

Digital Shift and Overall Factor Productivity: Taking Government Subsidies as a Mediating Influence

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Abstract: This study focuses on Chinese A-share listed companies in Shanghai and Shenzhen from 2012 to 2023. It examines the relationship between digital transformation and total factor productivity, with a particular emphasis on the role of government subsidies. Using a mediation effect model, the research finds that higher levels of digital transformation in enterprises correlate with increased total factor productivity. Additionally, government subsidies play a mediating role in this relationship. The study also highlights that the effect of digital transformation on productivity is more significant in the western region. These findings provide valuable insights for enterprises aiming to improve efficiency and enhance their competitiveness.

Keywords: digital transformation, government grants, total factor productivity

1. Introduction

The 20th National Congress of the Communist Party of China highlights the importance of pursuing high-quality economic growth and building a new development framework, with a focus on integrating the digital economy deeply into the real economy. The digital economy is reshaping China's economic and social landscape, transforming daily life and opening new avenues for national development. Driven by this trend, the digital transformation of enterprises has become an unavoidable direction of progress.

On July 2, 2024, Yu Xiaohui, President of the China Academy of Information and Communications Technology, unveiled the "2024 Global Digital Economy Whitepaper." The report reveals that Chinese AI enterprises represent 15% of the global total, compared to 34% for the United States. It also notes that the current level of digital transformation among Chinese enterprises still has room for improvement.

Total factor productivity, which captures the contribution to economic growth beyond traditional inputs, has emerged as a key indicator of new-quality productive forces. It plays a crucial role in advancing China's high-quality economic development and achieving socialism with Chinese characteristics. The digital transformation of enterprises accelerates the adoption of information technology, facilitates the efficient use of information resources, and boosts innovation performance [1]. This transformation inevitably influences total factor productivity. As digital transformation gains momentum, understanding its relationship with total factor productivity is essential for driving China's economic progress.

Government subsidies, defined as non-repayable monetary assets or resources provided to enterprises by the government, also impact total factor productivity. However, the nature of this

influence remains unclear. Additionally, does the increasing level of digital transformation affect government subsidies? In this context, examining the interplay between digital transformation, government subsidies, and total factor productivity holds significant value.

This paper makes several contributions: First, by introducing an innovative mediating variable, it enriches the existing literature on the relationship between digital transformation and total factor productivity. While most studies focus on innovation performance, this research incorporates government subsidies as a mediating factor. Second, this study explores the bidirectional chain relationship between digital transformation and government subsidies. While existing literature predominantly examines how government subsidies promote the advancement of digital transformation, there is limited research on whether the level of digital transformation influences government subsidies. Third, from a macro perspective, the paper investigates the impact of digital transformation on total factor productivity, analyzing how government subsidies, as a macro-level policy, affect the relationship between enterprise digital transformation and total factor productivity.

2. Theoretical analyses and research hypotheses

2.1. Digital transformation of enterprises and total factor productivity

In the process of advancing digital transformation, enterprises continuously adopt emerging digital technologies such as big data and artificial intelligence. These technologies are applied to enhance total factor productivity, thereby improving the overall efficiency from input to output. The primary mechanisms through which this occurs include technological innovation, management refinement, and efficient resource allocation.

Digital transformation has become a significant driver of productivity in the manufacturing sector, significantly boosting total factor productivity [2]. It positively impacts total factor productivity by influencing innovation performance [3]. Additionally, alleviating financing constraints for enterprises is a key pathway through which digital transformation enhances total factor productivity [4]. In the agricultural sector, digital transformation increases total factor productivity by improving capital utilization and increasing investment in R&D productivity [5].

Through digital transformation, enterprises can upgrade their equipment, foster new-quality productivity, and optimize resource allocation. This enables resources to flow more rationally and efficiently to relevant departments. As enterprises advance in digital transformation, their production factors evolve, leading to continuous improvements in total factor productivity. Based on this analysis, the following hypothesis is proposed:

H1: Enterprise digital transformation promotes the enhancement of total factor productivity.

2.2. Digital transformation of enterprises, government subsidies and total factor productivity

The extent of digital transformation in enterprises influences government subsidies to a certain degree. Companies with advanced digital transformation, such as high-tech firms, align more closely with national policy directions. Consequently, they are more likely to receive greater government subsidy support. As industrial digitization progresses, government subsidies increasingly favor enterprises with more developed digital economies.

