

**Original Article**



# Digital Transformation and Firm Performance --Based on the Mediating Effects of R&D Investment and Government Subsidies

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## Abstract:

The report of the 20th National Congress of the Communist Party of China proposed accelerating the development of the digital economy, promoting the deep integration of the digital economy and the real economy, building digitally focused industrial clusters with international competitiveness, and developing the digital economy has become an important driving force for advancing China's modernization. Against the macro background of digital economy development, digital transformation not only signifies technological innovations, updates, and upgrades related to digital technologies and platforms but also assists enterprises in harnessing emerging resources, managing R&D risks, enhancing operational and managerial efficiency, thereby exerting a positive impact on corporate performance.

The current research on enterprises' digital transformation predominantly adopts qualitative methodologies, with limited attention given by scholars to its impact on corporate performance, let alone investigating the intermediary mechanisms through which digital transformation affects corporate performance from the perspectives of R&D investment and government subsidies. Consequently, amidst the rise of digital transformation in enterprises, this paper explores the relationships between digital transformation, government subsidies, R&D investment, and corporate performance, thereby carrying significant theoretical and practical implications.

This paper comprehensively reviews existing literature, defining fundamental concepts such as digital transformation, R&D investment, government subsidies, and corporate performance. Based on relevant theoretical foundations, five hypotheses are formulated. Using a sample of Chinese A-share listed companies from 2013 to 2022, the study screens the samples through Excel, ultimately obtaining 29,433 valid observation samples. It empirically analyzes the impact of digital transformation on corporate performance, the influence of digital transformation on R&D investment, and the mediating effect of R&D investment and government subsidies.

The research findings are as follows: (1) Enterprise digital transformation has a significantly positive impact on corporate performance, and as the degree of digital transformation intensifies, corporate performance improves significantly; (2) Enterprise digital transformation can significantly increase R&D investment, and as the degree of digital transformation strengthens, R&D investment increases significantly; (3) R&D investment partially mediates the impact of digital transformation on corporate performance, and enterprise digital transformation can drive corporate performance growth by expanding R&D investment; (4) Government subsidies have a significant positive effect on digital transformation; (5) Government subsidies exhibit a significant negative correlation in the influence of digital transformation on corporate performance, demonstrating a negative mediating effect; (6) The nature of property rights influences the mediating effect of R&D investment. In the sample of private enterprises, R&D investment partially mediates the effect of digital transformation on corporate performance, whereas in the sample of state-owned enterprises, digital transformation does not play a mediating role. To facilitate the smooth digital transformation of enterprises, fully leverage the benefits of the digital economy for enterprises, and enhance corporate performance, this paper offers policy recommendations from both government and enterprise perspectives, ensuring their

genuine contribution to promoting enterprise digital transformation and enhancing corporate performance.

**Keywords: Digital transformation; Corporate performance; Government subsidies; R&D investment**

## 1. Introduction

The strategic goal of building a cyber power and digital China is clearly stated in the report of the 20th National Congress of the Communist Party, guiding enterprises toward a new round of technological changes. Many enterprises have implemented digital transformation strategies to seize the opportunities presented by the development of the digital economy. The "Overall Layout and Planning for the Construction of a Digital China" issued by the State Council provides clear guidance for the development of the digital economy, further strengthening the role of government subsidies in driving its advancement. In addition, General Secretary Xi Jinping's emphasis on the deep integration of digital technology with the real economy has enabled effective implementation of government subsidy policies, promoting this integration and accelerating the digital transformation of traditional industries. Currently, as uncertainty emerges regarding the impact of digital transformation on corporate performance, an increasing number of scholars are focusing their attention on this topic. While most scholarly research supports that digital transformation has a positive effect on corporate performance, with empirical evidence showing that digital transformation significantly contributes to the growth of ROA and ROE (Yin Xinan *et al.*, 2022), these studies mainly remain at the level of exploring the relationship between the two. There is still significant debate and limited academic research on the mechanism through which digital transformation affects corporate performance, directions and pathways, warranting further exploration.

Based on the proposed research hypotheses, this paper constructs a theoretical model examining the impact of digital transformation on corporate performance. Utilizing data from China's A-share listed companies from 2013 to 2022, the study delves into the differential effects of intermediary mechanisms through which digital transformation influences corporate performance, from the perspectives of research and development (R&D) investment and government subsidies. This endeavor enhances the theoretical framework

exploring the further implications of digital transformation and broadens the research scope regarding factors affecting corporate performance. The findings are significant for China's A-share listed companies in effectively enhancing performance and achieving long-term sustainable development.

## 1. Empirical Research Design

### 2.1 Research Hypothesis

#### 2.1.1 Digital Transformation and Enterprise Performance

In today's world where the wave of digitization is sweeping across the globe, enterprises have embarked on the journey of digital transformation, striving to seize the initiative in this epochal change. Digital transformation goes beyond a mere technological update; it represents a profound business transformation that reshapes the way enterprises create value, thereby significantly enhancing corporate performance. Through a sample survey of multiple enterprises, this study analyzed the reasons behind enterprises' adoption of digital processes and their impact on corporate performance. It was found that senior executives' choice of digital processes contributed to the discovery of new performance growth points (Ferreira *et al.*, 2019). At its core, this transformation involves leveraging digital technologies to deeply transform traditional business models and processes. The ripple effects of this transformation lead to more efficient business processes, more flexible operating modes, and more scientific management models within enterprises.

Meanwhile, digital transformation has also enhanced enterprises' digital capabilities, an intangible resource centered on digital technology. Digital capabilities not only empower enterprises to process vast amounts of information, heighten market sensitivity, but also optimize product upgrades and upgrades, thereby enhancing their competitiveness. Through digital transformation, enterprises can achieve precise control over production costs, enhance management efficiency, and thus drive sustained growth in corporate performance.

Therefore, digital transformation has emerged as a crucial engine driving corporate performance growth. By introducing digital technologies, optimizing business processes, and enhancing digital capabilities, enterprises can secure a favorable position in the fiercely competitive market and achieve sustained performance growth.

Based on the aforementioned analysis, the following hypothesis is proposed in this paper:

H1: Digital transformation has a positive impact on corporate performance.

### 2.1.2 Digital Transformation and R&D Investment

R&D activities are often characterized by long cycles and high risks, along with strong professionalism in R&D projects, which can deter managers from making decisions on R&D investments (Bostan et al., 2019). Additionally, the long-term capital commitment and high failure rates associated with R&D activities often threaten short-term performance goals of enterprises. Since managers' compensation is largely tied to corporate performance, even if they personally recognize the value of an R&D project after understanding it, they may still lack the willingness to initiate such activities due to personal interests and the high risk of failure. This is because if the R&D project fails, managers cannot diversify the risk through other means and must bear all the consequences, the most significant of which is a substantial reduction in compensation. Therefore, as key participants in R&D decision-making, managers tend to oppose high-risk decisions such as R&D projects and investments, compared to shareholders.

In the context of digital transformation, there are differences between exploratory and exploitative innovations within enterprises. Digital technology, as a crucial innovation factor, has broadened the types of corporate innovation and stimulated an increase in R&D investments. Digital transformation enhances enterprises' investment in innovation resources, i.e., increases the level of R&D investments. This further promotes R&D investment growth due to improved resource input effects, reduced R&D failure risks, and stronger successful R&D conversions (Xu Li, 2023). Digital transformation controls corporate costs, enhances profit margins, and further stimulates

the increase in R&D investments (Ji Yunyang, 2023).

Based on the above analysis, the following hypothesis is proposed in this paper:

H2: Digital transformation has a positive impact on R&D investments.

### 2.1.3 The Mediating Effect of R&D Investment on Digital Transformation and Enterprise performance

As research and development (R&D) investments increase, corporate operational efficiency improves, leading to enhanced corporate performance (Zhou Yuan, 2022). The growth in R&D investments facilitates the effective implementation of corporate innovation activities, which in turn assists in developing new products and upgrading processes, ultimately boosting corporate performance (Liu Jinying, 2022).

Digital transformation promotes the growth of R&D investments, thereby enhancing corporate performance. Leveraging technologies such as artificial intelligence and big data, digital transformation creates more transparent channels for information sharing within enterprises, mitigating information asymmetry across various business processes and between shareholders and managers. This reduces internal costs, enables shareholders to have a comprehensive grasp of R&D activities, enhances the enthusiasm for R&D investments, and fosters the development of new products to expand market share or upgrades production processes and operational efficiency, further driving corporate performance growth. From a governance perspective, digital transformation establishes an efficient digital management platform for enterprises. With the aid of operational and decision-making systems, enterprises can optimize business processes, make more precise R&D investment decisions, promptly align R&D needs with corporate resources, and allocate resources reasonably, providing adequate financial support for R&D investments. As R&D investments increase, enterprises gradually implement necessary R&D activities, developing new products to create unique competitiveness, rapidly expanding market share, and earning substantial profits, while also upgrading production processes and enhancing operational efficiency, thereby augmenting corporate performance.

