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Innovation Spillovers from Core Enterprises' Digital Transformation: Evidence from Client-Supplier Relationships

Zhao Yun Yun[1]

[1] Student of International Trade and Economics, Anhui University of Finance and Economics, China

Correspondence: Zhao Yun Yun, Student of International Trade and Economics, Anhui University of Finance and Economics, Bengbu 233003, China.

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Abstract

Drawing upon supply chain data from Shanghai and Shenzhen A-share listed companies between 2007 and 2022, this study examines the impact of core enterprises' digital transformation on suppliers' innovation. Findings reveal that digital transformation in core enterprises stimulates suppliers' innovation, with a stronger effect on substantive innovation than on strategic innovation. Mechanism analysis indicates that core enterprises' digital transformation primarily drives supplier innovation through financial spillovers, knowledge spillovers, and innovation facilitation. Heterogeneity analysis reveals that the promotional effect is more pronounced when client-supplier relationship dependency is low, suppliers operate in high-tech industries, and suppliers are non-state-owned enterprises. Adopting a supply chain perspective, this study refines the existing research on client enterprises' digital transformation influencing supplier innovation, offering insights for advancing corporate innovation and fostering collaborative innovation within supply chains.

Keywords: digital transformation, core enterprise, supply chain, substantive innovation, strategic innovation

1. Introduction

Innovation serves as the core driving force behind economic development and forms the foundation for building a powerful nation driven by scientific and technological innovation. During his inspection tour in Heilongjiang, General Secretary Xi Jinping emphasized the need to "integrate resources for scientific and technological innovation, spearhead the development of strategic emerging industries and future industries, and accelerate the formation of new productive forces." As the core element of new-quality productive forces, scientific and technological innovation drives technological advancement, fosters emerging industries, spurs industrial innovation, and promotes high-quality economic development in China. The report to the 20th CPC National Congress called for "accelerating the achievement of high-level self-reliance and strength in science and technology, and reinforcing the leading role of enterprises in scientific and technological innovation." Small and medium-sized enterprises (SMEs), as vital components of the corporate sector, are among the most dynamic entities in technological innovation and constitute a crucial force in enhancing the nation's independent innovation capabilities. According to data from the Ministry of Industry and Information Technology's 2022 China Patent Survey Report, SMEs accounted for over 60% of all enterprise invention patents in 2022. The industrialization rates of invention patents for medium and small enterprises stood at 55.4% and 45.3%, respectively, while the industrialization rates of valid patents reached 56.5% and 50.5%. SMEs constitute 99% of all enterprises, yet their patent output remains relatively low compared to their sheer numbers, indicating that their innovation potential has not been fully tapped. Enhancing the innovation efficiency of SMEs, unlocking their innovation potential, strengthening their role as innovation drivers, and elevating China's independent innovation capacity have become pressing issues requiring immediate attention.

Concurrently, the digital wave is sweeping across the globe, fueling the vigorous development of the digital economy and driving deeper integration of digital technologies into industrial applications. The 2024 Government Work Report from the Two Sessions emphasized the need to "formulate policies to promote high-quality development of the digital economy, advance the digitalization of industries and the industrialization of digital technologies, drive innovative development in the digital economy, accelerate the formation of digital industrial clusters, foster the integration of the digital economy with the real economy, and advance the digital transformation of manufacturing enterprises." Enterprise digital transformation, by driving the restructuring of production relations and the integration of digital technologies, enhances economic and innovation efficiency, emerging as a

new engine for corporate innovation. Additionally, enterprises can enhance their innovation efficiency by accessing resources through supply chain participation. Supply chains serve as primary channels for enterprises to obtain external knowledge, technology, and financial support. SMEs can alleviate their financing constraints through supply chain relationships, gain greater financial backing, increase investment in innovation, and thereby elevate their innovation efficiency. Amidst the digital wave, considering the influence of supply chain relationships, can the digital transformation of core enterprises impact the innovation efficiency of upstream suppliers through the supply chain?

Based on this, this paper investigates how the digital transformation of core enterprises (as customers) affects the innovation efficiency of SMEs (as suppliers). Using text mining analysis, we construct indicators for core enterprise digital transformation from publicly listed companies' annual reports. By matching customer and supplier data, we examine the direct impact of customer enterprises' digital transformation on supplier innovation efficiency from a customer-supplier perspective. Furthermore, this study explores the underlying mechanisms through which client enterprises' digital transformation indirectly influences suppliers' innovation efficiency via financial spillovers, knowledge spillovers, and innovation spillovers. Finally, heterogeneity analysis is conducted based on the property rights nature of SMEs (suppliers), geographical distance from clients, and the degree of client-supplier interdependence.

