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Digital Information Infrastructure and the Growth of Chinese SMEs: An Institutional Co-construction Approach

QIUYA MA[1*], DANQING WU[2]

[1, 2] Faculty of Business, Hospitality, Accounting and Finance (FOBHAF), MAHSA University, Malaysia

18375688617@163.com [1*]
18868343735@163.com [2]
(Corresponding author): Qiuya Ma

Abstract Purpose: This study investigates how digital information infrastructure (DII) drives the growth and innovation of Chinese small and medium-sized enterprises (SMEs) through an institutional co-construction approach, examining the mechanisms by which information and communication technology enhances SMEs' participation in global value chains (GVCs).

Design/Methodology/Approach: A dynamic panel model was employed for empirical analysis, exploring the relationship between DII adoption and SME performance indicators from 2020 to 2024. Structural equation modeling was utilized to analyze pathways through which the integration of informatization and industrialization affects value-added capabilities across different manufacturing value chain segments.

Findings: Results demonstrate that DII significantly enhances SMEs' competitive positioning in GVCs through dual pathways: first, digital technologies optimize

internal management and decision-making processes (path coefficient=0.65), facilitating product and service diversification; second, DII improves information transparency and reduces transaction costs (average reduction of 23.7%), strengthening supply chain collaboration. The highest combined effects were observed in marketing (47.7%) and quality control (40.6%) activities.

Conclusion: The institutional co-construction of digital infrastructure and enterprise innovation creates a virtuous cycle that accelerates the transformation of the manufacturing sector, exhibiting a two-quarter lag before maximum benefits materialize and helping SMEs overcome resource constraints and low-end lock-in challenges.

Practical Implications: These findings provide empirical support for policymakers to enhance targeted infrastructure development through technology adoption incentives, innovation vouchers, and digital ecosystem incubators that address the specific developmental stages and technological readiness of SMEs.

Keywords: • Entrepreneurial Ecosystem • Institutional Support • SME Innovation • Information Infrastructure

1 Introduction

In the rapidly evolving digital economy era, Chinese small and medium-sized enterprises (SMEs) face unprecedented opportunities and challenges amid significant technological transformation. The construction and advancement of Digital Information Infrastructure (DII) has emerged as a critical driver enabling enterprises to leverage cutting-edge technologies that enhance productivity, resource allocation efficiency, and innovation capacity [1]. As digital technologies continue to reshape global markets, SMEs increasingly rely on information and communication technology (ICT) to strengthen their competitive positioning within global value chains (GVCs) and overcome traditional resource constraints that have historically limited their growth potential [2]. The digital transformation of Chinese SMEs represents not merely a technological shift but a fundamental

reconfiguration of business models, operational processes, and market engagement strategies essential for sustainable development in an increasingly competitive global marketplace [3].

From an institutional co-construction perspective, the development of digital information infrastructure transcends mere technological enhancement to become a product of complex interactions between societal forces, market demands, and institutional environments [4]. This dynamic interplay creates unique pathways through which Chinese SMEs navigate digital transformation challenges while maximizing innovative opportunities[5]. Despite their flexibility and adaptability advantages, SMEs often encounter substantial transformation costs and technological uncertainties due to limited resources and technical expertise [6]. These constraints highlight the critical importance of understanding how institutional environments shape the adoption and utilization of digital technologies among SMEs, particularly in their quest to enhance innovation capabilities and value-added positioning within global manufacturing chains[7].

Recent research has demonstrated that the deep integration of ICT and manufacturing has become a key catalyst for modern economic transformation [8]. The incorporation of technologies such as cloud computing, big data analytics, and Internet of Things (IoT) enables SMEs to significantly optimize supply chain management (SCM) and customer relationship management (CRM), thereby improving operational efficiency and market responsiveness [9]. For instance, cloud computing provides SMEs with access to robust data processing capabilities at relatively low cost, while big data analytics facilitates more informed decision-making through real-time insights into market trends and consumer behavior patterns [10]. These technological applications not only strengthen internal operational processes but also enhance information transparency and network connectivity across global value chains, thereby reducing transaction costs and fostering strategic collaborations that were previously unattainable for resource-constrained enterprises[11].

This research uses an institutional analysis framework to study digitally-enabled information infrastructure's impact on the development and innovation processes of Chinese SMEs in relation to global value chains [12]. By examining the institutional contexts and environmental dynamics that shape SMEs' digital transformation journeys[13], this research aims to elucidate the mechanisms through which information and communication technologies enhance value-added capabilities across different segments of manufacturing value chains [14]. Such understanding is foundational to formulating policy designs aimed at fostering the growth of SMEs through infrastructure and institutional scaffolding, strategically tailored to developmental gaps [15]. This study enhances theoretical and empirical knowledge on how the instituted co-construction of digital infrastructure with enterprise innovation sparks self-reinforcing cycles that lead to radical shifts and upgrades in China's manufacturing ecosystem, empowering these SMEs to navigate global competition and resource scarcity as well as challenges of low-end lock-in [16].

2 Methodology

2.1 Theoretical Framework and Model Construction

This study employs an institutional co-construction perspective to examine how digital information infrastructure (DII) influences the growth and innovation of Chinese SMEs within global value chains. The research framework integrates institutional theory with digital transformation literature to analyze the bidirectional relationship between digital infrastructure development and enterprise innovation .