In summary, with the growth of R&D investments, enterprises expand market share through new product development and enhance production and operational efficiency, ultimately promoting corporate performance growth. In other words, the impact of digital transformation on corporate performance is achieved through the internal mechanism of R&D investments, which play a mediating role in the relationship between digital transformation and corporate performance.

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

H3: R&D investments mediate the relationship between digital transformation and corporate performance.

#### **2.1.4 Digital Transformation and Government Subsidies**

The role of government subsidies is pivotal in driving enterprises' digital transformation. Amidst the ever-evolving digital economy, governments have increasingly recognized the significance of digital transformation in enhancing national competitiveness. Consequently, they employ fiscal incentives such as subsidies and tax breaks to encourage enterprises to invest more in digital transformation, fostering a deeper integration of digital technologies with traditional industries.

Government subsidies not only mitigate the costs and risks associated with digital transformation but also provide enterprises with essential financial support and policy guarantees, accelerating their pace towards digital transformation. Furthermore, these subsidies ignite enterprises' innovative spirit, prompting them to strengthen independent research and development, thereby enhancing their technological innovation capabilities.

Therefore, government subsidies exert a positive impetus on digital transformation. Through these subsidies, enterprises can better achieve their digital transformation goals, ultimately enhancing their competitiveness.

Based on the above analysis, the following hypothesis is formulated in this paper:

H4: Government subsidies have a positive impact on digital transformation.

#### **2.1.5 The Mediating Effect of Government Subsidies on Digital Transformation and**

#### **Corporate Performance**

Government subsidies represent an incentive policy granted by the government to enterprises. Through policy effects such as financial support, directional guidance, image enhancement, and confidence boosting, they promote enterprises to continuously improve internal governance, intensify R&D efforts, and engage in technological innovation, thereby exerting a positive stimulus on corporate performance. As enterprises receive more government subsidies, they can establish a positive image of active development, stable funding, and high product trustworthiness, driving the continuous expansion of their scale. In turn, enterprises will increase investment in R&D and new product production, further enhancing their performance. Starting from high-tech enterprises, it is evident that government subsidies can impact corporate performance through R&D investment (Rong *et al.*, 2020).

Against the backdrop of digital transformation, government subsidies may be utilized to incentivize enterprises to invest in new technologies, improve production processes, or enhance management efficiency, thereby accelerating their digitalization progress. If government subsidies can effectively guide enterprises to increase investments in digital transformation and bring about substantial technological advancements and process optimizations, such subsidies are likely to positively influence corporate performance. For instance, the subsidy funds can be allocated towards purchasing advanced digital equipment, recruiting specialized talents, or conducting technological R&D, which in turn will enhance enterprises' production efficiency and product quality, ultimately leading to increased revenue and profits.

Therefore, government subsidies play a pivotal intermediary role between digital transformation and corporate performance. By effectively leveraging government subsidies, enterprises can better achieve the objectives of digital transformation, thereby fostering sustained growth in corporate performance.

Based on the above analysis, the following hypothesis is proposed in this paper:

H5: Government subsidies mediate the

relationship between digital transformation and corporate performance.

## 2.2 Sample Selection and Data Sources

The rapid proliferation of enterprise digital transformation primarily occurred after 2012. Therefore, this paper selects data from China's A-share listed companies between 2013 and 2022 as the sample to investigate the impact of digital transformation on corporate performance. The R&D investment data of the companies in the sample is sourced from the CNR&DS database, while other data is obtained from the CSMAR database and annual reports. To enhance the validity of data analysis, the following treatments are applied to the sample:

- (1) Exclude listed companies in the financial industry;
- (2) Exclude listed companies marked as ST or PT;
- (3) Exclude listed companies with missing critical variables.

Furthermore, to mitigate the influence of outliers, the continuous variables are winsorized at the 1% and 99% levels. Following these procedures, a total of 29,433 observations from 2013 to 2022 are obtained. This paper employs STATA 16.0 for

empirical analysis to examine the impact of digital transformation on corporate performance and whether R&D investment mediates the relationship between digital transformation and corporate performance.

## 2.3 Definition of Main Variables

### 2.3.1 Explained Variable

The explained variable in this paper is firm performance (FP). As evident from a review of previous literature, different methods of measuring firm performance have led to varying research conclusions. By weighing the pros and cons of various measurement approaches, this paper ultimately selects the factor analysis method to construct a comprehensive indicator for measuring firm performance, thereby ensuring precision and comprehensiveness in measurement. Drawing on the measurement methods for firm performance employed by Sheng *et al.* (2019) and Tong & Wei (2021), this paper selects a total of 12 specific indicators from four dimensions: profitability, solvency, operational efficiency, and growth potential. These indicators collectively provide a comprehensive assessment of firm performance, as detailed in Table 1.

**Table 1. Evaluation index system for enterprise performance**

Evaluation perspective	norm	calculation method	notation
solvency	Asset liability ratio	Total liabilities/total assets	X <sub>1</sub>
	Current ratio	Current assets/current liabilities	X <sub>2</sub>
	Quick ratio	Quick assets/current liabilities	X <sub>3</sub>
profitability	Net interest rate on total assets	Net profit/average balance of total assets	X <sub>4</sub>
	Return on equity	Average balance of net profit/net assets	X <sub>5</sub>
	Gross profit margin on sales	(Operating income - operating cost)/Operating income	X <sub>6</sub>
Operational capacity	Accounts receivable turnover rate	Average balance of revenue/accounts receivable	X <sub>7</sub>
	Turnover of current assets	Average balance of operating income/current assets	X <sub>8</sub>
	Turnover of total assets	Average balance of operating income/total assets	X <sub>9</sub>
Development ability	Revenue growth rate	(Ending operating income - beginning operating income)/Beginning operating income	X <sub>10</sub>
	Growth rate of total assets	(Ending total assets - Beginning total assets)/Beginning total assets	X <sub>11</sub>
	Rate of capital accumulation	(Ending owner's equity - Beginning owner's equity)/Beginning owner's equity	X <sub>12</sub>

After selecting specific indicators for corporate performance, the next step is to conduct factor analysis, which follows these detailed procedures:

### (1) Bartlett's Test of Sphericity and KMO Test

Prior to factor analysis, it is crucial to understand the correlations among the various indicators. To achieve this, after standardizing the data for the aforementioned indicators, we utilize Bartlett's Test of Sphericity and the KMO (Kaiser-Meyer-Olkin) Test to assess the correlations among the indicators. A P-value less than the set standard

indicates a successful pass of Bartlett's Test, confirming the existence of correlations among the indicators. Additionally, a higher KMO value signifies stronger correlations among the indicators, making them suitable for factor analysis. The threshold for a satisfactory KMO value is greater than 0.5. As evident from Table 2, the P-value is 0, which is less than 0.005, indicating a successful pass of Bartlett's Test. Furthermore, the KMO value is 0.654, exceeding the threshold of 0.5, suggesting that the selected indicators are appropriate for factor analysis.

**Table 2. KMO and Bartlett tests**

KMO sampling suitability quantity		0.654
Bartlett's test of sphericity	Approximate chi square	62805.243
	freedom	66
	Significance	0

### (2) Factor Analysis Process

Based on the Bartlett's Test and KMO Test, a factor analysis was conducted on 12 indicators reflecting solvency, profitability, operational capability, and growth potential. The variance contribution rates of these 12 indicators were obtained. Given that the eigenvalue criterion requires values greater than 1, after statistical analysis, the first four factors were retained. The

cumulative variance contribution rate of these four factors, as calculated, amounted to 73.62%. This indicates that these four factors encapsulate the primary characteristics of the 12 indicators, adequately explaining the essence of corporate performance. Consequently, it is determined that these four factors constitute the principal components of corporate performance, as detailed in Table 3.

**Table 3. Common factor variance contribution table**

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	3.36802	0.78573	0.2807	0.2807
Factor2	2.58229	0.90375	0.2152	0.4959
Factor3	1.67854	0.47276	0.1399	0.6357
Factor4	1.20578	0.20881	0.1005	0.7362
Factor5	0.99696	0.37014	0.0831	0.8193
Factor6	0.62683	0.05607	0.0522	0.8715
Factor7	0.57076	0.14668	0.0476	0.9191
Factor8	0.42408	0.15957	0.0353	0.9544
Factor9	0.26451	0.08512	0.022	0.9765
Factor10	0.17939	0.09568	0.0149	0.9914
Factor11	0.08371	0.0646	0.007	0.9984
Factor12	0.01912		0.0016	1

The variance contribution rates of the four principal component factors were obtained through rotation, with a cumulative variance

contribution rate of 73.62%. The specific details are shown in Table 4.

