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Research on the Impact of Supply Chain Digitalization on TFP

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Abstract. This study empirically analyzes the impact of supply chain digitalization on the total factor productivity of enterprises. Research has found that the digitalization of the supply chain has enhanced the total factor productivity of enterprises and has undergone a series of robustness tests. Mechanism analysis indicates that the efficiency of enterprise resource allocation and enterprise innovation input can further positively regulate the promoting effect of supply chain digitalization on the total factor productivity of enterprises. Heterogeneity analysis indicates that for private enterprises and those without significant deficiencies, the positive impact of supply chain digitalization on the total factor productivity of enterprises is more significant, while for state-owned enterprises and those with significant deficiencies, this impact effect is not significant.

Keywords: Digitalization of the supply chain, Total factor productivity, Enterprise resource allocation efficiency, Enterprise innovation investment

1. Introduction

Empowering the digital transformation of supply chains and ensuring the security and stability of industrial chains with digital technologies has become a strategic choice and an inevitable requirement for a country's industrial development. Faced with the dual pressures of a waning demographic dividend and tightening resource and environmental constraints, leveraging digital technologies to overcome supply chain efficiency bottlenecks and reshape the growth momentum of enterprise productivity has become a key issue in achieving high-quality development.

This raises a series of questions that need to be considered: (1) Does supply chain digitalization (SCD) significantly affect the total factor productivity (TFP) of enterprises? What kind of heterogeneity does its impact direction and intensity show in different industries and enterprises with different ownership types? (2) Through which transmission mechanisms does SCD affect the TFP of enterprises? (3) In the context of the continuous increase in digital economy policies, how to build a SCD path that adapts to the characteristics of different industries to maximize productivity dividends? Based on this, this paper will conduct an in-depth study on the relationship between SCD and TFP.

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2. Literature review

2.1. Direct effect

Existing studies generally confirm that SCD can significantly improve TFP. At the macro level, SCD can significantly improve TFP, especially for export-oriented, state-owned and capital-intensive enterprises [1]. At the industry level, SCD has a significant positive impact on TFP by improving supply chain management, driving digital innovation and optimizing human capital [2]. The digitalization of downstream customers can produce significant spillover effects, improving the TFP of upstream suppliers, and this effect increases as the customer's market influence increases [3]. At the enterprise level, supply chain digitization positively impacts the TFP of enterprises by optimizing the allocation of financial, talent, and technology resources [4].

2.2. Indirect effect

The first is the efficiency improvement path. Firstly, it is manifested in optimizing supply chain efficiency. SCD significantly improves supply chain efficiency by integrating, expanding and deepening the vertical connection of the supply chain, such as improving inventory turnover, which in turn transmits to the TFP of enterprises [5]. Secondly, it is manifested in improving operational efficiency [3]. Finally, it is manifested in logistics efficiency coordination [6]. Innovation-driven: SCD boosts green innovation: transparency, financing, cash flow [7,8], and its dynamic capability enhances innovation & agility through digitalization, especially with high integration [9,10].

The third is the governance and collaborative optimization path. First, it is manifested in information transparency and governance improvement. SCD improves supply chain information transparency, optimizes the internal and external governance level of enterprises, alleviates information asymmetry and financing constraints, and thus improves the TFP of enterprises [11]. Secondly, SCD boosts TFP via resource collaboration and business model reconstruction, while also enhancing industrial chain and city resilience through improved collaboration, financing [1], energy efficiency, and green empowerment [8], fostering a favorable ecology for micro-enterprises..

3. Research design

3.1. Model setting

This study establishes the following model:

$$TFP_{it} = \alpha_0 + \beta_0 Digitalization + \sum \gamma_k Control_{it} + Firm_i + Year_t + \varepsilon_{it} \quad (1)$$

TFP, $Digitalization$, $Control$, $Year$, $Firm$ respectively represent the total factor productivity of the enterprise, supply chain digitization, a series of control variables, time fixed effects, individual fixed effects, and error terms.

3.2. Definition of variables

Regarding the explained variable, i.e., the measurement of the TFP, this study uses the LP method to calculate the TFP of the enterprise [12]. Among them, it involves four major factors: enterprise output, capital input, labor input, and intermediate product input.

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Regarding the core explanatory variable, i.e., the measurement of SCD, this study uses the frequency of relevant words in the annual reports of listed companies [13].

Regarding the mediating variables, the first is the efficiency of enterprise resource allocation. This study first estimate the reasonable investment level of the enterprise this year, and then calculate overinvestment to measure the investment efficiency of the enterprise. The second is the enterprise's innovation investment, which is measured by the proportion of R&D expenses to application revenue [14].