Government subsidies also affect total factor productivity. They can accelerate the development of new productivity by speeding up the digital transformation of enterprises [6]. A significant positive relationship exists between government subsidies and total factor productivity [7]. Government subsidies positively impact both R&D investment and total factor productivity [8]. Overall, government subsidies contribute to the enhancement of total factor productivity [9]. First, as an "invisible hand," government subsidies improve the financial position of enterprises. This reduces their financing pressure, freeing up more funds for R&D activities within the enterprise. This, in turn,

boosts productivity and innovation capabilities, promoting the improvement of total factor productivity. At the same time, government subsidies have a favorable signaling effect. They send positive signals to the market, demonstrating government support for the enterprise's R&D efforts. Additionally, these positive signals encourage more funds to flow into the enterprise, leading to increased development and utilization of advanced equipment, ultimately enhancing total factor productivity. Based on this analysis, the following hypothesis is proposed:

H2: Government subsidies serve as a mediating variable between the degree of digital transformation and its impact on total factor productivity.

3. Research design

3.1. Sample and data sources

This research examines Chinese A-share listed companies from 2012 to 2023. Several data-processing steps are undertaken: ① Due to the distinct governance structures and financial conditions of financial listed companies, such firms are excluded from the initial sample. ② Non-representative ST, *ST, and PT companies, as well as samples with incomplete data, are removed. ③ To reduce the influence of outliers, the data undergoes winsorization, with the extreme values trimmed at the 1% and 99% levels. Ultimately, a total of 34,255 sample observations are obtained, and the data for this study is sourced from the CSMAR database.

3.2. Description of variables

3.2.1. Explanatory variable

Various methods exist for measuring total factor productivity. In this study, the LP method is employed to estimate total factor productivity (TFP), as it enables the selection of suitable proxy variables to account for unobservable productivity shocks. The estimation formula is as follows:

$$\ln Y_{it} = \ln A_{it} + \alpha \ln K_{it} + \beta \ln L_{it} \quad (1)$$

where Y_{it} denotes the output of firm i in period t , K_{it} is the capital input, L_{it} is the labour input such that A_{it} is total factor productivity (TFP), and α and β denote the output elasticities of capital and labour respectively.

3.2.2. Explanatory variable

The core variable in this study is enterprise digitalization degree (DGT1). Following Wu Fei's approach [10], this paper identifies and tallies keywords related to digital transformation. These values are aggregated, and a logarithmic transformation is applied to the total. The outcome serves as a comprehensive measure of the enterprise's digital transformation level.

3.2.3. Intermediary variable

The intermediary factor in this analysis is government subsidies (Sub). Drawing on Chen Xiaoshan's framework [11], this paper quantifies the level of government support by deriving the natural logarithm of the annual subsidy amounts received by enterprises.

3.2.4. Control variables

This study aligns with established methodologies in existing literature by selecting control variables that reflect enterprise characteristics. These variables include internal governance (IC), largest shareholder ownership percentage (TOP1), capital return rate (Cr), company size (Size), leverage

ratio (LEV), and return on equity (ROE). Time (YEAR) and industry (IND) factors are also integrated into the regression framework.

3.3. Modelling

To test hypotheses H1 and H2, the following model was constructed based on the mediation effect test method:

$$TFP_{it} = \alpha_0 + \alpha_1 DGT_{it} + \sum Controls_{it} + \sum YEAR + \sum ind + \varepsilon_{it} \quad (2)$$

$$Sub_{it} = \beta_0 + \beta_1 DGT_{it} + \sum Controls_{it} + \sum YEAR + \sum ind + \varepsilon_{it} \quad (3)$$

$$TFP_{it} = \gamma_0 + \gamma_1 DGT_{it} + \gamma_2 Sub_{it} + \sum Controls_{it} + \sum YEAR + \sum ind + \varepsilon_{it} \quad (4)$$

In the above equation, *i* represents region, *t* represents time, TFP represents total factor productivity, Sub represents government subsidy, DGT represents the degree of digital transformation, YEAR represents year fixed effects, ind represents industry fixed effects, and Controls is a control variable.

ε denotes the random interference term.