**Table 4. Variance contribution rate of principal component factors**

Factor	Variance	Difference	Proportion	Cumulative
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Factor1	2.60746	0.42926	0.2173	0.2173
Factor2	2.1782	0.02859	0.1815	0.3988
Factor3	2.14961	0.25025	0.1791	0.5779
Factor4	1.89936		0.1583	0.7362

To understand the meanings expressed by the four principal component factors, the variance maximization method was further employed to

rotate the factor loading matrix, resulting in the rotated factor loading matrix. The specific details are shown in Table 5.

**Table 5. The factor load matrix after rotation**

Variable	Factor1	Factor2	Factor3	Factor4
X <sub>1</sub>	-0.7636	0.0474	-0.2827	0.1025
X <sub>2</sub>	0.9635	0.0048	0.0484	-0.097
X <sub>3</sub>	0.9642	0.0121	0.0477	-0.0861
X <sub>4</sub>	0.1636	0.1718	0.9322	0.0539
X <sub>5</sub>	0.0238	0.1878	0.9245	0.0775
X <sub>6</sub>	0.3176	-0.0152	0.4980	-0.4864
X <sub>7</sub>	0.0407	0.0104	-0.0276	0.1205
X <sub>8</sub>	-0.1706	-0.0445	0.0641	0.8773
X <sub>9</sub>	-0.0529	-0.0013	0.0758	0.9134
X <sub>10</sub>	-0.0531	0.7099	0.1751	0.0681
X <sub>11</sub>	-0.0169	0.9236	0.1291	-0.0566
X <sub>12</sub>	0.0397	0.8670	0.1884	-0.0154

In Table 5, by observing the indicators with larger loadings for each principal component factor, we can discern the underlying meaning expressed by each factor. From Table 5, it is evident that the first principal component factor, Factor1, is primarily associated with the debt-to-assets ratio (X<sub>1</sub>), current ratio (X<sub>2</sub>), and quick ratio (X<sub>3</sub>), making it a factor measuring solvency. Factor2, the second principal component, is closely linked to the revenue growth rate (X<sub>10</sub>), total asset growth rate (X<sub>11</sub>), and capital accumulation rate (X<sub>12</sub>), indicating that it measures development capability. Factor3, the third principal component, focuses on the net profit margin on total assets (X<sub>4</sub>), return on equity (X<sub>5</sub>), and gross profit

margin on sales (X<sub>6</sub>), signifying it as a factor for profitability. Lastly, Factor4, the fourth principal component, is related to accounts receivable turnover (X<sub>7</sub>), current asset turnover (X<sub>8</sub>), and total asset turnover (X<sub>9</sub>), making it a factor for measuring operational efficiency.

### (3) Factor Scores

Finally, the factor score coefficient matrix is presented in Table 6. Based on the values in the factor score coefficient matrix, a linear model for each factor is computed. Subsequently, the comprehensive index value for corporate performance is calculated by assigning weights according to each factor's variance contribution rate.

**Table 6. Factor score coefficient matrix**

Variable	Factor1	Factor2	Factor3	Factor4
X <sub>1</sub>	-0.28596	0.04194	-0.06348	-0.03628
X <sub>2</sub>	0.41296	0.03932	-0.10872	0.07677
X <sub>3</sub>	0.41525	0.04346	-0.11096	0.08322
X <sub>4</sub>	-0.04490	-0.07655	0.47251	0.02192
X <sub>5</sub>	-0.10254	-0.07326	0.48441	0.01659
X <sub>6</sub>	0.00271	-0.09455	0.25842	-0.25166
X <sub>7</sub>	0.03953	0.01482	-0.02801	0.07548
X <sub>8</sub>	0.03360	-0.02785	0.03694	0.47275

X <sub>9</sub>	0.09197	-0.00104	0.01715	0.51001
X <sub>10</sub>	-0.00455	0.33572	-0.02866	0.03776
X <sub>11</sub>	0.01161	0.45527	-0.09557	-0.02271
X <sub>12</sub>	0.03145	0.41819	-0.06090	0.00543

Based on the above factor score coefficient matrix, the expressions for each principal component factor are listed as follows:

$$F1 = -0.28596 * X_1 + 0.41296 * X_2 + 0.41525 * X_3 - 0.04490 * X_4 - 0.10254 * X_5 + 0.00271 * X_6 +$$

$$0.03953 * X_7 + 0.03360 * X_8 + 0.09197 * X_9 - 0.00455 * X_{10} + 0.01161 * X_{11} + 0.03145 * X_{12}$$

$$F2 = 0.04194 * X_1 + 0.03932 * X_2 + 0.04346 * X_3 - 0.07655 * X_4 - 0.07326 * X_5 - 0.09455 * X_6 +$$

$$0.01482 * X_7 - 0.02785 * X_8 - 0.00104 * X_9 + 0.33572 * X_{10} + 0.45527 * X_{11} + 0.41819 * X_{12}$$

$$F3 = -0.06348 * X_1 - 0.10872 * X_2 - 0.11096 * X_3 + 0.47251 * X_4 + 0.48441 * X_5 + 0.25842 * X_6 -$$

$$0.02801 * X_7 + 0.03694 * X_8 + 0.01715 * X_9 - 0.02866 * X_{10} - 0.09557 * X_{11} - 0.06090 * X_{12}$$

$$F4 = -0.03628 * X_1 + 0.07677 * X_2 + 0.08322 * X_3 + 0.02192 * X_4 + 0.01659 * X_5 - 0.25166 * X_6 +$$

$$0.07548 * X_7 + 0.47275 * X_8 + 0.51001 * X_9 + 0.03776 * X_{10} - 0.02271 * X_{11} + 0.00543 * X_{12}$$

After obtaining the expressions of the principal component factors F1, F2, F3, and F4, the corresponding weights are assigned based on their variance contribution rates to calculate the comprehensive index value of corporate performance. The specific formula is as follows:

$$FP = (0.2173 * F1 + 0.1815 * F2 + 0.1791 * F3 + 0.1583 * F4) / 0.7362$$

### 2.3.2 Explanatory Variable

The explanatory variable in this study is digital

transformation (Digital). By utilizing text mining methodologies to measure digital transformation, we can not only precisely evaluate the intensity of digital transformation among listed companies but also address the limitations of previous studies that relied solely on dummy variables. Therefore, drawing upon the research of Xiao Tusheng *et al.* (2022) and Zhao Chengyu *et al.* (2021), we employ text mining techniques to count the frequency of keywords related to digital transformation in the "Management's Discussion and Analysis" section of annual reports, thereby quantifying the degree of digital transformation.

### 2.3.3 Intermediate Variable

The mediating variables examined in this paper are government subsidies and R&D investment. Following the studies of Gu Qun *et al.* (2020) and Liu Yuexin (2022), we measure R&D investment by the ratio of R&D expenses to operating revenue, serving as an indicator for the mediating variable. Drawing on the research methodology of Chen Tao, Zhao Jingjun *et al.* (2020), we use the ratio of total government subsidies to the company's total assets at the end of the period as another mediating variable.

### 2.3.4 Control Variable

Incorporating the availability of data and existing research findings, this paper summarizes the definitions and measurement methods for firm performance (FP), digital transformation (Digital), R&D investment (R&D), and all control variables. Specific details are presented in Table 7.

**Table 7. Main variable definitions and descriptions**

Variable type	variable name	variable symbol	Description of variables
Explained variable	Enterprise performance	FP	Calculated by factor analysis method
Explanatory variable	Digital transformation	Digital	Ln (1+ total word frequency of digital feature words in the MD&A section of the Annual report)
Intermediate variable	R&d investment	R&D	R&d investment/operating income
	Government subsidy	Sub	Total government grants/total assets at end of period

Control variable	Company size	Size	Take the logarithm of total assets
	Equity ratio	DER	Total liabilities at year-end/owners' equity at
	Capital intensity	CAP	Total assets/operating income
	Number of directors	BoaRD	Take the natural logarithm of the number of board members
	Proportion of independent directors	Indep	Independent directors divided by the number of directors
	Ownership concentration	Top1	The proportion of the largest shareholder
	Cash flow adequacy	Cashflow	Net operating cash flow/total assets
	Years of establishment	FirmAge	ln(Year of the year - year of establishment +1)

## 2.4 Model Design

After determining the primary variables and their measurement methods, this paper constructs models to examine the impact of digital transformation on firm performance and to validate the mediating effects of R&D investment and government subsidies. Model (1) is a regression model examining the relationship between digital transformation and firm performance, aimed at testing Hypothesis H1. In this model, FP represents the explained variable (firm performance), Digital represents the explanatory variable (digital transformation), and Controls encompass all control variables. Additionally, the model includes fixed effects for year and industry. Model (2) is a regression model of digital transformation on R&D investment,

aimed at testing Hypothesis H2, where R&D serves as the mediating variable (R&D investment), and the meanings of other variables are the same as in Model (1). Model (3) is a regression model examining the joint effects of digital transformation and R&D investment on firm performance, intended to verify Hypothesis H3. Model (4) is a regression model of digital transformation on government subsidies, aimed at testing Hypothesis H4, where government subsidies serve as the mediating variable in this context, and the meanings of other variables remain the same as in Model (1). Finally, Model (5) is a regression model examining the combined effects of digital transformation and government subsidies on firm performance, with the objective of validating Hypothesis H5.