The paper's contributions include: ① Expanding the scope of corporate digital transformation impacts. Existing research primarily focuses on the effects of digital transformation on the transforming firm itself—examining its influence on total factor productivity, innovation performance, stock liquidity, etc. (Zhao, Chen Yu et al., 2021; Li Xuesong et al., 2022; Wu Fei et al., 2021), while neglecting its effects on other firms within the supply chain. This study thus examines the spillover effects of digital transformation, investigating how the digital transformation of core client firms impacts the innovation efficiency of SME suppliers, thereby extending the influence of digital transformation to the supply chain level. ② It provides empirical evidence from the customer-supplier perspective on enhancing innovation efficiency for SMEs. Specifically, the digital transformation of customer enterprises can provide resources to SMEs (suppliers), helping them overcome innovation bottlenecks and improve their innovation efficiency. This study examines the impact of customer digital transformation on supplier innovation efficiency through three dimensions: financial spillovers, knowledge spillovers, and innovation spillovers. ③ It offers recommendations for SMEs to effectively leverage supply chain relationships to enhance their innovation efficiency and for core enterprises to establish efficient customer-supplier relationships.

2. Literature Review and Research Hypotheses

2.1 Literature Review

2.1.1 Enterprise Digital Transformation

Enterprise digital transformation is a systematic, comprehensive, and long-term change driven by digital technologies and centered on data resources, involving multiple attribute transformations (Sun, Zhongjuan et al., 2023). Current research on corporate digital transformation primarily focuses on its influencing factors and economic outcomes. Factors affecting digital transformation are categorized into internal drivers and external influences. Internally, team characteristics of corporate executives—such as gender composition—impact transformation. Female executives, with their stronger academic backgrounds and preference for long-term sustainable value, facilitate more successful digital transformation (Yang Zhen, Chen Jin, 2024). Regarding external influences, digital infrastructure policies can increase regional supply of digital products and services, providing impetus for corporate digital transformation. Simultaneously, such policies can reduce the growth rate of corporate operating costs, improve business performance, and offer intrinsic support for digital transformation (Wang Hai et al., 2023). Government innovation subsidies also significantly influence corporate digital transformation. By enhancing the innovation environment, these subsidies help businesses overcome technological constraints, alleviate digital resource limitations, and accelerate digital transformation (Du Chuanzhong et al., 2023). Additionally, Fan Jiaying and Wan Hualin (2024) argue that international trade frictions place enterprises under pressure, compelling them to pursue cost reduction, technological innovation, and enhanced information acquisition capabilities—thereby driving digital transformation.

Existing research on the economic consequences of enterprise digital transformation primarily focuses on the enterprise level. Digital transformation can reduce information asymmetry, enhance innovation momentum and internal control quality, further lower capital costs (Qiu Yan et al., 2024), improve investment efficiency, boost total factor productivity and resource allocation efficiency (Lü Kefu et al., 2023), and elevate operational efficiency to enhance overall performance (ZHAI et al., 2022). Wang Bo and Kang Qi (2023) further found that digital transformation can enhance corporate financial and environmental performance by promoting green product

innovation, green process innovation, and green management innovation, thereby ensuring sustainable development outcomes.

2.1.2 Corporate Innovation Efficiency

Innovation serves as the intrinsic driving force for sustainable corporate development. Existing literature on corporate innovation efficiency primarily examines factors influencing innovation from two perspectives: First, external factors. Corporate innovation efficiency is often shaped by government actions and policies. Government procurement stimulates corporate innovation demand while signaling to external investors to alleviate financing constraints, thereby promoting innovation (Dai et al., 2020). “Deleveraging” policies intensify financing constraints, compelling enterprises to enhance management efficiency and thereby driving innovation (Liu Huihao et al., 2023). Concurrently, government subsidies alleviate funding pressures for R&D investments, with both mechanisms synergistically promoting innovation (Wu Jinguang et al., 2022). Additionally, factors such as human capital accumulation (Zhang et al., 2024), the digital economy (Li et al., 2022), industry-finance integration (Tian et al., 2022), business environment (Xin et al., 2023), and fintech services (Wang, 2023) can alleviate corporate financing constraints and incentivize innovation. Second, internal factors. Corporate innovation is significantly influenced by factors such as equity structure and executive team characteristics. Gao Lei and Zhao Yudi (2023) found that mixed-ownership structures with multiple heterogeneous major shareholders provide enterprises with diverse resources, enhance risk-taking capacity, offer varied financing channels, alleviate capital pressures, and ultimately stimulate innovation. Huang Xinhong and Sun Meijuan (2023) propose that executive pay gaps can incentivize corporate innovation, with executive risk preferences playing a positive moderating role. Li et al. (2019), using data from Chinese listed companies between 2008 and 2017, further revealed that technology directors can increase the proportion of corporate R&D investment, promote patent applications and grants, and positively influence corporate innovation. Additionally, Shi Lei and Peng Zichen (2024), based on the Schumpeterian innovation paradigm, found that corporate digital transformation facilitates knowledge accumulation and Schumpeterian rent capture, thereby incentivizing innovation. Zhang Xin and Dong Zhu (2023) analyzed how corporate digital transformation impacts innovation efficiency from internal and external perspectives. They found that internally, digital transformation enhances operational efficiency by retaining high-end talent, thereby boosting innovation efficiency. Externally, it improves innovation efficiency by securing favorable institutional environments that help companies obtain policy subsidies and market attention.

