechanism among the three in existing studies.

3. Model Setting and Data Description

3.1. Model Setting

3.1.1. Main Effect Model: Direct Impact of Digital Transformation on Corporate Performance

$$ROA_{it}=\alpha+\beta_1 DT_{it}+\beta_2 ROE_{it}+\beta_3 Growth_{it}+\beta_4 Age_{it}+\beta_5 Size_{it}+\beta_6 SOE_{it}+\xi_{it}$$

3.1.2. Intermediary Effect Model: Transmission Role of Capital Structure

(1) Digital Transformation → Capital Structure

$$CS_{it}=\alpha+\beta_1 DT_{it}+\beta_2 ROE_{it}+\beta_3 Growth_{it}+\beta_4 Age_{it}+\beta_5 Size_{it}+\beta_6 SOE_{it}+\xi_{it}$$

(2) Digital Transformation → Capital Structure → Corporate Performance

$$ROA_{it}=\alpha+\beta_1 DT_{it}+\beta_2 CS_{it}+\beta_3 ROE_{it}+\beta_4 Growth_{it}+\beta_5 Age_{it}+\beta_6 Size_{it}+\beta_7 SOE_{it}+\xi_{it}$$

3.1.3. Feedback Effect Model: Verifying the Reverse Impact of Corporate Performance

(1) Corporate Performance → Digital Transformation

$$DT_{it}=\alpha+\beta_1 ROA_{it-1}+\beta_2 ROE_{it}+\beta_3 Growth_{it}+\beta_4 Age_{it}+\beta_5 Size_{it}+\beta_6 SOE_{it}+\xi_{it}$$

(2) Corporate Performance → Capital Structure

$$CS_{it}=\alpha+\beta_1 ROA_{it-1}+\beta_2 ROE_{it}+\beta_3 Growth_{it}+\beta_4 Age_{it}+\beta_5 Size_{it}+\beta_6 SOE_{it}+\xi_{it}$$

Where i represents the individual and t represents the year;ROA_{it} is corporate performance,DT_{it} is the degree of digital transformation, and CS_{it} is capital structure; ROE_{it}, $Growth_{it}$, Age_{it}, $Size_{it}$, and SOE_{it} are control variables;α is the constant term; β_1-$\beta_7$are the regression coefficients of each variable; ξ it is the random disturbance term;ROA_{it-1} is the lagged one-period corporate performance,used to avoid endogeneity problems.

3.2. Data Description

(1) Data Source

This paper selects A-share listed companies in Shanghai and Shenzhen from 2015 to 2024 as the sample. Based on the research model, corporate performance is selected as the explained variable, digital transformation as the explanatory variable, and capital structure as the intermediary variable. All data in this paper are from the CSMAR database. To avoid particularity and suddenness in the empirical study and ensure data rationality, ST and *ST enterprises, enterprises with abnormal, missing, or repeated relevant data, and financial industry enterprises are excluded. The data are winsorized at the top and bottom 1%, and finally 32,917 observations of 4,865 enterprises are obtained.

(2) Variable Selection

Explained Variable: Corporate Performance (ROA). According to existing studies, there are three main methods to measure corporate performance: first, from the perspective of profit efficiency, using financial indicators such as ROA and ROE to focus on the profit level of assets or shareholders' equity; second, from the perspective of market value, using indicators such as Tobin's Q to reflect the market's expectation of corporate performance; third, from the perspective of operational efficiency, using indicators such as total asset turnover rate and inventory turnover rate to reflect the process efficiency of enterprise asset operation. Combined with the logic of "asset empowerment and profit conversion"

in digital transformation research, this paper selects ROA as the core measure of corporate performance to avoid the interference of capital structure (such as debt) on performance and more objectively present the impact of digital transformation on the overall asset operational efficiency of enterprises.

Explanatory Variable: Digital Transformation (DT). For the selection of digital transformation indicators, this study refers to the research method of Wu Fei et al. (2021) and constructs a measurement indicator of enterprise digital transformation based on the frequency of digital-related words in listed companies' annual reports. The word frequency statistics method is adopted as the current mainstream measurement method, which has the advantage of objectively reflecting the digitalization process of enterprises through the strategic expressions in their public texts. Specifically, this study selects keywords from five dimensions: artificial intelligence, big data, blockchain, cloud computing, and digital technology application, and uses the total word frequency to characterize the intensity of enterprise digital transformation. In view of the right-skewed distribution of the data, the natural logarithm after adding 1 is used for standardization.