$$FP_{i,t} = \alpha_0 + \alpha_1 Digital_{i,t} + \sum \alpha Controls_{i,t} + \sum Year + \sum Ind + \varepsilon_{i,t} \quad (1)$$

$$RD_{i,t} = \beta_0 + \beta_1 Digital_{i,t} + \sum \beta Controls_{i,t} + \sum Year + \sum Ind + \varepsilon_{i,t} \quad (2)$$

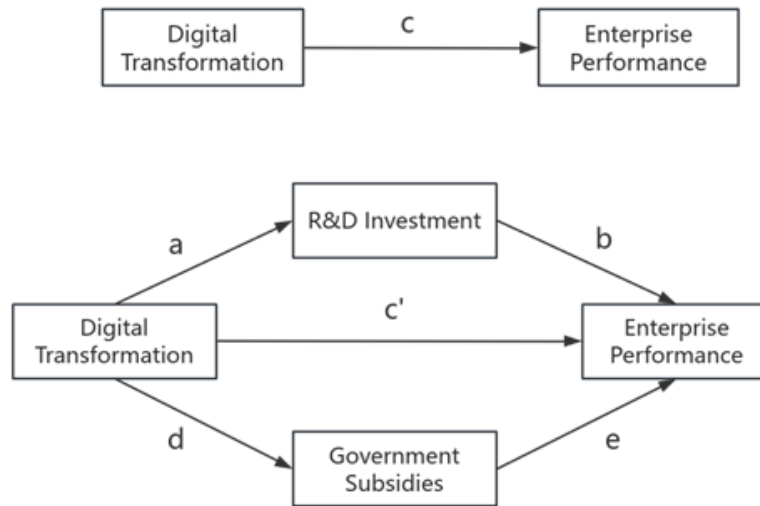
$$FP_{i,t} = \gamma_0 + \gamma_1 Digital_{i,t} + \gamma_2 RD_{i,t} + \sum \gamma Controls_{i,t} + \sum Year + \sum Ind + \varepsilon_{i,t} \quad (3)$$

$$Sub_{i,t} = \beta_0 + \beta_1 Digital_{i,t} + \sum \beta Controls_{i,t} + \sum Year + \sum Ind + \varepsilon_{i,t} \quad (4)$$

$$FP_{i,t} = \gamma_0 + \gamma_1 Digital_{i,t} + \gamma_2 Sub_{i,t} + \sum \gamma Controls_{i,t} + \sum Year + \sum Ind + \varepsilon_{i,t} \quad (5)$$

In the stage of testing the mediating effect, this article examines whether there is a mediating effect in R&D investment based on the testing

steps of Wen Zhonglin and Ye Baojuan (2014). The mediating mechanism relationship is shown in Figure 1:



**Figure 1. Mediating effect test diagram**

The specific testing procedures are as follows:

Step 1: Initially, the main effect model is examined, which involves testing the influence of the explanatory variable (digital transformation) on the dependent variable (firm performance). If the coefficient *c* is significant, proceed to Step 2; otherwise, halt the mediation test.

Step 2: Next, the significance of the indirect effect is investigated by examining the coefficient *a*, which represents the effect of digital transformation on the mediator variable (R&D investment), and the coefficient *b*, which represents the effect of R&D investment on firm performance while controlling for digital transformation. If both coefficients *a* and *b* are significant, proceed to Step 4. If either is not significant, conduct the Sobel test in Step 3.

Step 3: If the Sobel test result indicates a P-value less than 0.05, proceed to Step 4. Otherwise, it implies that the indirect effect fails to meet the significance requirement, and the mediation test is terminated.

Step 4: Subsequently, the significance of the direct effect is evaluated by incorporating the

explanatory variable (digital transformation), the mediator variables (R&D investment and government subsidies) into a regression model that examines their joint influence on firm performance. If the coefficient of digital transformation becomes insignificant, it signifies that R&D investment and government subsidies have a full mediation effect. If the coefficient remains significant, proceed to Step 5 to determine whether R&D investment and government subsidies exhibit a partial mediation effect.

Step 5: If the signs of *ab* and *c'* are consistent, it confirms the existence of a partial mediation effect of R&D investment and government subsidies. The proportion of the mediation effect can be further calculated using the formula  $ab/c'$ . Conversely, if the signs of *ab* and *c'* are opposite, it indicates that no mediation effect is present.

**2. Empirical Test Result**

**3.1 Descriptive Statistics and Correlation Analysis**

**3.1.1 Descriptive Statistics**

**Table 8. Descriptive statistics of major variables**

variable	N	mean	sd	min	p50	max
FP	29433	-0.00520	0.467	-1.186	-0.0439	1.580
Digital	29433	0.910	1.186	0	0	4.419
R&D	29433	0.0346	0.0434	0	0.0270	0.236
Sub	29433	0.00450	0.00480	0	0.00310	0.0269
Size	29433	22.30	1.280	20.05	22.11	26.10
Der	29433	1.101	1.233	0.0666	0.714	7.482

Cashflow	29433	0.0474	0.0667	-0.143	0.0462	0.230
Cap	29433	2.550	2.040	0.433	1.964	12.70
BoaRD	29433	2.113	0.195	1.609	2.197	2.639
Indep	29433	37.75	5.345	33.33	36.36	57.14
Top1	29433	33.91	14.51	9.125	31.57	72.64
FirmAge	29433	2.962	0.301	2.079	2.996	3.526

Table 8 presents the descriptive statistics results. According to Table 8, the minimum value of the dependent variable firm performance (FP) is -1.186, while the maximum value is 1.5580, indicating a significant variation in firm performance among different listed companies. The mean value is -0.00520, and the median is -0.0439, with the mean being less than the median, suggesting that over half of the listed companies have firm performance above the average level. The mean value of the explanatory variable digital transformation (Digital) is 0.910, with a standard deviation of 1.186, indicating that most sample firms have undertaken or are undergoing digital transformation, and the extent of digital transformation varies among listed companies. The mean value of the mediator variable research and development (R&D) investment is 0.0346, with a maximum of 0.236 and a minimum of 0.0000. The maximum value of government subsidies is 0.0269, the minimum is 0.000, and the mean is 0.0045, demonstrating a certain degree of disparity in R&D investment and government subsidy levels among listed companies.

Among the control variables, the maximum value of firm size (Size) is 26.10, and the minimum is 20.05, indicating a range of sizes among listed companies, encompassing both small and medium-to-large firms. The mean value of the debt-to-equity ratio (DER) is 1.101, with a standard deviation of 1.233, reflecting an uneven distribution of capital structures among sample companies. The standard deviation of cash flow adequacy (Cashflow) is 0.0667, suggesting relatively little variation in cash flow positions among listed companies. The maximum value of capital intensity (CAP) is 12.7, and the minimum is 0.433, indicating substantial differences in capital accumulation among listed companies. The standard deviation of the number of board members (Board) is 0.195, implying minor variations in board sizes across companies. The mean value of the proportion of independent directors (Indep) is 37.75, reflecting an average of

37.75% of board members being independent in listed companies. The standard deviation of ownership concentration (Top1) is 14.51, indicating notable disparities in the shareholding percentages of major shareholders among listed companies. The minimum and maximum values of firm age (FirmAge) are 2.079 and 3.526, respectively, suggesting a relatively close range of years since establishment among listed companies.

### 3.1.2 Correlation Analysis

Table 9 presents the results of the correlation analysis. According to Table 9, the correlation coefficient between digital transformation (Digital) and firm performance (FP) is 0.074, which is significant at the 1% level, initially confirming the positive effect of digital transformation on firm performance, and hence, Hypothesis H1 is preliminarily verified.

The correlation coefficient between digital transformation (Digital) and R&D investment is 0.412, significant at the 1% level, indicating that digital transformation significantly promotes the growth of R&D investment, thereby preliminarily confirming Hypothesis H2. The correlation coefficient between R&D investment (R&D) and firm performance (FP) is 0.099, also significant at the 1% level, suggesting that increased R&D investment effectively improves firm performance. In conjunction with the results of Hypothesis H2, Hypothesis H3 is preliminarily confirmed.

The correlation coefficient between digital transformation (Digital) and government subsidies (Sub) is 0.239, significant at the 1% level, demonstrating that digital transformation is significantly influenced by government subsidies, thus preliminarily verifying Hypothesis H4. The correlation coefficient between government subsidies (Sub) and firm performance (FP) is 0.070, significant at the 1% level, indicating that increased government subsidies effectively enhance firm performance. Together with the

results of Hypothesis H4, Hypothesis H5 is confirmed.

It is noteworthy that correlation analysis merely provides a linear examination. In practice, the relationship between variables can vary with external environments and factors. Correlation

analysis serves as an initial prediction of the relationship between variables without considering other factors. To ensure accuracy, further analysis using regression models is necessary.