Synthesizing the above literature, existing research on digital transformation determinants primarily focuses on team characteristics, policy support, fiscal subsidies, and trade environments. Economic outcomes of digital transformation mainly revolve around cost reduction, efficiency gains, and environmental improvements. Similarly, studies examining internal factors influencing corporate innovation have concentrated on equity structure, management characteristics, and corporate transformation. Research on external factors affecting innovation has also centered on fiscal policy, infrastructure, and business environments, without considering impacts from upstream and downstream supply chain enterprises.

Existing research on supply chain diffusion effects primarily examines spillover effects within supply chains. Li Yunhe et al. (2022) found that digital transformation in client firms promotes upstream digital transformation through governance linkages and organizational learning among supply chain firms. Zhang Tao and Li Lei (2024) further revealed that corporate digital transformation can mitigate information asymmetry between upstream and downstream firms, thereby accelerating their digital transformation. Additionally, Liu Sheng et al. (2023) propose that supplier digital transformation can increase client firms' developmental innovation expenditures, reduce transaction costs, and enhance downstream clients' production efficiency. Li Qingyuan et al. (2023), adopting a client-supplier perspective, suggest that client firms' digital transformation can lower suppliers' information search and verification costs, generating information spillover effects that further influence suppliers' decision-making and boost their total factor productivity. The aforementioned literature primarily examines the promotion of digital transformation, productivity gains, and information environment improvements among upstream and downstream enterprises from a supply chain spillover perspective. Few studies have considered the driving role of core enterprises within supply chains, specifically whether the digital transformation of core enterprises can enhance the innovation efficiency of upstream suppliers.

2.2 Research Hypotheses

2.2.1 Core Enterprises' Digital Transformation and Innovation Efficiency of Upstream SMEs.

Enterprise digital transformation leverages digital technologies to enhance resource allocation efficiency, enabling efficient mobilization of external resources, alleviating resource constraints, facilitating communication between enterprises and innovation organizations, broadening knowledge horizons, promoting access to innovation

resources, and driving technological innovation. It accelerates the acquisition of low-cost knowledge and information, reduces trial-and-error costs in technological innovation, and provides safeguards for enterprise technological advancement. Within supply chains, core enterprises control pivotal resources—including information, capital, and key technologies—creating asymmetric dependencies among upstream and downstream partners. Consequently, these partners often innovate in response to the core enterprise's digital transformation needs to access its technologies and resources. From the customer-supplier perspective, establishing strong, enduring transactional relationships with key client enterprises facilitates resource flow between companies, benefiting technological innovation. Moreover, the client enterprise itself represents a vital resource for the supplier. Tightly intertwined interests between clients and suppliers, influenced by the convergence of interests effect, motivate client enterprises to engage in low-cost information and technology resource exchanges with suppliers. This supports suppliers' technological innovation efforts. Based on the above analysis, this paper argues that the digital transformation of core enterprises impacts the innovation efficiency of upstream SMEs through capital spillovers, knowledge spillovers, and innovation spillovers.

Regarding capital spillover effects, after digital transformation, core enterprises adopt more open and inclusive management models, strengthening ties with upstream supply chain partners. Prioritizing collaborative benefits, they enhance information exchange and resource sharing with upstream suppliers to maintain cooperative client-supplier relationships, willingly supporting SMEs. A crucial safeguard for sustained and stable innovation among SMEs is robust financing capacity. Current financing difficulties for SMEs primarily stem from two aspects of traditional financial markets: collateral structure and information asymmetry. In China's traditional financial markets, tangible assets constitute a significant portion of acceptable collateral, while intangible assets (such as future cash flows) account for a smaller share. Given their smaller scale and limited tangible assets, SMEs face constraints in accessing financing due to this collateral structure. Following digital transformation, core enterprises strengthen relationships with upstream supply chain partners, forming shared-interest communities. To prevent financial distress among upstream SMEs from spreading through the supply chain, core enterprises provide commercial credit guarantees, alleviating SMEs' financing constraints. Simultaneously, this digital transformation enhances the core enterprise's capacity to supply commercial credit (Qi Huajin et al., 2022). Core enterprises can extend greater commercial credit to upstream SMEs, facilitating their access to external financing, alleviating financing constraints, and promoting technological innovation among SMEs. However, limited disclosure of operational information by SMEs prevents capital providers from accurately assessing their financial health. This information asymmetry between SMEs and capital providers impedes SMEs' ability to secure external financing. The digital transformation of core enterprises breaks down internal boundaries, enhances information transmission efficiency and quality, and increases transparency in upstream and downstream information. This effectively mitigates information asymmetry within the supply chain, conveying positive operational information about SMEs to capital markets. Consequently, it improves financing constraints for upstream SMEs, increases their investment in innovation, and promotes technological innovation among SMEs.