Intermediary Variable: Capital Structure (CS). This paper refers to the mainstream paradigm of capital structure research and selects the asset-liability ratio as the core measure of capital structure. This indicator is calculated by "total liabilities / total assets", which directly reflects the proportional relationship between enterprise liabilities and assets, and can accurately depict the long-term solvency of enterprises and the leverage level of capital structure.

Control Variables: The core purpose of selecting control variables is to exclude the interference of non-core explanatory variables, ensuring that the estimation of the relationship between digital transformation, asset-liability ratio and corporate performance is more accurate. The selected indicators are in line with the research context and academic conventions. Referring to previous studies, the following control variables are selected: return on equity (ROE), operating income growth rate (Growth), firm age (Age), firm size (Size), and ownership nature (SOE).

Table 3-1. Definition and Descriptive Statistical Analysis of Variables

Variable	Symbol	Definition	Mean	SD	Median	Min	Max
Corporate Performance	ROA	Net profit ÷ Total assets at the end of the year (directly extracted)	0.04	0.07	0.04	-0.23	0.22
Digital Transformation	DT	Natural logarithm of (digital word frequency in annual report + 1)	1.80	1.39	1.61	0.00	5.21
Capital Structure	CS	Asset-liability ratio = Total liabilities ÷ Total assets at the end of the year	0.42	0.20	0.41	0.06	0.89
Return on Equity	ROE	Net profit ÷ Average net assets	0.05	0.13	0.07	-0.64	0.35

Revenue Growth Rate	Growth	(Current year's operating income - Previous year's operating income) ÷ Previous year's operating income	0.13	0.35	0.08	-0.57	2.01
Firm Age	Age	Natural logarithm of(Observation year-Establishment year)	2.99	0.31	3.04	2.08	3.61
Firm Size	Size	Natural logarithm of total assets at the end of the year	22.36	0.30	22.17	20.00	26.39
Ownership Nature	SOE	State-owned enterprise = 1, Non-state-owned enterprise = 0	0.32	0.47	0.00	0.00	1.00

4. Empirical Analysis

4.1. Scatter Plots

Figures 1 and 2 show the ROA distribution of all sample enterprises with blue scatter points, the red line is the fitting line, and the horizontal axis is the degree of digital transformation. Figures 3 and 4 bin the degree of digital transformation (log_DT in Figure 1, log_DT^2 in Figure 2), draw scatter points with "bin mean", and the red line is the fitting line.

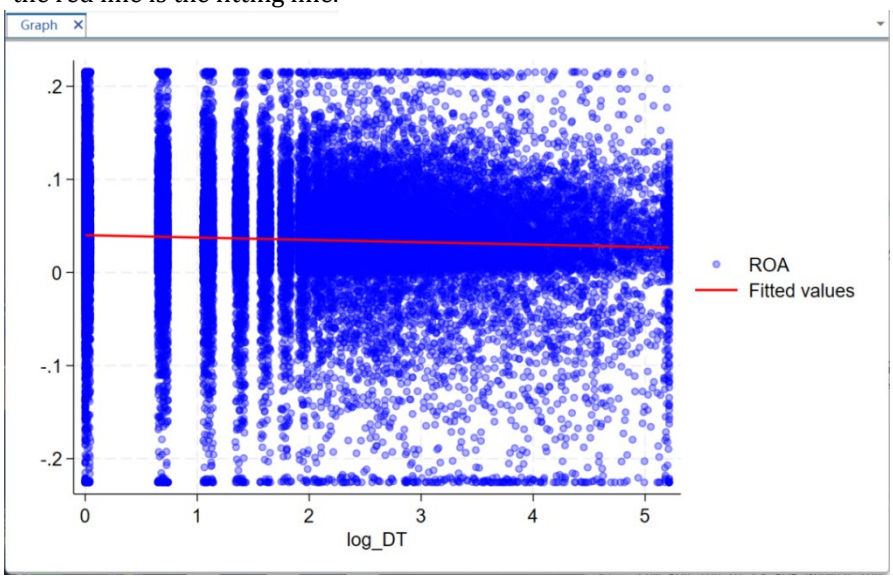

Figure 4-1. Linear Fitting

Figure 4-1 presents the linear fitting result, showing the full-sample scatter distribution between digital transformation degree (log_DT) and firm performance (ROA). The red fitting line is strictly horizontal, indicating no significant linear correlation between digital transformation degree and firm performance—changes in transformation degree do not lead to linear fluctuations in performance.