**Table 9. Correlation analysis**

	FP	Digital	R&D	Sub	Size	Der	Cashflow	Cap	BoaRD	Indep	Top1	Firm Age
FP	1											
Digital	0.074 ***	1										
R&D	0.099 ***	0.412 ***	1									
Sub	0.070 ***	0.072 ***	0.239 ***	1								
Size	- 0.174 ***	- 0.031 ***	- 0.247 ***	- 0.205 ***	1							
Der	- 0.442 ***	- 0.075 ***	- 0.224 ***	- 0.138 ***	0.397 ***	1						
Cashflow	0.270 ***	- 0.043 ***	- 0.010 *	0.067 ***	0.071 ***	- 0.170 ***	1					
Cap	- 0.257 ***	- 0.047 ***	0.054 ***	- 0.135 ***	0.053 ***	0.062 ***	- 0.206 ***	1				
BoaRD	- 0.064 ***	- 0.052 ***	- 0.097 ***	- 0.047 ***	0.265 ***	0.106 ***	0.040 ***	0.007 00	1			
Indep	- 0.002 00	0.041 ***	0.040 ***	0.012 **	- 0.018 ***	- 0.005 00	- 0.008 00	0.017 ***	- 0.572 ***	1		
Top1	0.068 ***	- 0.083 ***	- 0.137 ***	- 0.033 ***	0.202 ***	0.041 ***	0.108 ***	- 0.038 ***	0.029 ***	0.038 ***	1	
Firm Age	- 0.143 ***	- 0.092 ***	- 0.195 ***	- 0.105 ***	0.175 ***	0.145 ***	0.002 00	0.070 ***	0.072 ***	- 0.023 ***	- 0.070 ***	1

\* p < 0.1, \*\* p < 0.05, \*\*\* p < 0.01

### 3.2 Empirical Result Analysis

#### 3.2.1 The Result Analysis of the Mediating Effect of R&D Investment

**Table 10. The mediating effect of R&D investment on the impact of digital transformation on firm performance**

	(1)	(2)	(3)
	FP	R&D	FP

Digital	0.014*** (5.533)	0.006*** (30.340)	0.012*** (4.880)
R&D			0.234*** (3.265)
Size	-0.006*** (-2.644)	-0.003*** (-15.805)	-0.005** (-2.333)
Der	-0.151*** (-70.224)	-0.002*** (-13.102)	-0.151*** (-69.782)
Cashflow	1.240*** (33.997)	0.020*** (6.827)	1.235*** (33.845)
Cap	-0.037*** (-29.196)	0.003*** (30.294)	-0.038*** (-29.323)
BoaRD	-0.083*** (-5.498)	0.001 (0.855)	-0.083*** (-5.516)
Indep	-0.002*** (-3.761)	0.000*** (2.998)	-0.002*** (-3.818)
Top1	0.002*** (12.450)	-0.000*** (-5.510)	0.002*** (12.551)
FirmAge	-0.087*** (-10.256)	-0.011*** (-16.433)	-0.084*** (-9.899)
_cons	0.708*** (10.216)	0.093*** (16.465)	0.686*** (9.859)
N	29433	29433	29433
r2	0.323	0.479	0.323

t statistics in parentheses \* p < 0.1, \*\* p < 0.05, \*\*\* p < 0.01

To examine whether R&D investment mediates the relationship between digital transformation and firm performance, this study will follow the mediation testing procedures outlined by Wen Zhonglin and Ye Baojuan (2014) to investigate the mediating role of R&D investment in the link between digital transformation and firm performance. As shown in Table 10, while controlling for industry and year fixed effects and including other control variables, Column (1) reveals that the regression coefficient of digital transformation (Digital) on firm performance (FP) alone is 0.014, significant at the 1% level, confirming that digital transformation significantly enhances firm performance, thus supporting Hypothesis H1. In other words, the higher the degree of digital transformation undertaken by a firm, the greater its firm performance. Column (2) indicates that the regression coefficient of digital transformation (Digital) on R&D investment (R&D) is 0.006, also significant at the 1% level, demonstrating that even after including other control variables, the positive impact of digital transformation on R&D investment remains unchanged, further

confirming that digital transformation significantly promotes the growth of R&D investment, thereby supporting Hypothesis H2. That is, the more intensive a firm's digital transformation efforts, the more it can stimulate R&D investment growth.

Column (3) in the table presents the mediation effect testing structure of R&D investment in the relationship between digital transformation and firm performance. In this model, the influence coefficient of digital transformation (Digital) on firm performance (FP) is 0.012, significant at the 1% level. Applying the mediation effect principle proposed by Wen Zhonglin, the regression results above reveal that the product of the indirect effect influence coefficients is positive, and so is the direct effect influence coefficient, suggesting that R&D investment partially mediates the relationship between digital transformation and firm performance. Thus, Hypothesis H3 is supported. This finding indicates that digital transformation can drive firm performance growth by promoting R&D investment through both information and governance effects. In terms of the information effect, digital transformation

leverages advanced digital technologies to establish transparent information-sharing channels within firms, alleviating information asymmetry and leading to increased R&D investment, thereby fostering performance growth. Regarding the governance effect, the advancement of digital transformation creates an efficient digital

management platform that enhances operational and decision-making efficiency within firms. Improved R&D decision-making efficiency, in turn, contributes to the growth of firm performance.

### 3.2.2 The Result Analysis of the Mediating Effect of Government Subsidies

**Table 11. The mediating effect of government subsidies on the impact of digital transformation on firm performance**

	(1)	(2)	(3)
	FP	Sub	FP
Digital	0.014*** (5.533)	0.000*** (4.162)	0.014*** (5.622)
Size	-0.006*** (-2.644)	-0.001*** (-20.922)	-0.007*** (-3.072)
Der	-0.151*** (-70.224)	0.000*** (2.903)	-0.151*** (-70.166)
Cashflow	1.240*** (33.997)	0.003*** (6.757)	1.245*** (34.123)
Cap	-0.037*** (-29.196)	-0.000*** (-12.418)	-0.037*** (-29.392)
BoaRD	-0.083*** (-5.498)	0.001*** (4.853)	-0.082*** (-5.393)
Indep	-0.002*** (-3.761)	0.000*** (3.044)	-0.002*** (-3.695)
Top1	0.002*** (12.450)	0.000*** (2.971)	0.002*** (12.515)
FirmAge	-0.087*** (-10.256)	-0.001*** (-7.963)	-0.088*** (-10.418)
Sub			-1.858*** (-3.692)
_cons	0.708*** (10.216)	0.016*** (19.896)	0.738*** (10.576)
N	29433	29433	29433
r2	0.323	0.128	0.323

t statistics in parentheses \* p < 0.1, \*\* p < 0.05, \*\*\* p < 0.01

The previous discussion has established the positive impact of digital transformation on firm performance, with digital transformation directly contributing to improved firm performance by enhancing operational efficiency, reducing costs, and fostering innovation capabilities. In Column (2), after controlling for industry and year fixed effects and incorporating all control variables, the regression coefficient of digital transformation (Digital) on government subsidies (Sub) is found to be 0.000 and significant at the 1% level, indicating that the inclusion of additional control

variables does not alter the positive influence of digital transformation on government subsidies. Hypothesis H4 is thus supported, suggesting that firms with a higher degree of digital transformation are significantly more likely to receive increased amounts of government subsidies.

When government subsidies are introduced as a mediator variable into the model, the regression results are presented in Table 11. Column (3) in the table examines the mediating effect of government subsidies between digital

transformation and firm performance. Within the mediating role of government subsidies, the coefficient of digital transformation remains significantly positive, while the coefficient of government subsidies is significantly negative at -1.858. This result suggests that government subsidies may play a negatively mediating role between digital transformation and firm performance, potentially due to factors such as

subsidy dependency or inefficient use. Hypothesis H5 is therefore supported. However, the negative coefficient of government subsidies also highlights the need to pay attention to the efficiency and effectiveness of subsidy utilization, avoiding them from becoming a hindrance to firm development.

A summary of the hypothesis testing results in this paper is presented in Table 12.

**Table 12. Summary of hypothesis test results**

Serial number	Hypothetical content	Test result
(1)	H1: Digital transformation has a positive impact on enterprise performance.	set up
(2)	H2: Digital transformation has a positive impact on R&D investment.	set up
(3)	H3: R&d investment plays a mediating role in the impact of digital transformation on firm performance.	set up
(4)	H4: Government subsidies have a positive impact on digital transformation.	set up
(5)	H5: Government subsidies play an intermediary role in the impact of digital transformation and firm performance.	set up

### 3.3 Robustness Test

This paper further validates the robustness of the regression results by substituting the explanatory variable. Drawing on the approach of Wang Yinghuan and Guo Yongzhen (2023), we utilize text mining methods, taking annual reports as the text analysis object, and employ the natural logarithm of the frequency of digital transformation-related feature words appearing in the annual reports (Digital\_CSMAR) as an alternative variable. We select all original data from 2013 to 2022 without any processing. The

reason for choosing this alternative variable is that corporate annual reports serve as a vehicle reflecting the company's overall business strategy and decision-making priorities. In particular, the semantic words related to digital transformation disclosed in the annual reports can reflect the progress and status of the company's digital transformation. After substituting the explanatory variable, we regress the models (1) to (3) again, and the results are presented in Table 13.