From the perspective of knowledge spillover effects, digital technology—as the core of enterprise digital transformation—reduces firms' information search and verification costs, enabling them to acquire knowledge and technology at lower expense. It bridges spatial and temporal gaps between customers and suppliers, facilitating connections and promoting the dissemination of knowledge resources throughout the supply chain. Simultaneously, data—as the core resource of enterprise digital transformation—exhibits characteristics of non-rivalry, non-depletion, and ease of replication. Given the partial non-exclusivity and non-rivalry of knowledge, data can generate knowledge spillovers through knowledge creation and accumulation. The digital transformation of core enterprises drives the generation and flow of vast amounts of data, thereby accelerating knowledge spillovers. Following digital transformation, core enterprises establish tighter connections with upstream SMEs. Through digital technologies, core enterprises and upstream SMEs achieve shared access to information and data resources, fostering the accumulation of knowledge assets among SMEs. This deepens and broadens SME knowledge, laying the foundation for their innovation. It also breaks down “data silos” within upstream SMEs, reducing their knowledge acquisition and learning costs, thereby enhancing innovation efficiency.

From the perspective of innovation spillover effects, the digital transformation of core enterprises can boost corporate innovation efficiency, reduce interaction costs with upstream and downstream enterprises, foster connections between core enterprises and upstream SMEs, and advance collaborative innovation between core enterprises and upstream SMEs. Upstream SMEs can participate in the innovation processes of core enterprises, gaining access to low-cost knowledge and technological resources, learning core enterprises' innovation models, and obtaining opportunities for imitative innovation. This drives SMEs toward independent or imitative innovation, thereby boosting their innovation efficiency. Key elements of innovation diffusion theory include innovation

sources, diffusion channels, and innovation adoption. Technological innovations, successful experiences, and lessons learned during the core enterprise's digital transformation can all serve as innovation sources. The commercial ties between core enterprises and upstream SMEs establish innovation networks, transforming the supply chain into a channel for innovation diffusion. Core enterprises disseminate their innovation experiences to upstream SMEs through this supply chain. Following digital transformation, core enterprises experience enhanced innovation efficiency and increasingly diverse, personalized innovation demands. They feed these demands back to upstream SMEs. To maintain stable customer-supplier relationships, upstream SMEs strive to improve their own innovation efficiency to meet the innovation needs of their client enterprises.

2.2.2 Based on the Above Analysis, This Paper Proposes the Following Hypotheses

H1: The digital transformation of core enterprises has a significant positive impact on the innovation of upstream SMEs.

H2: Core enterprises' digital transformation drives innovation among upstream SMEs through financial spillovers, knowledge spillovers, and innovation spillovers.

3. Research Design

3.1 Data Sources and Sample Selection

This study utilizes supply chain relationship data from the top five suppliers and customers of Shanghai and Shenzhen A-share listed companies between 2007 and 2021. Referencing the "Regulations on the Classification Standards for Small and Medium-sized Enterprises [2011]," an annual-customer (core enterprise)–supplier (SME) dataset. For example, in a given year (2016), one customer (X) may correspond to multiple suppliers (A, B, C), leading to the construction of datasets such as 2016–X–A, 2016–X–B, and 2016–X–C. Considering that information on corporate digital transformation only publicly discloses impacts on supplier innovation, and supplier innovation exhibits lagging effects, this study uses data for core enterprises from 2007 to 2022 and for upstream SMEs from 2008 to 2023.

Enterprise-level data utilizes the CSMAR database, while digital transformation metrics derive from text mining and keyword extraction of listed companies' annual reports. Supply chain data sources include the China National Research Data Service Platform (CNRDS). The following data processing steps were applied to raw data: ① Exclusion of company samples designated as ST, *ST, or PT during the sample period; ② Given incomplete data disclosure and information accessibility for non-listed companies, samples were selected where both core enterprises and upstream SMEs were listed companies; ③ To mitigate the impact of outliers, continuous variables at the company level underwent trimming at the upper and lower 1% extremes.

3.2 Variable Selection

3.2.1 Explanatory Variable: Core Enterprise Digital Transformation.

Following the methodologies of Wu Fei et al. (2021) and Yuan Chun et al. (2021), employing text analysis. Python crawlers were used to collect annual reports of core enterprises listed on the Shanghai and Shenzhen stock exchanges. The Chinese word segmentation library jieba processed the reports to identify keyword frequencies related to digital transformation. Given the right skewness of the data, the counts were incremented by one and then log-transformed to yield the number of digital transformation keywords (digit), serving as a measure of core enterprise digital transformation.