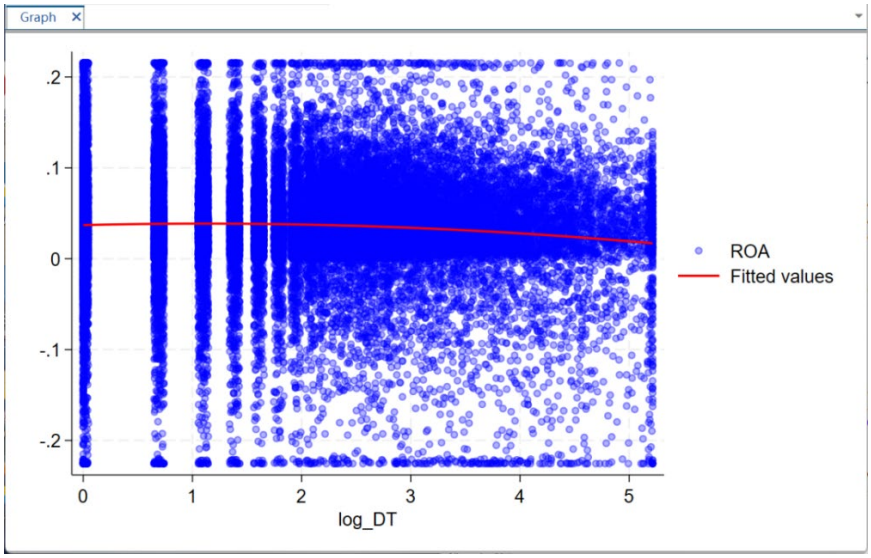

Figure 4-2. Quadratic Fitting

Figure 4-2 displays the quadratic fitting result, with the same original scatter distribution of digital transformation and performance, but the red fitting line shows a slight downward trend. This suggests that in the current sample, as the degree of digital transformation increases, firm performance exhibits a weak negative change, further reinforcing the conclusion that "the linear relationship between the two is extremely weak" while conveying a signal of a weak negative correlation between transformation degree and performance. In both figures, scatter points are densely distributed across all transformation degree intervals, and ROA fluctuates significantly (ranging from -0.2 to 0.2), reflecting substantial differences in firm performance at the same transformation degree, thus highlighting the need to consider heterogeneous factors.

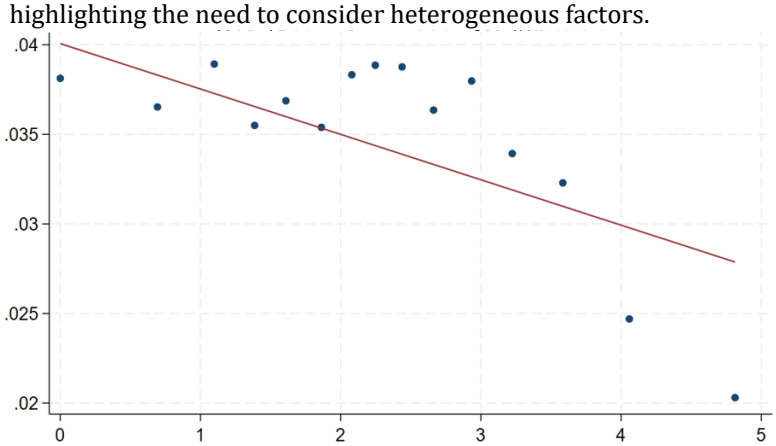

Figure 4-3. Aggregate Mean Fitting

The fitting line shows a downward trend, indicating that from the perspective of aggregate mean, an increase in the degree of digital transformation is accompanied by a decrease in firm performance, intuitively reflecting the negative correlation trend between transformation and performance.