#### 3.3.1 R&D Investment

**Table 13. Regression estimates of alternative explanatory variables**

	(1)	(2)	(3)
	FP	R&D	FP
Digital_CSMAR	0.004*	0.003***	0.004*
	(1.874)	(11.185)	(1.674)
Size	-0.005**	-0.003***	-0.005**
	(-2.278)	(-9.728)	(-2.103)
Der	-0.148***	-0.002***	-0.148***
	(-66.919)	(-8.256)	(-66.705)
Cashflow	1.246***	0.008	1.245***
	(32.013)	(1.540)	(31.989)
Cap	-0.034***	0.005***	-0.035***
	(-26.296)	(29.261)	(-26.433)

BoaRD	-0.089***	0.002	-0.089***
	(-5.438)	(0.785)	(-5.452)
Indep	-0.002***	0.000	-0.002***
	(-3.831)	(1.572)	(-3.859)
Top1	0.002***	-0.000***	0.002***
	(11.914)	(-4.152)	(11.985)
FirmAge	-0.083***	-0.016***	-0.081***
	(-9.163)	(-13.901)	(-8.890)
R&D			0.140***
			(3.017)
_cons	0.701***	0.099***	0.687***
	(9.378)	(10.510)	(9.177)
N	29433	29433	29433
r2	0.296	0.278	0.297

t statistics in parentheses \* p < 0.1, \*\* p < 0.05, \*\*\* p < 0.01

### 3.3.1 政府补助

**Table 14. Regression estimates of alternative explanatory variables**

	(1)	(2)	(3)
	FP	Sub	FP
Digital_CSMAR	0.012***	0.000***	0.013***
	(3.410)	(5.948)	(3.708)
Size	0.006*	-0.001***	0.004
	(1.789)	(-13.268)	(1.110)
Der	-0.119***	0.000	-0.119***
	(-43.162)	(1.480)	(-43.135)
Cashflow	0.893***	-0.001*	0.888***
	(15.307)	(-1.671)	(15.239)
Cap	-0.049***	-0.000***	-0.049***
	(-26.433)	(-5.239)	(-26.694)
BoaRD	-0.098***	0.001***	-0.094***
	(-4.481)	(3.700)	(-4.296)
Indep	-0.003***	0.000***	-0.003***
	(-4.135)	(3.708)	(-3.950)
Top1	0.002***	-0.000	0.002***
	(7.455)	(-0.067)	(7.461)
FirmAge	0.014	-0.001***	0.012
	(0.920)	(-3.191)	(0.760)
Sub			-3.959***
			(-5.034)
_cons	0.121	0.015***	0.180*
	(1.192)	(11.586)	(1.768)
N	9952	9952	9952
r2	0.371	0.172	0.373

t statistics in parentheses \* p < 0.1, \*\* p < 0.05, \*\*\* p < 0.01

In summary, based on Tables 13 and 14, it is evident that after changing the measurement of the explanatory variable, the results in columns

(1) to (3) of both tables remain significant and consistent with the previous regression results. In Table 13, column (1) shows that the regression coefficient of digital transformation

(Digital\_CSMAR) on firm performance (FP) is 0.004, indicating a significant positive impact of digital transformation on firm performance. This result validates the hypothesis that digital transformation enhances firm performance, thus confirming Hypothesis H1. Column (2) reveals that the regression coefficient of digital transformation (Digital\_CSMAR) on R&D investment is 0.003, supporting Hypothesis H2. In model (3), when both digital transformation and R&D investment are included to examine their joint effect on firm performance, the coefficient of digital transformation (Digital\_CSMAR) is 0.004, and the coefficient of R&D investment is 0.140. Additionally, the product of the coefficient of Digital\_CSMAR in model (2) and the coefficient of R&D in model (3) is positive, consistent with the sign of the coefficient of Digital\_CSMAR in model (3), verifying Hypothesis H3.

In Table 14, column (2) indicates that the regression coefficient of digital transformation (Digital\_CSMAR) on government subsidies (Sub) is 0.000, supporting Hypothesis H4. When both digital transformation and government subsidies are included in model (3) to examine their joint effect on firm performance, the coefficient of digital transformation (Digital\_CSMAR) is 0.013, while the coefficient of government subsidies (Sub) is -3.959. Notably, the product of the coefficient of Digital\_CSMAR in model (2) and the coefficient of Sub in model (3) is negative, contradictory to the sign of the coefficient of Digital\_CSMAR in model (3). The significant negative coefficient of government subsidies suggests that, under direct observation, government subsidies may not directly enhance firm performance or their effects may be offset by other factors, verifying Hypothesis H5. Consequently, after changing the measurement of the explanatory variable, following the previous mediation effect testing procedures, it can be concluded that R&D investment partially mediates the relationship between digital transformation and firm performance, while government subsidies exhibit a negative mediation effect in the relationship between digital transformation (Digital\_CSMAR) and firm performance, further confirming the robustness of the regression results.

### 3.4 Further Analysis: Based on The Heterogeneity of Property Rights

Enterprises with different ownership structures exhibit significant disparities in their operational management, which subsequently influence their objectives, behaviors, and efficiency in digital transformation, ultimately affecting corporate performance. Compared to private enterprises, state-owned enterprises (SOEs) enjoy the advantage of having the government as a "protective umbrella," making it easier for them to access high-quality resource allocations, policy preferences, and other forms of support. This, however, leads to inequalities between SOEs and private enterprises in the market environment (Su Kun, 2012). The review and decision-making mechanisms for R&D investments in SOEs are intricate, often not solely determined by the enterprise's management. The utilization and approval of funds are subject to government control, which can delay R&D investment decisions (Dong Xiaoqing *et al.*, 2014). Beyond profit-seeking, SOEs engaging in technological innovation also consider political mandates and social responsibility goals (Qi Yongjun *et al.*, 2022). Given the differentiation between SOEs and private enterprises, there may be variations in the mediating role of R&D investment in digital transformation and corporate performance, necessitating separate research.

#### 3.4.1 R&D Investment

Based on Table 15, Column (1) shows that the impact coefficient of digital transformation (Digital) on firm performance (FP) in state-owned enterprises (SOEs) is 0.015, which is significant at the 1% level. This indicates that digital transformation in SOEs can significantly enhance firm performance. In Column (2), the impact coefficient of digital transformation (Digital) on research and development (R&D) investment is 0.004, also significant at the 1% level, suggesting that digital transformation in SOEs can significantly boost R&D investment. Column (3) examines the mediating role of R&D investment, revealing that the impact coefficient of R&D investment (R&D) on firm performance (FP) is -0.322, with a significant and negative regression coefficient. This indicates that digital transformation in SOEs fails to further enhance firm performance through increased R&D investment. Therefore, Hypothesis H3 is not supported in the context of SOEs.

**Table 15. Regression analysis of state-owned and private enterprises**

	State-owned enterprise			Private enterprise		
	(1)	(2)	(3)	(1)	(2)	(3)
	FP	R&D	FP	FP	R&D	FP
Digital	0.015***	0.004***	0.017***	0.007**	0.006***	0.006*
	(3.533)	(14.328)	(3.823)	(2.271)	(24.853)	(1.940)
Size	0.006*	-0.001***	0.006*	-0.002	-0.003***	-0.001
	(1.947)	(-5.718)	(1.813)	(-0.628)	(-13.247)	(-0.465)
Der	-0.119***	-0.002***	-0.119***	-0.183***	-0.003***	-0.182***
	(-43.183)	(-8.050)	(-43.236)	(-57.428)	(-11.421)	(-57.101)
Cashflow	0.895***	-0.002	0.894***	1.318***	0.030***	1.314***
	(15.339)	(-0.385)	(15.333)	(28.852)	(7.746)	(28.715)
Cap	-0.049***	0.001***	-0.048***	-0.032***	0.004***	-0.032***
	(-26.580)	(10.584)	(-26.194)	(-18.748)	(29.261)	(-18.695)
BoaRD	-0.098***	-0.002	-0.099***	-0.012	0.006***	-0.013
	(-4.453)	(-1.247)	(-4.483)	(-0.604)	(3.303)	(-0.644)
Indep	-0.003***	-0.000	-0.003***	-0.001	0.000***	-0.001
	(-4.146)	(-0.993)	(-4.170)	(-0.763)	(4.148)	(-0.813)
Top1	0.002***	-0.000***	0.002***	0.003***	-0.000**	0.003***
	(7.465)	(-5.476)	(7.329)	(12.990)	(-2.274)	(13.017)
FirmAge	0.015	-0.012***	0.011	-0.085***	-0.010***	-0.083***
	(0.957)	(-10.663)	(0.708)	(-8.167)	(-11.838)	(-7.995)
R&D			-0.322**			0.143*
			(-2.286)			(1.687)
_cons	0.110	0.085***	0.137	0.560***	0.079***	0.549***
	(1.086)	(11.849)	(1.349)	(5.423)	(8.973)	(5.304)
N	9952	9952	9952	19481	19481	19481
r2	0.371	0.462	0.371	0.311	0.480	0.311