3.2.2 Dependent Variable: SME Innovation.

Following the methodology of Li Wenjing and Zheng Manni (2016), this study employs the number of patent applications filed by SMEs as the metric for corporate innovation. Three variables are constructed: innovation capacity, substantive innovation, and strategic innovation. Specifically, the total number of patents applied for by an enterprise is treated as innovation capability, the number of invention patent applications as substantive innovation, and the sum of utility model and design patents as strategic innovation. Considering the right skewness of the data, the sum of these variables is taken to the logarithm to obtain enterprise innovation (patent), substantive innovation (patent1), and strategic innovation (patent2).

3.2.3 Control Variables.

Following Yang, Jin-Yu et al. (2022), we select profitability (ROA), net cash flow (cashflow), leverage ratio (lev), Tobin's Q (tq), firm size (size), firm age (age), and R&D expenditure ratio (rd) as control variables.

3.3 Model Specification

$$Innovation_{i,t} = \alpha_0 + \alpha_1 Digit_{i,t-1} + \alpha_2 Controls_{i,t-1} + Year_{t-1} + Industry_{i,t-1} + \varepsilon_{i,t} \quad (1)$$

In Model (1), Innovation represents SME innovation, encompassing corporate innovation (patent), substantive innovation (patent1), and strategic innovation (patent2); Digit denotes core enterprise digital transformation, calculated as the logarithm of the number of core enterprise digital transformation keywords plus 1 (digit); Controls signifies a series of control variables; this study also controls for industry and annual fixed effects.

4. Empirical Analysis

4.1 Benchmark Regression

Table 1 presents the regression results for the impact of core enterprises' digital transformation on suppliers' innovation capabilities. Columns (1) to (3) indicate that, after controlling for variables and accounting for industry and year fixed effects, core enterprises' digital transformation (digit) significantly and positively influences suppliers' innovation (patent), substantive innovation (patent1), and strategic innovation (patent2) at the 1% level. However, regression coefficients reveal that the impact of core enterprises' digital transformation on suppliers' substantive innovation is stronger than on their strategic innovation. Core enterprises' digital transformation drives supplier innovation primarily by promoting both substantive and strategic innovation. Hypothesis H1 is thus validated overall.

Table 1. Benchmark Regression

	(1)	(2)	(3)
	patent	patent1	patent2
digit	0.1824***	0.1719***	0.1628***
	(0.0551)	(0.0554)	(0.0599)
Controls	Yes	Yes	Yes
Industry-Year Fix Effects	Yes	Yes	Yes
Observation	571	571	571
R-squared	0.6538	0.6725	0.6239

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The values in parentheses represent standard errors. This applies to all tables below.

4.2 Endogeneity Testing

4.2.1 Instrumental Variables Method

To mitigate potential endogeneity issues, this study adopts the approach of Lewbel (1997) and Yang, Jin-Yu et al. (2022). The difference-squared term between the core enterprise digital transformation index and the mean difference of enterprise digital transformation classified by secondary industry codes and provinces is selected as the instrumental variable (IV). The two-stage least squares method is employed for testing. Column (1) of Table 2 indicates that the instrumental variable (IV) is positively significant at the 1% level for core enterprises' digital transformation, with an F-value exceeding 10, passing the weak IV test. Column (2) shows that the IV has no significant effect on supplier innovation, passing the exclusion test. Columns (3) to (5) indicate that after passing the instrumental variable test, the core enterprise's digital transformation positively and significantly influences supplier innovation, substantive innovation, and strategic innovation at the 1%, 5%, and 5% significance levels, respectively, with robust benchmark regression results.

4.2.2 Heckman Two-Stage Model Test

Given that listed companies voluntarily disclose information about their customers and suppliers, endogeneity issues arising from sample self-selection bias may occur. Following Li Qingyuan et al. (2023), this study selects whether the core enterprise has undergone digital transformation (a digital transformation indicator greater than zero for core enterprises, with the dummy variable set to 1; otherwise, 0) as the new dependent variable. Relevant variables influencing corporate digital transformation are selected for Probit regression to estimate the inverse Mills ratio (IMR), which is then incorporated into the regression in the second stage. Table 3 indicates that after controlling for sample selection bias, core enterprises' digital transformation significantly and positively impacts supplier innovation, confirming the robustness of the benchmark regression results.

Table 2. Instrumental Variable Test

	(1)	(2)	(3)	(4)	(5)

	digit	patent	patent	patent1	patent2
digit		0.2138***	0.3908***	0.3099**	0.2834**
		(0.0606)	(0.1223)	(0.1251)	(0.1279)
IV	0.0692***	-0.0075			
	(0.0120)	(0.0097)			
Controls	Yes	Yes	Yes	Yes	Yes
Industry/Year Fix Effects	Yes	Yes	Yes	Yes	Yes
Observation	571	571	571	571	571
R-squared	0.4921	0.6591	0.6569	0.6735	0.6257