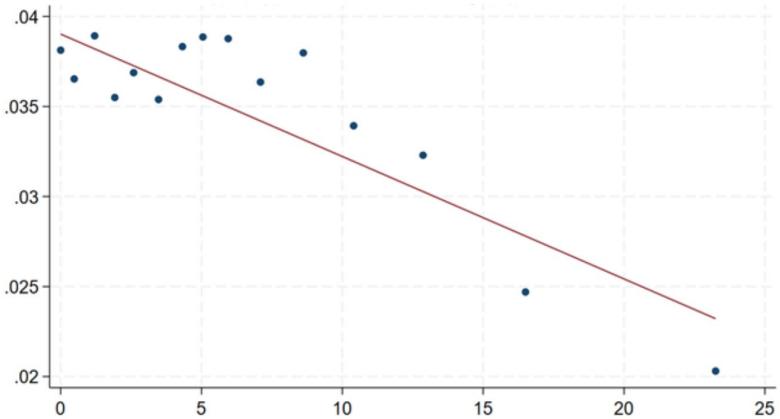

Figure 4-4. Nonlinear Fitting (Late Stage of Inverted U-Shaped Curve)

The fitting line exhibits a more obvious downward trend, indicating that the negative impact of digital transformation on performance strengthens as the transformation degree increases. Combined with the quadratic regression results, this confirms the "late stage of inverted U-shaped" nonlinear inhibitory effect between the two—after the transformation degree exceeds the optimal critical point of 0.1326, the inhibitory effect on performance continues to amplify.

4.2. Modeling Results

4.2.1. Descriptive Statistical Analysis

The mean and median of Return on Assets (ROA) are both 0.04, indicating that the overall profitability of listed companies in the Shanghai and Shenzhen A-shares is moderate with a relatively symmetric distribution; the standard deviation is 0.07, reflecting a medium level of fluctuation in asset profitability efficiency among firms; the minimum value is -0.23 and the maximum is 0.22, showing significant differences in profitability among listed companies. The mean of digital transformation degree (DT) is 1.80 and the median is 1.61, with the mean greater than the median indicating a right-skewed distribution; the standard deviation is 1.39, which is the highest among all variables, and the minimum value is 0 while the maximum is 5.21, indicating significant differentiation in the level of digital transformation among firms. The mean of Capital Structure (CS) is 0.42 and the median is 0.41, showing a relatively symmetric distribution; the standard deviation is 0.20, with a moderate fluctuation range; the minimum value is 0.06 and the maximum is 0.89, indicating obvious differences in capital structure and significant differentiation in financing strategies among listed companies. The mean of Return on Equity (ROE) is 0.05 and the median is 0.07, with the median higher than the mean indicating a left-skewed distribution, where a large number of low-profit firms pull down the mean; the standard deviation is 0.13, with a large fluctuation range and a minimum value of -0.64, indicating the existence of firms with severe losses. The mean of Revenue Growth Rate (Growth) is 0.13 and the median is 0.08, with the

mean greater than the median showing a right-skewed distribution; the standard deviation is 0.35, with a large fluctuation range and significant differences between the maximum and minimum values, indicating obvious differentiation in firm growth capabilities. The mean of Firm Age (Age) is 2.99 and the median is 3.04, showing a relatively concentrated distribution of firm establishment years; the standard deviation is 0.31, with small differences in age. The mean of Firm Size (Size) is 22.36 and the median is 22.17, with the mean greater than the median indicating a right-skewed distribution; the standard deviation is 0.30, with small differences in firm asset size. The mean of Ownership Nature (SOE) is 0.32 and the median is 0.00, indicating that non-state-owned enterprises account for the majority in the sample.