Regarding control variables, this study selected a series of control variables from the enterprise level and the macro level, including: (1) enterprise level variables: enterprise size (natural logarithm), enterprise profitability (return on assets), enterprise debt repayment ability (asset-liability ratio), enterprise liquidity level (cash-to-asset ratio), enterprise age (time of establishment), board size (number of board members), executive compensation (ratio of total executive compensation), equity concentration (sum of squares of shareholding ratios of the top five shareholders), and enterprise price-to-earnings ratio; (2) macro level variables: regional economic development level (logarithm of regional GDP), regional industrial structure (ratio of regional tertiary industry added value to GDP), and regional financial development level (ratio of regional financial institution loans to GDP).

3.3. Data sources and descriptive statistics

This paper selects A-share listed companies in Shanghai and Shenzhen from 2012 to 2023 as the research sample. Regarding data sources, enterprise-level data is obtained from the CSMAR database, and macro-level data is obtained from the Wind database.

Table 1. Descriptive statistics of variables

Variable type	Variable Name	Variable Symbol	Observations	Mean	Standard Deviation	Min	Max
Explained Variable	Total Factor Productivity	TFP	37214	8.367	1.083	4.403	13.106
Explanatory Variable	Supply Chain Digitalization	Digitalization	39871	0.030	0.013	0.000	0.386
	Firm Size	Size	41628	3.097	0.060	2.704	3.357
	Return on Assets	ROA	41627	0.036	0.060	-0.163	0.171
	Financial Leverage	Leverage	36173	1.288	0.738	0.630	4.947
	Cash to Suit Ratio	Cash	41591	0.693	2.010	-5.723	8.204
	Firm Age	Age	41625	9.735	8.012	0.000	27.000
	Board Size	Board	30545	8.408	1.662	0.000	18.000

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Table 1. (continued)

Control Variable	Proportion of Total Executive Compensation	Salary	30483	0.288	0.350	0.005	1.689
	Price - Earnings Ratio	PE	34853	72.049	100.902	6.843	550.452
	Top 5 Equity Concentration	Top5	41383	0.488	0.190	0.200	0.994
	Level of Regional Economic Development	GDP	41831	10.700	0.764	6.565	11.818
	Regional Industrial Structure	Industry	41831	54.922	11.224	34.500	84.800
	Level of Regional Financial Development	Finance	41831	1.666	0.458	0.701	2.998

4. Empirical analysis

4.1. Baseline regression results

The regression results are shown in Table 2, indicating that supply chain digitization improves TFP.

Table 2. Basic regression results

VARIABLES	(1)	(2)	(3)	(4)
	ols	ols	ols	ols
Digitalization	6.316***	1.376***	1.288***	0.956***
	(17.34)	(5.75)	(5.02)	(3.72)
Size		14.434***	11.505***	11.239***
		(208.65)	(111.65)	(106.67)
ROA		3.840***	3.209***	3.200***
		(55.79)	(40.82)	(40.76)
Leverage		-0.004	0.007*	0.010***
		(-1.21)	(1.89)	(2.66)
Cash		0.001	0.000	-0.000

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Table 2. (continued)

		(1.07)	(0.01)	(-0.38)
Age			0.014***	0.008***
			(19.57)	(8.91)
Board			0.001	0.005**
			(0.47)	(2.11)
Salary			-0.738***	-0.760***
			(-55.40)	(-56.63)
PE			-0.000***	-0.000***
			(-13.82)	(-13.85)
Top5			-0.029	0.001
			(-1.41)	(0.05)
GDP				0.086***
				(9.38)
Industry				0.003***
				(4.35)
Finance				0.017
				(1.32)
Constant	8.028***	-36.599***	-27.322***	-27.589***
	(454.06)	(-171.35)	(-86.16)	(-85.33)
Observations	35,877	30,833	22,930	22,923
Number of enterprise	4,922	4,787	3,313	3,308
R-squared	0.0067	0.6564	0.7019	0.7109

Note: The values in brackets are Z values, *** p<0.01, ** p<0.05, * p<0.1.

4.2. Robustness analysis

First, replace the explained variables. This study uses TFP indicators calculated by other methods (OP method, GMM method) to replace the original indicators. The regression results are shown in columns (1) to (2) of Table 3. Second, use other models for regression. This study uses random effect models and fixed effect models for re-estimation. The regression results are shown in columns (3) to (4) of Table 3. Third, remove outliers and re-estimate. The regression results are shown in column (5) of Table 3. It can be seen that the impact of SCD on TFP is always positive.