4. Empirical analyses

4.1. Descriptive statistics

Descriptive statistics were performed on key variables in the research sample, with results summarized in the table below. For the core dependent variable (TFP), the mean value is 9.220, ranging from a minimum of 7.090 to a maximum of 12.25, indicating notable variation in total factor productivity across listed companies. The primary independent variable, digital transformation level (DGT1), shows values spanning from 0 to 5.220, reflecting considerable divergence in digital adoption among enterprises. The mediating variable, government subsidies (Sub), displays a mean of 16.35, with values extending from 11.98 to 20.26, suggesting uneven subsidy distribution across firms. Among control variables, substantial differences appear in largest shareholder ownership (TOP1), capital return rate (Cr), and internal governance (IC). In contrast, company size (Size), equity return (ROE), and leverage ratio (LEV) exhibit less pronounced variations.

Table 1: Descriptive statistics

Variable	N	Mean	SD	Min	p50	Max
DGT1	34255	1.590	1.420	0	1.390	5.220
DGT2	34255	0.0200	0.0200	0	0.0100	0.140
Sub	34255	16.35	1.500	11.98	16.34	20.26
TFP	34255	9.220	1.100	7.090	9.090	12.25
IC	34255	3.650	0.550	1	4	4
TOP1	34255	33.78	14.70	8.420	31.51	74.30
Cr	34255	2.610	2.560	0.360	1.770	16.11
ROE	34255	0.0500	0.130	-0.730	0.0700	0.300
Size	34255	22.24	1.280	20.07	22.04	26.29
LEV	34255	0.410	0.200	0.0600	0.400	0.880

4.2. Analysis of baseline results

Regression analysis conducted under the defined framework yielded the following results. The total factor productivity coefficient registers 0.0460, remaining statistically significant at the 1% threshold. This demonstrates that intensified digital transformation demonstrates a significant positive effect on total factor productivity. Specifically, enhanced digital transformation correlates with increased enterprise productivity levels. These empirical findings align with hypothesis H1.

Table 2: Baseline regression test

	(1)
	TFP
DGT1	0.0460 *** (0.00257)
TOP1	0.00211 *** (0.000194)
Cr	-0.0109 *** (0.00144)
ROE	1.105 *** (0.0218)
Size	0.653 *** (0.00282)
LEV	0.662 *** (0.0217)
IC	-0.00830 * (0.00501)
YEAR	YES
ind	YES

4.3. Mechanism test analysis

The analysis of government subsidies' intermediary role between digital transformation and total factor productivity aligns with theoretical expectations. As enterprises deepen their digital transformation, their ability to secure government funding increases, which subsequently elevates productivity levels.

Empirical evidence reveals critical patterns: In regression column (1), the coefficient α_1 for digital transformation (DGT1) measures 0.0713 with statistical significance below 0.01. This confirms that enhanced digital transformation strongly correlates with higher government subsidy acquisition.

In column (2), the regression coefficient linking government subsidies (Sub) to total factor productivity (TFP) stands at 0.0306. This significant positive relationship demonstrates that government support actively contributes to productivity improvement.

These findings collectively verify the mediating effect of government subsidies in connecting digital transformation with total factor productivity. The results substantiate hypothesis H2 and provide actionable insights for subsequent policy and academic investigations.

Table 3: Mechanism test

	(1)	(2)
	Sub	TFP
DGT1	0.0713 *** (0.00545)	0.0439 *** (0.00257)
TOP1	0.00124 *** (0.000411)	0.00207 *** (0.000194)
Cr	-0.0213 ***	-0.0102 ***
ROE	0.447 *** (0.0461)	1.092 *** (0.0217)
Size	0.855 *** (0.00596)	0.627 *** (0.00356)
LEV	0.0522 (0.0459)	0.661 *** (0.0216)
IC	0.00185 (0.0106)	-0.00836* (0.00500)
YEAR	YES	YES
Ind	YES	YES
Sub		0.0306 *** (0.00255)
_cons	-2.377 *** (0.158)	-5.816 *** (0.0749)
N	34255	34255
R ²	0.525	0.802
adj. R ²	0.523	0.802

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.4. Robustness check

The alternative measures for enterprise digital transformation levels draw from Chen-Yu Zhao's framework. This approach quantifies keyword mentions across four dimensions: digital technology adoption, internet-based business models, smart manufacturing, and modern information systems. After standardizing word-frequency data, the entropy weighting method assigns values to each dimension, culminating in the digital transformation index (DGT).