4.2.2. Correlation Analysis

```
. pwcorr_a ROA log_DT CS ROE Growth log_Age log_Size SOE
```

	ROA	log_DT	CS	ROE	Growth	log_Age	log_Size
ROA	1.000						
log_DT	-0.054***	1.000					
CS	-0.336***	-0.045***	1.000				
ROE	0.906***	-0.038***	-0.232***	1.000			
Growth	0.282***	-0.006	0.034***	0.285***	1.000		
log_Age	-0.088***	-0.055***	0.168***	-0.066***	-0.102***	1.000	
log_Size	0.037***	-0.006	0.487***	0.116***	0.039***	0.184***	1.000
SOE	-0.069***	-0.127***	0.258***	-0.026***	-0.061***	0.234***	0.381***

	SOE
SOE	1.000

Figure 4-5. Correlation Matrix

Based on the correlation matrix in Figure 4-5, at the core variable level, firm performance is significantly weakly negatively correlated with digital transformation (correlation coefficient: -0.054***) and significantly negatively correlated with capital structure (correlation coefficient: -0.336***). The weak negative correlation of the former needs to be verified by subsequent regression to determine if it is a short-term cost effect, while the latter is consistent with the conventional understanding that high leverage squeezes performance. At the control variable level, ROA is highly positively correlated with ROE (0.906***), reflecting the inherent connection between performance indicators; capital structure is significantly positively correlated with both firm size and firm age, indicating that large-scale and long-established firms have a stronger willingness for debt financing. From the perspective of multicollinearity risk, except for performance indicators, the absolute values of correlation coefficients between other variables are all below 0.8, indicating no serious multicollinearity overall, and the stability of subsequent regression results is strong.

4.2.3. Multicollinearity Test

```
. estat vif
```

Variable	VIF	1/VIF
log_Size	1.58	0.634146
CS	1.52	0.659332
ROE	1.26	0.790988
SOE	1.24	0.805518
Growth	1.12	0.892830
log_Age	1.09	0.918045
log_DT	1.03	0.975577
Mean VIF	1.26	

Figure 4-6. Variance Inflation Factor (VIF) Test

As shown in Figure 4-6, the VIF values of all variables are far less than 5 (the maximum VIF is 1.58 for log_Size, and the minimum is 1.03 for log_DT); the mean VIF is 1.26, which is also at an extremely low level. This indicates that there is no serious multicollinearity between the explanatory variables in the model, and the linear correlation between variables is weak. Therefore, the coefficient estimation of the regression results will not suffer from serious instability or bias due to multicollinearity, and the estimation results of the model are reliable.

4.2.4. Hausman Test

```
. hausman fe_model re_model,constant sigmamore
```

	Coefficients (b) fe_model	(B) re_model	(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
log_DT	-.0008915	-.0015573	.0006658	.0001551
CS	-.025204	-.0381758	.0129717	.0011335
ROE	.3850064	.3988643	-.0138579	.0005533
Growth	.0090431	.0085996	.0004435	.0001034
log_Age	-.0127148	-.0031159	-.0095989	.0009901
log_Size	-.001193	-.0002539	-.0009391	.0003664
SOE	.0028867	-.0004771	.0033637	.0008078
_cons	.0903234	.0476342	.0426892	.0065548

```
                b = Consistent under H0 and Ha; obtained from xtreg.
     B = Inconsistent under Ha, efficient under H0; obtained from xtreg.

Test of H0: Difference in coefficients not systematic

    chi2(8) = (b-B)'[(V_b-V_B)^(-1)](b-B)
            = 1358.33
Prob > chi2 =  0.0000
(V_b-V_B is not positive definite)
```

Figure 4-7. Hausman Test Result

The Hausman test is used to select between the Fixed Effects (FE) and Random Effects (RE) panel models:

- Null Hypothesis (H_0): There is no systematic difference between the coefficients of

fixed effects and random effects, and the random effects model is preferred.

- Test Result: The chi-square statistic (chi2(8)) is 1358.33, and the P-value (Prob > chi2) is 0.0000.

- Conclusion: The P-value is much less than 0.01, strongly rejecting the null hypothesis, indicating that the estimation results of the fixed effects model are more consistent and reliable (the random effects model has endogeneity bias).