t statistics in parentheses \* p < 0.1, \*\* p < 0.05, \*\*\* p < 0.01

Due to the complex review and decision-making mechanisms for R&D investment in state-owned enterprises (SOEs), the path to enhancing corporate performance through digital transformation cannot be achieved solely through increased R&D investment. R&D investment is largely controlled and dominated by the government, which explains why the mediating mechanism of R&D investment does not hold in SOEs. Although SOEs enjoy superior resource allocation and policy preferences, they are also prone to corruption and inefficiency issues. During the process of digital transformation in SOEs, when R&D investment increases, the enterprises may inadvertently raise operating costs due to misappropriation of funds and low R&D efficiency, thereby inhibiting the growth of corporate performance. Therefore, if the direction of R&D investment in SOEs does not align with the actual needs of digital transformation or if resource allocation is unreasonable, it may lead to

resource waste, further impacting corporate performance. In summary, R&D investment plays a negative mediating role in the relationship between digital transformation and corporate performance in SOEs.

According to the regression results for private enterprises (PEs), in Column (1), the coefficient of the impact of digital transformation (Digital) on corporate performance (FP) for PEs is 0.007, significant at the 5% level, indicating a significant positive effect of digital transformation on corporate performance in PEs. In Column (2), the coefficient of the impact of digital transformation (Digital) on R&D investment (R&D) is 0.006, significant at the 1% level, demonstrating that digital transformation in PEs significantly increases R&D investment. Column (3) tests the mediating role of R&D investment, where the regression coefficient of digital transformation (Digital) on corporate performance (FP) for PEs is 0.006, significant and positive at the 10% level,

and the coefficient of the impact of R&D investment (R&D) on corporate performance (FP) is 0.143, also significant and positive at the 10% level. This confirms that R&D investment partially mediates the effect of digital transformation on corporate performance in PEs, supporting Hypothesis H3 in the context of PEs. It can be observed that PEs possess advantages such as strong R&D motivation and flexible decision-making mechanisms. Strengthening digital transformation efforts in PEs can enhance information transparency, effectively alleviating information asymmetry within the enterprise. As information asymmetry in R&D activities is mitigated, R&D investment significantly increases. Meanwhile, digital transformation

enhances operational and decision-making efficiency, leading to improved decision-making efficiency in R&D activities, further boosting R&D investment and ultimately promoting corporate performance. Additionally, R&D investment drives the in-depth development of digital transformation, enhancing the enterprise's technological level and innovation capabilities, thereby contributing to the improvement of corporate performance. Therefore, R&D investment partially mediates the effect of digital transformation on corporate performance in PEs, and digital transformation in PEs can promote corporate performance growth through increased R&D investment.

### 3.4.1 Government Subsidy

**Table 16. Regression analysis of state-owned and private enterprises**

	State-owned enterprise			Private enterprise		
	(1)	(2)	(3)	(1)	(2)	(3)
	FP	Sub	FP	FP	Sub	FP
Digital	0.015*** (3.533)	0.000*** (5.508)	0.016*** (3.810)	0.007** (2.271)	0.000 (1.441)	0.007** (2.287)
Size	0.006* (1.947)	-0.001*** (-13.024)	0.004 (1.280)	-0.002 (-0.628)	-0.001*** (-14.945)	-0.002 (-0.793)
Der	-0.119*** (-43.183)	0.000 (1.434)	-0.119*** (-43.159)	-0.183*** (-57.428)	0.000 (0.910)	-0.183*** (-57.419)
Cashflow	0.895*** (15.339)	-0.001 (-1.631)	0.890*** (15.273)	1.318*** (28.852)	0.005*** (9.085)	1.323*** (28.895)
Cap	-0.049*** (-26.580)	-0.000*** (-5.444)	-0.049*** (-26.847)	-0.032*** (-18.748)	-0.000*** (-10.275)	-0.032*** (-18.814)
BoaRD	-0.098*** (-4.453)	0.001*** (3.740)	-0.094*** (-4.267)	-0.012 (-0.604)	0.001*** (2.687)	-0.012 (-0.573)
Indep	-0.003*** (-4.146)	0.000*** (3.700)	-0.003*** (-3.962)	-0.001 (-0.763)	0.000 (1.522)	-0.001 (-0.746)
Top1	0.002*** (7.465)	-0.000 (-0.077)	0.002*** (7.470)	0.003*** (12.990)	0.000*** (3.537)	0.003*** (13.027)
FirmAge	0.015 (0.957)	-0.001*** (-3.117)	0.012 (0.800)	-0.085*** (-8.167)	-0.001*** (-7.423)	-0.086*** (-8.240)
Sub			-3.951*** (-5.024)			-1.008 (-1.582)
_cons	0.110 (1.086)	0.015*** (11.382)	0.168* (1.652)	0.560*** (5.423)	0.016*** (13.912)	0.576*** (5.554)
N	9952	9952	9952	19481	19481	19481
r2	0.371	0.172	0.373	0.311	0.113	0.311

t statistics in parentheses \* p < 0.1, \*\* p < 0.05, \*\*\* p < 0.01

Based on Table 16, Column (1) indicates that the impact coefficient of digital transformation (Digital) on firm performance (FP) in Chinese

state-owned enterprises (SOEs) is 0.015, significant at the 1% level, suggesting that digital transformation in SOEs can significantly enhance firm performance. Column (2) shows that the

impact coefficient of digital transformation (Digital) on government subsidies (Sub) is 0.000, significant and positively influential at the 1% level. Column (3) examines the mediating role of government subsidies, revealing that the influence coefficient of government subsidies (Sub) on firm performance (FP) is -3.951, significant and negatively influential, indicating that government subsidies play a negative mediating role in the relationship between digital transformation and firm performance in SOEs, thereby supporting Hypothesis H5 in the context of SOEs.

For private enterprises, the impact coefficient of digital transformation (Digital) on firm performance (FP) is 0.007, also demonstrating a significant positive impact, albeit with a relatively smaller coefficient value. This may imply that private enterprises face more challenges or require a longer time to realize the benefits of digital transformation. Additionally, while private enterprises may respond more flexibly to digital transformation, they may be constrained by factors such as resources, technology, and talent. The impact coefficient of government subsidies (Sub) on firm performance (FP) in private enterprises is -1.008, with an insignificant regression coefficient. Given that one of the two coefficients for the indirect effect is insignificant, a Sobel test is necessary. The Sobel test results in a P-value greater than 0.05, failing to meet the significance threshold for the indirect effect, indicating that government subsidies do not mediate the relationship between digital transformation and firm performance in private enterprises. Thus, digital transformation in private enterprises does not further enhance firm performance through government subsidies, and Hypothesis H5 is not supported in the context of private enterprises.

### 3. Research Conclusions and Policy Recommendations

#### 4.1 Research Conclusion

Based on a comprehensive review of previous research findings, this paper formulates research hypotheses and selects Chinese A-share listed companies as the study subject. Utilizing financial data spanning from 2013 to 2022, it examines the impact of digital transformation on firm performance, introducing R&D investment and government subsidies as mediating variables to

further explore the mechanism underlying the effect of digital transformation on firm performance. To mitigate biases associated with single-indicator performance measurement, factor analysis is employed to construct a comprehensive performance measure for the dependent variable, ensuring the stability and accuracy of the research results. Appropriate control variables are selected to form an evaluation system, and a multiple regression model is constructed to investigate the impact of supply chain concentration on firm performance. The key findings are as follows:

(1) Digital transformation has a significant positive impact on firm performance. This is because digital resources resulting from digital transformation are unique to the enterprise, accumulated based on its development trajectory, and are scarce, difficult to imitate, and difficult to replace. With these resources, enterprises can establish a leading position in the industry, forming a strong competitive advantage that contributes to enhanced firm performance (Hu Dongbin *et al.*, 2023). Additionally, the openness and interconnectivity inherent in digital transformation facilitate the de-intermediation of internal business processes, enhancing transparency in production, procurement, finance, and other operations, significantly reducing internal costs and leading to an overall improvement in performance. Thus, firms with a higher degree of digital transformation tend to perform better.