Regression outcomes using these alternative variables are shown in the table. The findings remain consistent despite changes in core variable measurement methods, confirming the robustness of the results.

Table 4: Robustness test

	(1) TFP
DGT2	1.660 *** (0.145)
TOP1	0.00206 *** (0.000194)
Cr	-0.0108 *** (0.00145)
ROE	1.106 *** (0.0218)
Size	0.657 *** (0.00280)
LEV	0.654 *** (0.0217)
IC	-0.00862 * (0.00503)
YEAR	YES
Ind	YES
_cons	-5.970 *** (0.0748)
N	34255
R ²	0.800
adj. R ²	0.800

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.5. Heterogeneity test

The classification of enterprises into two distinct groups is determined by their geographic locations: the Eastern Region Group and the Non-Eastern Region Group. The Eastern Region Group includes enterprises located in Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan, Taiwan, the Hong Kong Special Administrative Region, and the Macao Special Administrative Region. Conversely, enterprises situated in all other provinces are categorized under the Non-Eastern Region Group.

After conducting group-based regression analysis, the results are summarized in the table. Regarding the coefficient of digital transformation, the value for enterprises within the Eastern Region Group is 0.0425. In comparison, the regression coefficient for enterprises in the Non-Eastern Region Group is 0.0521. This suggests that the coefficient of digital transformation is higher for the Non-Eastern Region Group relative to the Eastern Region Group. Based on this analysis, it can be concluded that the influence of digital transformation on total factor productivity is more significant for enterprises in the Non-Eastern Region.

Table 5: Heterogeneity test

	(1)	(2)
	TFP	TFP
DGT1	0.0425 *** (0.00296)	0.0521 *** (0.00508)
TOP1	0.00195 *** (0.000227)	0.00176 *** (0.000364)
Cr	-0.00701 *** (0.00164)	-0.0177 *** (0.00298)
ROE	1.125 *** (0.0261)	1.040 *** (0.0386)
LEV	0.805 *** (0.0261)	0.455 *** (0.0390)
Size	0.643 *** (0.00334)	0.669 *** (0.00524)
IC	-0.0235 *** (0.00614)	-0.00462 (0.00857)
YEAR	YES	YES
ind	YES	YES

5. Conclusions and recommendations

5.1. Findings

This study focuses on Chinese A-share listed companies in Shanghai and Shenzhen from 2012 to 2023 as the research sample. By reviewing relevant literature, the paper introduces government subsidies as an intermediary variable in a model to explore the impact of digital transformation on total factor productivity. The findings are summarized as follows:

(1) The regression results demonstrate that government subsidies serve as a mediating factor in the relationship between digital transformation and total factor productivity. This conclusion holds even after robustness tests involving variable substitutions. It suggests that digital transformation can boost a firm's total factor productivity through the channel of government subsidies. Enterprises that advance their digital transformation efforts are more likely to achieve technological upgrades and gain recognition, increasing their chances of receiving government subsidies, which in turn enhances their total factor productivity.

(2) Heterogeneity test results indicate that the effect of digital transformation on total factor productivity is more pronounced for firms in the non-eastern region compared to those in the eastern region. This highlights regional differences in the impact of digital transformation on productivity.

5.2. Recommendations for countermeasures

1. Accelerate the pace of digital transformation in enterprises to promote high-quality development. Companies should increase their investment in research and development, upgrade to advanced technological equipment, integrate technological strength into the digital economy, and leverage technologies such as blockchain and artificial intelligence to foster high-quality growth within the organization.

2. Learn from the digital transformation experiences and models of enterprises in non-eastern regions. Prioritize the construction of digital infrastructure to ensure efficient data transmission. During the digital transformation process, emphasize regional industrial coordination and encourage collaboration with upstream and downstream enterprises as well as academic institutions to achieve resource sharing and collaborative innovation.

3. The government should actively support the sustainable development of relevant high-tech enterprises. It should assist in protecting intellectual property rights and enhance support for research and development expenditures. At the same time, the government should actively promote enterprises with advanced digital transformation levels, cultivate a positive corporate image, and drive the continuous improvement of digital transformation across enterprises in the market.

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