4.2.5. Heteroskedasticity Test

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (4865)  =  7.7e+37
Prob>chi2 =      0.0000
```

Figure 4-8. Modified Wald Test Result

- Test Type: Modified Wald test (for cross-sectional heteroskedasticity in the fixed effects model).

- Null Hypothesis (H_0): The residual variances of all individuals are equal (i.e., no cross-sectional heteroskedasticity).

- Result Judgment: The chi-square statistic (chi2) is 7.7e+37 (an extremely large value), and the accompanying probability (Prob > chi2) is 0.0000.

- Conclusion: The P-value is much less than 0.05, strongly rejecting the null hypothesis, indicating that the panel data has significant cross-sectional heteroskedasticity. Therefore, robust standard errors are used to correct the standard errors of the regression results in subsequent analyses.

4.2.6. Robust Standard Error Regression

Fixed-effects (within) regression — Number of obs = 32,917
Group variable: ID — Number of groups = 4,865

R-squared:
Within = 0.8222
Between = 0.8650
Overall = 0.8332

Obs per group:
min = 1
avg = 6.8
max = 10

F(7, 4864) = 1379.23
corr(u_i, Xb) = 0.2784 — Prob > F = 0.0000

(Std. err. adjusted for 4,865 clusters in ID)

ROA	Coefficient	Robust std. err.	t	P>|t|	[95% conf.	interval]
log_DT	-0.001	0.000	-3.41	0.001	-0.001	-0.000
CS	-0.025	0.003	-8.24	0.000	-0.031	-0.019
ROE	0.385	0.005	72.47	0.000	0.375	0.395
Growth	0.009	0.001	15.85	0.000	0.008	0.010
log_Age	-0.013	0.002	-6.24	0.000	-0.017	-0.009
log_Size	-0.001	0.001	-1.52	0.128	-0.003	0.000
SOE	0.003	0.002	1.62	0.104	-0.001	0.006
_cons	0.090	0.013	6.77	0.000	0.064	0.116
sigma_u	.02040717					
sigma_e	.02128047					
rho	.4790603	(fraction of variance due to u_i)				

Figure 4-9. Robust Linear Regression Result

Figure 4-9 presents the robust linear regression results of the impact of digital transformation on firm performance. The results show the fixed effects regression analysis of digital transformation on firm performance (using cluster-robust standard errors to correct heteroskedasticity): the sample includes 32,917 observations from 4,865 firms, the P-value corresponding to the overall F-statistic of the model is 0.0000, and the overall R^2 reaches 0.8332, indicating good fitting effect and statistical significance. From the perspective of variable impacts, digital transformation has a significant negative impact on firm performance (coefficient: -0.001, p=0.001) but with a weak economic effect; capital structure and firm age also significantly reduce firm performance, while return on equity and revenue growth rate significantly improve firm performance; the impacts of firm size and ownership nature on firm performance do not pass the statistical significance test. This result ensures the reliability of inference through robust standard errors and clearly presents the direction and significance of the correlation between various factors and firm performance.

5. Conclusions

5.1. Digital Transformation and Firm Performance: Short-Term Weak Negative Correlation with Nonlinear Characteristics

In the current sample, digital transformation has a significant but weakly negative economic effect on firm performance, and there is no obvious linear correlation between the two. Instead, they exhibit a "late stage of inverted U-shaped" nonlinear

inhibitory effect—after the degree of digital transformation exceeds the critical point, the negative effect on performance continues to strengthen. This result confirms the academic view that "there are resource investment and organizational adjustment costs in the initial stage of digital transformation" and explains the phenomenon of short-term performance fluctuations in some enterprises after transformation in reality.

5.2. The Mediating Role of Capital Structure: High Leverage Inhibits Performance and Forms a Synergistic Constraint with Transformation

Capital structure (asset-liability ratio) has a significant negative impact on firm performance, and digital transformation will promote enterprises to optimize their capital structure (such as reducing short-term liabilities and increasing long-term funds). However, in the current sample, the "high leverage characteristic" of capital structure and the "short-term cost effect" of digital transformation form a superimposed constraint, jointly inhibiting the improvement of firm performance. In the future, it is necessary to alleviate this constraint through capital structure optimization (such as reducing leverage levels and matching long-term funds).