(2) Digital transformation exerts a notable positive influence on R&D investment. On the one hand, digital transformation enhances the transparency of R&D information, enabling shareholders who are at an informational disadvantage to obtain more comprehensive information about R&D activities. Through digital platforms, shareholders can clearly distinguish between the causes of R&D failures and successes, control R&D risks, and accelerate the growth of R&D investment (Shen L *et al.*, 2022). On the other hand, digital transformation assists shareholders in accurately assessing the responsibilities of managers in R&D activities, preventing excessive punishment of management that might discourage R&D investment, thereby stimulating managers' R&D motivation and increasing R&D investment. Consequently, as enterprises vigorously promote digital transformation and enhance the

transparency of information across R&D activities, shareholders' concerns about R&D investment risks are significantly reduced.

(3) R&D investment partially mediates the positive effect of digital transformation on firm performance. Firstly, by leveraging advanced digital technologies to build transparent information-sharing platforms, R&D investment mitigates issues in internal business processes, communication between shareholders and management, and R&D processes. This reduces information gathering costs, enabling shareholders to grasp R&D information more accurately and control risks, thereby increasing their willingness to invest in R&D and promoting its growth. Furthermore, R&D activities can improve outdated production processes and technological processes, enhancing production and operational efficiency, ultimately boosting firm performance. Secondly, by enhancing digital management capabilities and improving R&D governance through operational and decision-making systems, enterprises can make more precise R&D decisions. As the efficiency of R&D investment decisions improves, R&D investment grows, and the development of new products expands market share and competitiveness. Additionally, innovations in production management processes enhance operational efficiency, further augmenting firm performance (Guo Xiaochuan *et al.*, 2022).

(4) Government subsidies have a significant positive impact on digital transformation. Government subsidies can directly reduce the costs associated with implementing digital transformation, which often requires substantial investments in digital equipment, software, and employee training. By providing partial or full financial support, government subsidies alleviate financial pressures on enterprises, making it easier for them to take the first step towards digital transformation. This cost-reduction effect incentivizes more enterprises to participate in digital transformation, thereby accelerating the digital transformation process across the economy. Beyond financial support, government subsidies may also encompass technical assistance and training, which are crucial for effectively applying digital technologies in business operations. By offering consulting and training services through subsidy programs, governments

can help enterprises better understand and adopt digital technologies, enhancing their digital capabilities. Ultimately, government subsidies facilitate the wider adoption of digital transformation, driving the development and expansion of the digital economy. This not only contributes to national economic strength and comprehensive competitiveness but also promotes the optimization and upgrading of economic structures.

(5) Government subsidies exhibit a negative mediating effect in the relationship between digital transformation and firm performance.

On the one hand, this stems from misallocated resources. Government subsidies may not be precisely allocated to enterprises that genuinely need and can effectively utilize these funds for digital transformation. This could lead to the flow of subsidies towards enterprises with weak transformation intentions or inadequate transformation capabilities, resulting in resource waste and misallocation. On the other hand, there is inefficiency in their utilization. Even if enterprises receive government subsidies, they may fail to effectively utilize these funds due to internal mismanagement, the absence of effective digital transformation strategies, and other reasons. In such cases, government subsidies not only fail to enhance firm performance but may instead have a negative impact due to ineffective fund utilization.

(6) The nature of ownership influences the mediating effect of R&D investment. In both state-owned enterprises (SOEs) and private enterprises, digital transformation exerts a significant positive effect on both firm performance and R&D investment. This indicates that regardless of ownership, enhancing digital transformation intensity can not only boost firm performance but also promote R&D investment growth. Therefore, both SOEs and private enterprises can leverage the advantages of digital transformation and increase firm performance through R&D activities. However, the mediating effect of R&D investment differs between SOEs and private enterprises. In private enterprises, R&D investment mediates the impact of digital transformation on firm performance, suggesting that digital transformation can enhance firm performance by increasing R&D investment. Conversely, in SOEs, digital transformation fails

to further enhance firm performance through increased R&D investment. This may be because R&D investments often require extended periods to materialize into tangible outcomes, with no guaranteed success rate. This long-term nature and uncertainty make it difficult for R&D investments to directly enhance firm performance in the short term. Particularly in SOEs, due to their unique institutional mechanisms, they may prioritize short-term benefits and have a relatively low tolerance for long-term investments, thereby preventing R&D investments from significantly and positively mediating the impact of digital transformation on firm performance.

Similarly, the mediating effect of government subsidies varies between private and SOEs. In SOEs, government subsidies have a significant negative impact on firm performance in the context of digital transformation. In contrast, government subsidies do not exhibit a significant mediating effect on firm performance in private enterprises undergoing digital transformation. This disparity may stem from several factors. Firstly, SOEs, with their larger scale and stronger financial capabilities, are more likely to receive government subsidies. However, they may also face more complex decision-making mechanisms and bureaucratic systems, resulting in inefficiencies in subsidy utilization. Furthermore, SOEs may prioritize social responsibilities such as social stability and employment over purely economic gains, affecting their digital transformation performance. Secondly, government subsidies may not fully cover all private enterprises requiring digital transformation, particularly smaller ones with weaker innovation capabilities. This dilutes the overall effectiveness of subsidies, making it difficult to significantly enhance overall firm performance. Private enterprises often confront multifaceted challenges in digital transformation, including technology, talent, and funding. If they lack sufficient transformation capabilities, even with government subsidies, they may struggle to effectively drive the transformation process and significantly enhance firm performance.

#### 4.2 Policy Suggestion

Based on the research findings presented in this paper, it becomes evident that amidst the wave of digital transformation, enterprises seeking sustainable competitive advantages and

performance growth must embark on a moderate path of digital transformation. To facilitate the proactive implementation of digital transformation by enterprises and fully leverage the benefits offered by the digital economy, this paper offers the following policy recommendations from both governmental and enterprise perspectives:

##### 4.2.1 Government Level

(1) Formulate Clear Digital Transformation Strategies and Plans. Governments should introduce forward-looking and operable digital transformation strategic plans, clarifying development goals, key tasks, and safeguard measures to provide enterprises with a clear guidance direction. Simultaneously, establish cross-departmental coordination mechanisms to ensure the effective implementation of various policies and measures.

(2) Strengthen Infrastructure Construction and Upgrades. Increase investment in digital infrastructure such as information and communication networks, data centers, and cloud computing platforms, enhancing network coverage and service quality while reducing hardware costs for enterprises' digital transformation. Additionally, promote the research, development, and application of emerging technologies like 5G, the Internet of Things, and blockchain to provide a solid technological foundation for enterprises' digital transformation.

(3) Governments Must Address Financing Issues for Enterprises' Digital Transformation. For digital transformation initiatives, governments can coordinate with financial institutions to reduce financing costs, addressing the financial difficulties faced by enterprises in pursuing digital transformation. Furthermore, enhance the promotion of digital transformation, fostering a wave of industry-wide digital transformation throughout the supply chain. Encourage leading digital transformation enterprises to drive lagging ones, fully stimulating the positive impact of digital transformation on corporate performance.

##### 4.2.2 Enterprise Level

(1) Clarify digital transformation objectives. Enterprises should establish clear digital transformation goals and pathways based on their own developmental realities and industry characteristics. Through market research,

competitive analysis, and other means, identify key areas and pain points for digital transformation, formulating practical digital transformation plans. Enterprises should prepare and adapt to digital transformation in advance, introducing necessary digital talent and advanced digital technologies to quickly adapt to the process, thereby driving corporate performance growth.

(2) Enhance internal organizational and management innovation. Drive changes in organizational structures and management models, establishing flat and flexible organizational systems adapted to digital transformation. Strengthen cross-departmental collaboration and communication, breaking down information silos to improve decision-making efficiency and execution. Additionally, emphasize fostering employees' innovative mindset and digital skills, stimulating internal vitality within the enterprise.

(3) Increase investment in technological research and development (R&D). Research findings confirm a significant positive relationship between digital transformation and R&D investment, with R&D investment partially mediating the relationship between digital transformation and corporate performance. Therefore, enterprises should stimulate R&D innovation, intensify R&D investment efforts, and minimize the issue of insufficient R&D investment due to management's reluctance to take responsibility for potential failures. Fully leverage the role of R&D investment in boosting corporate performance through digital transformation. Acquire core technologies and intellectual property rights through independent R&D or collaborative introductions, enhancing the enterprise's core competitiveness and market position.

### 4.3 Research Deficiency and Prospect

The positive impact of digital transformation on corporate performance has been demonstrated through theoretical analysis and empirical methods, yet several limitations persist. Firstly, digital transformation may exert differential effects across various industries. Large-sample tests have not specifically focused on the impact of digital transformation on corporate performance within a particular industry,

suggesting that future research could anchor in specific industries to further deepen the conclusions. Secondly, the potential existence of a "threshold theory" in digital transformation implies that investments in digital transformation may not simultaneously coincide with performance gains. As digital transformation is a dynamic process, achieving favorable outcomes necessitates navigating through the "gradual" adaptation process within the corporate organization. Thus, a nonlinear relationship between digital transformation and corporate performance may exist, which deserves attention in future research endeavors.

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