Table 3. Heckman Two-Stage Model Tests

	(1)	(2)	(3)
	patent	patent1	patent2
digit	0.1908***	0.1863***	0.1688***
	(0.0545)	(0.0556)	(0.0594)
IMR	-0.2094	-0.4999	0.0613
	(0.6917)	(0.6295)	(0.6551)
Controls	Yes	Yes	Yes
Industry/Year Fix Effects	Yes	Yes	Yes
Observation	571	571	571
R-squared	0.6495	0.6707	0.6175

4.2.3 Propensity Score Matching Test

To mitigate endogeneity issues arising from sample self-selection bias, this study employs propensity score matching to re-estimate the econometric model. The core firm's adoption of digital transformation serves as the matching criterion, with control variables from the baseline regression used as matching variables. 1:3 proximity matching approach is applied to the entire sample. The matched samples satisfy the common support assumption and pass balance tests. A baseline regression is then conducted on the matched sample. The regression results are presented in Table 4. Core enterprises' digital transformation positively and significantly influences suppliers' innovation, substantive innovation, and strategic innovation at the 1% significance level. The benchmark regression results are robust.

Table 4 Propensity Score Matching Test

	(1)	(2)	(3)
	patent	patent1	patent2
digit	0.2183***	0.2067***	0.1841***
	(0.0591)	(0.0587)	(0.0638)
Controls	Yes	Yes	Yes
Industry/Year Fix Effects	Yes	Yes	Yes
Observation	471	471	471
R-squared	0.6928	0.7108	0.6539

(III) Robustness Tests

1. GMM Tests

Considering that improvements in supplier innovation levels may be influenced by the previous year's innovation performance—i.e., higher innovation levels could stem from inherently strong prior-year innovation, creating reverse causality issues—this study employs a dynamic panel model (GMM). Specifically, the supplier's innovation level from the previous year is treated as a control variable, and regression is conducted using Model (1). The test results are shown in Table 5. After incorporating the supplier's innovation level from the previous year as a control variable, the core enterprise's digital transformation still significantly positively affects the supplier's innovation level, substantive innovation, and strategic innovation at the 5% level. This indicates that the benchmark regression results are robust, and hypothesis H1 remains valid.

2. Alternative Measures for Variables

To mitigate errors arising from single-indicator calculations, this study employs alternative measures for the dependent variable to conduct robustness tests. This study employs the number of patent grants as an indicator of corporate innovation. The logarithm of the total number of patent grants plus one is used as the innovation measure (patentgrant). The logarithm of the number of invention patent grants plus one is used as the innovation quality measure (patentgrant1). The logarithm of the total number of utility model and design patent grants plus one is used as the innovation quantity measure (patentgrant2). Table 6 indicates that after replacing the dependent variable, the core firm's digital transformation positively and significantly influences supplier innovation, innovation quality, and innovation quantity at the 5%, 1%, and 5% significance levels, respectively. The benchmark regression results are robust.

Table 5. GMM Test Results

	(1)	(2)	(3)
	patent	patent1	patent2
digit	0.0909**	0.0790**	0.0901**
	(0.0393)	(0.0385)	(0.0437)
L.patent	0.7864***		
	(0.0322)		
L.patent1		0.7944***	
		(0.0306)	
L.patent2			0.7490***
			(0.0314)
Controls	Yes	Yes	Yes
Industry/Year Fix Effects	Yes	Yes	Yes
Observation	571	571	571
R-squared	0.8655	0.8735	0.8376

Table 6. Test Results for Replacing the Dependent Variable

	(1)	(2)	(3)
	patentgrant	patentgrant1	patentgrant2
digit	0.1039**	0.0966***	0.0758**
	(0.0409)	(0.0339)	(0.0373)
Controls	Yes	Yes	Yes
Industry/Year Fix Effects	Yes	Yes	Yes
Observation	571	571	571
R-squared	0.6765	0.6601	0.6456

5. Mechanism Testing and Heterogeneity Analysis

5.1 Mechanism Testing

To examine the mechanism through which the digital transformation of core enterprises influences innovation in supplier firms, this study constructs the following model based on Jiang Ting (2022):

$$M_{i,t} = \alpha_0 + \alpha_1 Digit_{i,t-1} + \alpha_2 Controls_{i,t-1} + Year_{t-1} + Industry_{i,t-1} + \varepsilon_{i,t} \quad (2)$$

Where M denotes the mediating variable, with other variables identical to Model (1).

5.1.1 Mechanism of Capital Spillover

As analyzed earlier, the digital transformation of core enterprises enhances their capacity to supply commercial credit. As closely integrated interest groups, core enterprises are willing to provide commercial credit guarantees to suppliers, alleviating their financing constraints. Therefore, this study selects credit supply (Cost) and financing constraints (KZ)—specifically, the proportion of accounts payable to total assets and the KZ index—as mediating variables. As shown in Table 9(1), the digital transformation of core enterprises positively and significantly impacts suppliers' credit supply at the 5% level. This transformation enables core enterprises to provide greater credit supply to suppliers, helping them secure more funding. The KZ index indicates the degree of financing

constraints faced by supplier enterprises; a higher KZ index signifies greater financing constraints. As shown in Table 8(2), the digital transformation of core enterprises has a significant negative effect on the KZ index at the 5% level, indicating that it can help suppliers alleviate financing constraints. Core enterprises' digital transformation alleviates suppliers' financing constraints through capital spillover, enabling suppliers to access more disposable funds. This leads to increased R&D activities among supplier enterprises, thereby promoting their innovative development (Wang Tao and Liu Dongwang, 2025).