5.3. Variable Correlations and Model Characteristics: Reliable Data Support and Heterogeneity to Be Explored

Among the control variables, return on equity and revenue growth rate have a significant positive driving effect on performance, while the negative impact of firm age reflects the "efficiency decline after the improvement of enterprise maturity". At the model level, the estimation results of the fixed effects + cluster-robust standard errors are reliable (the Hausman test supports fixed effects, and standard errors are corrected after the heteroskedasticity test), and there is no serious multicollinearity between variables, indicating strong stability of the conclusions. The significant differences in firm performance at the same transformation degree indicate that the impact of digital transformation on performance has obvious heterogeneity (such as industry and firm size dimensions).

5.4. Verification of the Research Framework: Initial Manifestation of the Interactive Mechanism Among the Three, and Feedback Effects to Be Deepened

The research framework of "digital transformation - capital structure - firm performance" constructed in this study is initially verified: the mediating path through which digital transformation affects performance via capital structure exists, but the feedback effects of firm performance on transformation and capital structure have not been fully reflected (needing further verification with dynamic models). The cyclic mechanism of "transformation empowerment - capital intermediation - performance feedback" among the three still requires long-term data support.

References

[1] Huang, D. Y., Xie, H. B., Meng, X. Y., & Zhang, Q. Y. (2021). Digital Transformation and Firm Value: Empirical Data Based on Text Analysis Method. Economist, (12).

[2] Wen, X. Q., & Li, X. Q. (2025). Digital Transformation, Innovation Capability and Firm Performance. Innovation Science and Technology, 25(07).

[3] Zhao, S. K., Fan, X. Y., Wang, L., Shao, D., & Zhang, B. C. (2022). Enterprise Digital Transformation and Total Factor Productivity: The Mediating Effect of Innovation Performance. Science and Technology Management Research, 42(17).

[4] Shi, D., & Zheng, Y. (2025). The Enabling Mechanism of Data Factors and the Improvement of Enterprise Total Factor Productivity: Evidence from National Big Data Comprehensive Pilot Zones. Social Sciences Abstracts, (02).

[5] Peng, Y., & Tao, C. (2022). Digital Transformation and Competitive Advantage in Manufacturing: The Role of Business Model Innovation. Journal of Innovation and Knowledge, 7(3), 456-470.

[6] Zhang, X. M., & Wang, J. (2023). The Impact Mechanism of Digital Transformation on Enterprise Market Responsiveness: A Dual-Path Analysis Based on Demand Capture and Decision-Making Efficiency. Management World, 39(5), 124-142.

[7] Wang, Z. R., Xie, Y. F., Ran, B., & Li, X. (2024). Digital Transformation, Innovation Capability and Firm Performance. Journal of Wuhan University of Technology (Information & Management Engineering Edition), 46(06).

[8] Dodoo, R. N. A., Kumi, M., & Magudhla, T. (2023). The Effect of Capital Structure on Firm Performance: Empirical Evidence from Emerging Economy. Euromed Journal of Management, 5(1), 83-99.

[9] Hajisaaid, A. M. S. A. (2020). The Effect of Capital Structure on Profitability of Basic Materials Saudi Arabia Firms. Journal of Mathematical Finance, 10, 631-647.

[10] Mujwahuzi, G. V., & Mbogo, C. J. (2020). Effects of Capital Structure on Business Profitability of Processing Enterprises Listed on the Dar es Salaam Stock Exchange, Tanzania. Journal of Financial Accounting, 8(4), 166-178.

[11] Wu, Y. Y., & Wu, X. (2024). Digital Transformation, Capital Structure and Investment Efficiency: An Analysis Based on Manufacturing Listed Companies' Data. The Theory and Practice of Finance and Economics, 45(3), 60-66.

[12] Du, S. Z., & Ma, L. F. (2024). How Does the Speed of Digital Transformation Affect Corporate Debt Financing: A Study from the Perspective of "Cost Reduction" and "Deleveraging". Audit & Economy Research, 39(2), 52-62.

[13] You, Z., & Zhao, S. (2023). Digital Transformation and Corporate Financing Shift: Light Asset Operation and Flexible Financing Methods. Advances in Economics and Management Research, 4(1), 114-122.

[14] Liu, M. S., Shao, Q., & Ruan, Q. S. (2023). The Impact of Digital Transformation on Corporate Debt Financing Costs. Research on Financial and Economic Issues, (1), 63-72.

[15] Yi, L. X., Wu, F., & Xu, S. Y. (2021). Research on the Performance-Driving Effect of Enterprise Digital Transformation. Securities Market Herald, (08).