Table 3. Robustness test results

VARIABLES	(1)	(2)	(3)	(4)	(5)
	OP	GMM	RE	FE	Delete outliers
Digitalization	0.851***	1.297***	1.297***	0.612**	0.769***
	(3.30)	(4.64)	(4.64)	(2.08)	(2.91)
Control variable	Yes	Yes	Yes	Yes	Yes
Constant	-19.396***	-14.902***	-14.902***	-13.078***	-27.373***

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Table 3. (continued)

	(-59.68)	(-42.16)	(-42.16)	(-27.63)	(-85.68)
Observations	22,923	22,923	22,923	22,923	22,923
Number of enterprise	3,308	3,308	3,308	3,308	3,308
R-squared	0.581	0.446		0.487	0.72

Note: Same as above.

4.3. Mechanism verification

Table 4 confirms that resource allocation efficiency (overinvest) and innovation investment (R&D) serve as moderators. Efficient allocation aligns digital investment with production needs to minimize waste, while high R&D spending boosts absorptive capacity, enabling firms to fully leverage SCD's innovative potential.

Table 4. Mechanism test results

VARIABLES	(1)	(2)
	TFP_LP	TFP_LP
Overinvest	-0.042***	
	(-2.98)	
Overinvest*Digitalization	0.944**	
	(2.34)	
R&D		-4.443***
		(-13.87)
R&D*Digitalization		45.343***
		(5.96)
Digitalization	0.269	-0.492
	(0.94)	(-1.04)
Control variable	Yes	Yes
Constant	-25.233***	-28.611***
	(-73.45)	(-61.89)
Observations	19,870	12,758
Number of enterprise	3,154	3,084

Note: Same as above.

4.4. Heterogeneity test

The results of the heterogeneity test are shown in Table 5. For private enterprises and those without major deficiencies, supply chain digitization has a significant positive impact on TFP, while for state-owned enterprises and those with major deficiencies, this impact is insignificant.

For private enterprises, with clear property rights and a clear market orientation, management focuses more on operational efficiency and long-term competitiveness. Supply chain digitization can directly address the pain points of private enterprises in information collaboration, inventory

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turnover, and supplier management. Furthermore, private enterprises have shorter decision-making chains and higher execution efficiency, allowing them to quickly integrate digital tools into production processes, significantly improving resource allocation efficiency and output levels. In contrast, while state-owned enterprises have resource advantages, they are constrained by administrative assessment targets (such as employment stability and scale expansion) or hierarchical approval systems, which may limit their internal motivation for digital transformation. Some state-owned enterprises prefer to maintain traditional supply chain models or divert digital investment to inefficient areas, preventing them from fully realizing the benefits of technology.

For enterprises with major deficiencies (such as financial difficulties, disorganized management, or weak technical foundations), the effectiveness of supply chain digitization is significantly suppressed. These companies often lack supporting digital infrastructure (such as ERP systems), data management capabilities, or specialized talent, making it difficult to effectively integrate digital information from upstream and downstream supply chains. Furthermore, these core deficiencies prioritize corporate resources, squeeze digital investment, and even exacerbate operational risks due to improper technology application. Therefore, even if digitalization is promoted, its impact on improving TFP is unlikely to be evident.

Table 5. Heterogeneity test results

VARIABLES	(1)	(2)	(3)	(4)
	State-owned enterprise	Private enterprise	Enterprises with significant defects	Enterprises without major defects
Digitalization	0.153	0.780**	2.012	0.951***
	(0.31)	(2.51)	(0.54)	(3.68)
Control variable	Yes	Yes	Yes	Yes
Constant	-27.434***	-26.759***	-20.241***	-27.691***
	(-43.40)	(-67.85)	(-5.15)	(-85.41)
Observations	6,554	14,765	160	22,763
Number of enterprise	906	2,491	133	3,306

Note: Same as above.

5. Conclusion

This study empirically analyzes the impact of SCD on the TFP of enterprises. Research has found that the digitalization of the supply chain has enhanced the TFP of enterprises and has undergone a series of robustness tests. Mechanism analysis indicates that the efficiency of enterprise resource allocation and enterprise innovation input can further positively regulate the promoting effect of SCD on the TFP of enterprises. Heterogeneity analysis indicates that for private enterprises and those without significant deficiencies, the positive impact of SCD on the TFP of enterprises is more significant, while for state-owned enterprises and those with significant deficiencies, this impact effect is not significant.

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