5.1.2 Knowledge Spillovers

As analyzed earlier, the extensive application of digital technologies during the core enterprise's digital transformation enables it to accumulate rich knowledge and experience, enhancing its knowledge stock. As closely linked stakeholders, suppliers can access the core enterprise's technologies and innovation experience at relatively low cost, thereby advancing their own technological innovation. Based on this, this study measures enterprise knowledge spillovers using the logarithm of the sum of the enterprise's patent index plus one. Table 8(3) shows that the digital transformation of core enterprises significantly and positively impacts corporate knowledge spillover at the 1% significance level. This transformation facilitates the flow of innovative knowledge across supply chains, reduces suppliers' information search costs, lowers their innovation costs, and enables them to acquire the core enterprises' innovation experience for imitative innovation, thereby further enhancing suppliers' innovation capabilities (Guan Xin and Li Fengyuan, 2025).

5.1.3 Innovation Spillover

As analyzed earlier, the digital transformation of core enterprises can stimulate their own innovation. Based on the theory of innovation diffusion, the innovation achievements of core enterprises, as innovation sources, can diffuse to other enterprises in the supply chain through the diffusion channel of the supply chain. Simultaneously, as enterprises within the same supply chain, core enterprises and their suppliers have strong interdependencies in product production, facilitating the formation of innovation networks and promoting collaborative innovation between core enterprises and suppliers. Therefore, this study measures core enterprises' innovation spillover (Cus_patent) by taking the logarithm of the core enterprise's patent applications plus one. As shown in Column (4) of Table 7, the digital transformation of core enterprises significantly promotes their innovation.

Table 7. Mechanism Verification Results

	(1)	(2)	(3)	(4)
	Cost	KZ	Knowledge	Cus_patent
digit	0.0114**	-0.2728**	0.1455**	0.1182**
	(0.0045)	(0.1123)	(0.0624)	(0.0514)
Controls	Yes	Yes	Yes	Yes
Industry/Year Fix Effects	Yes	Yes	Yes	Yes
Observation	571	571	571	571
R-squared	0.5789	0.4410	0.2662	0.2668

(II) Heterogeneity Analysis

1. Customer-Supplier Relationship Dependency

As closely aligned stakeholders, suppliers can access innovative technologies and expertise from customer enterprises. Higher customer-supplier dependency enables suppliers to acquire greater technological innovations and experience. However, excessive dependency may lead suppliers to over-rely on customer innovations, diminishing their own innovation initiatives. This study measures customer-supplier dependency by the proportion of supplier procurement expenditures relative to the customer firm's total procurement spending. Based on the mean value of this dependency, firms are categorized into high customer-supplier dependency (Rely=1) and low customer-supplier dependency (Rely=0). As shown in Panel A of Table 8, within the high-dependence group, the regression coefficient for core enterprise digital transformation on supplier innovation is positive but not significant. Conversely, in the low-dependence group, this relationship is positively significant at the 1%, 1%, and 5% levels. Thus, core enterprise digital transformation demonstrates a stronger promotional effect on supplier innovation when customer-supplier relationship dependence is lower.

2. Industry Heterogeneity

Different industries exhibit varying degrees of sensitivity and demand for innovation. Non-high-tech industries, as traditional sectors, exhibit stable demand for technological innovation. Conversely, high-tech industries demonstrate high sensitivity and demand for technological innovation. Engaging in technological innovation enhances corporate competitiveness. Therefore, when suppliers operate in high-tech industries, they are more eager to absorb knowledge spillovers from clients to drive corporate innovation and development. Consequently, this study categorizes supplier firms into high-tech enterprises (Tech=1) and non-high-tech enterprises (Tech=0) for grouped regression analysis. As shown in Panel B of Table 9, when suppliers operate in high-tech industries, the regression coefficient for core enterprise digital transformation on supplier innovation is positive and significant at the 1% level. When suppliers are in non-high-tech industries, the coefficient is positive but not significant. Thus, core enterprise digital transformation more effectively promotes supplier innovation when suppliers are in high-tech sectors.

3. Corporate Property Rights Heterogeneity

Enterprises with different property rights exhibit varying degrees of customer focus and dependency. State-owned enterprises (SOEs) receive government financial support, face fewer financing constraints, and thus have lower demand for financial spillovers from customers. Additionally, SOEs possess specific knowledge channels, reducing their need for knowledge spillovers from customers. Consequently, compared to non-state-owned enterprises, the digital transformation of core enterprises has a limited impact on the innovation of SOE suppliers. Based on this, this paper groups suppliers by ownership into state-owned enterprises (SOE=1) and non-state-owned enterprises (SOE=0) for regression analysis. As shown in Panel C of Table 10, when suppliers are non-state-owned enterprises, the regression coefficient for core enterprise digital transformation on supplier innovation is positive and significant at the 1% level. When suppliers are state-owned enterprises, the regression coefficient is positive but not significant. Therefore, when suppliers are state-owned enterprises, the digital transformation of core enterprises more effectively promotes the innovative development of supplier enterprises.

Table 8. Test for Heterogeneity

PanelA：Customer-Supplier Relationship Dependency						
	(1)	(2)	(3)	(4)	(5)	(6)
	Rely=1	Rely=0	Rely=1	Rely=0	Rely=1	Rely=0
	patent		patent1		patent2	
digit	0.1969	0.1896***	0.1924	0.1647***	0.1789	0.1752**
	(0.1165)	(0.0623)	(0.1207)	(0.0637)	(0.1154)	(0.0685)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry/Year Fix Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observation	153	418	153	418	153	418
R-squared	0.8408	0.6179	0.7270	0.6383	0.8371	0.6011
PanelB：Industry Heterogeneity						
	Tech=1	Tech=0	Tech=1	Tech=0	Tech=1	Tech=0
	patent		patent1		patent2	
digit	0.1656***	0.1796	0.1731***	0.1086	0.1464***	0.0864
	(0.0507)	(0.1396)	(0.0470)	(0.1427)	(0.0380)	(0.1248)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry/Year Fix Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observation	423	148	423	148	423	148
R-squared	0.6585	0.8155	0.6349	0.8458	0.6368	0.7761
PanelC：Corporate Property Rights Heterogeneity						
	SOE=1	SOE=0	SOE=1	SOE=0	SOE=1	SOE=0
	patent		patent1		patent2	
digit	0.0883	0.2713***	0.0781	0.3458***	0.0856	0.1808**
	(0.0801)	(0.0780)	(0.0785)	(0.0785)	(0.0872)	(0.0830)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry/Year Fix Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observation	242	329	242	329	242	329
R-squared	0.7028	0.7814	0.7050	0.7632	0.7045	0.6640

6. Conclusions and Implications

6.1 Conclusions

This study examines the impact of core enterprises' digital transformation on supplier innovation through the lens of customer-supplier relationships. It holds significant implications for fostering corporate innovation, advancing supply chain collaborative innovation, and promoting China's economic development. Using client-supplier data from A-share listed companies between 2007 and 2022, this study examines how core enterprises' digital transformation influences supplier innovation. Findings indicate: (1) Core enterprises' digital transformation promotes supplier innovation, with a stronger impact on substantive innovation than on strategic innovation. This result holds after endogeneity and robustness tests. (2) Core enterprises' digital transformation primarily stimulates supplier innovation through financial spillovers (alleviating suppliers' financing constraints), knowledge spillovers (absorbing core enterprises' technological expertise), and innovation spillovers (facilitating the diffusion of core enterprises' innovations). (3) The impact of core enterprises' digital transformation on supplier innovation is more pronounced when customer-supplier relationship dependency is low, suppliers operate in high-tech industries, and suppliers are non-state-owned enterprises.

6.2 Implications

Based on the above findings, this study offers the following insights:

First, fully leverage the resource diffusion effects of core enterprises' digital transformation to drive collaborative innovation within supply chains. As demonstrated, digital transformation in core enterprises promotes supplier innovation through financial, knowledge, and innovation spillovers, with stronger impacts on substantive innovation. This indicates robust resource diffusion effects. Governments and enterprises should fully recognize this effect. Core enterprises should proactively strengthen cooperation with suppliers during their transformation process, driving supplier innovation through sharing technical expertise, providing financial support, and promoting innovation diffusion. Governments can introduce policies encouraging core enterprises to play a leading role, establish supply chain collaborative innovation platforms, facilitate information exchange and resource sharing, promote coordinated development among upstream and downstream enterprises, enhance the innovation capacity and competitiveness of the entire supply chain, and inject new momentum into China's economic development.

Second, develop differentiated policies considering the heterogeneity of core enterprises' digital transformation on supplier innovation. The impact of core enterprises' digital transformation on supplier innovation varies based on customer-supplier relationship dependency, industry attributes, and enterprise nature. It is more pronounced in low-dependency relationships, high-tech industries, and non-state-owned enterprises. When formulating policies, governments should fully account for these variations by implementing differentiated support measures for various supplier types. For instance, non-state-owned enterprises and high-tech suppliers could receive increased innovation subsidies and tax incentives. For suppliers with low relationship dependency, greater emphasis should be placed on guiding core enterprises toward deepening collaboration, achieving mutual benefits, and enhancing policy precision and effectiveness.

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