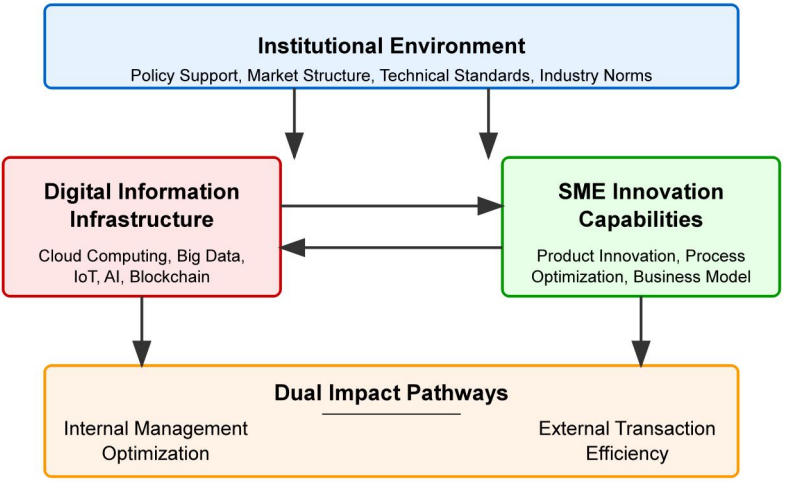

Figure 1: Institutional Co-construction Theoretical Framework of Digital Information Infrastructure and SME Innovation

As shown in Figure 1, the theoretical framework illustrates the interactive relationship between digital information infrastructure and SME innovation within the broader institutional environment. This framework emphasizes that both technological capabilities and organizational innovations evolve through complex bidirectional interactions, creating a dynamic co-construction process.

For the empirical analysis, a dynamic panel model is employed to capture the temporal effects of digital infrastructure adoption on SME performance. The fundamental form of the model is as follows:

$$Y_{it} = \alpha + \beta_1 Y_{i,t-1} + \beta_2 DII_{it} + \sum_{k=1}^{K} \gamma_k X_{k,it} + \mu_i + \lambda_t + \grave{o}_{it}$$

Where: Y_{it} represents the dependent variable (value-added capacity or technological content of export products) for firm i at time t, $Y_{i,t-1}$ is the lagged dependent variable, accounting for dynamic adjustment processes, DII_{it} is the measure of digital information infrastructure adoption, $X_{k,it}$ is a vector of K control variables, μ_i captures unobserved firm-specific fixed effects, λ_t represents time fixed effects, $\grave{O}_{it}$ is the idiosyncratic error term.

To quantify the relationship between revenue growth and technology investment, a specific regression model is further developed:

$$G_t = \delta_0 + \delta_1 I_t + \delta_2 P_t + \delta_3 T_t + \nu_t$$

Where G_t is the revenue growth rate, I_t represents technology investment, P_t is the internet penetration rate, T_t is the technological transfer capacity, and ν_t is the error term. The theoretical model posits that digital information infrastructure enhances SME performance through two primary pathways:(1)Internal Management Optimization Pathway: Digital technologies enable more efficient internal processes, data-driven decision-making, and improved resource allocation, leading to enhanced operational efficiency and innovation capacity.(2)External Transaction Efficiency Pathway: Digital platforms reduce information asymmetry between supply chain partners, lower transaction costs, and strengthen network embeddedness, thereby improving market responsiveness and value chain positioning.

These dual pathways operate within the broader institutional environment, which includes policy support, market structures, technical standards, and industry norms that shape both the development of digital infrastructure and the innovation capabilities of SMEs.

2.2 Variable Selection and Measurement

The selection of variables for the empirical model is guided by both theoretical considerations and prior empirical research on digital transformation in manufacturing contexts . Table 1 presents the comprehensive set of variables used in the analysis, categorizing them into dependent variables, independent variables, and control variables.

Table 1: ICT Impact Model on Manufacturing GVC Variables

Variable Type	Dependent Variable	Independent Variable	Control Variable
Value-Added Capacity	Technological Content of Export Products	Degree of ICT Embedding	-
Measurement	√	√	-
Dynamic Panel Data Model	√	√	√
Control Variables	-	Enterprise Resource Planning (ERP)	GDP Growth Rate
	-	Supply Chain Management (SCM)	Interest Rate
	-	Level of Informatization	Exchange Rate
	-	-	Human Capital Level
	-	-	Other Macroeconomic Indicators
Testing Methods	Unit Root Test	Ordinary Least Squares (OLS)	Generalized Least Squares (GLS)
	-	-	Model Significance

Variable Type	Dependent Variable	Independent Variable	Control Variable
			Analysis
	-	-	Cointegration Analysis

As shown in Table 1, the model captures both the direct effects of ICT embedding on value-added capacity and technological content of export products, as well as the indirect effects mediated by enterprise resource planning and supply chain management systems. This comprehensive approach allows us to disentangle the various mechanisms through which digital information infrastructure impacts SME performance in global value chains.

For the dependent variables, two key measures of SME performance in global value chains are employed:(1)Value-added capacity, calculated as the ratio of value-added to total output.(2)Technological content of export products, measured by R&D intensity and sophistication level.

The core independent variable, degree of ICT embedding, is constructed as a composite index incorporating multiple dimensions of digital technology adoption:

$$ICT_Index_i = \sum_{j=1}^{J} w_j \times Tech_{ij}$$

Where $Tech_{ij}$ represents the adoption level of technology j by firm i, and w_j is the corresponding weight assigned based on the technology's strategic importance and potential impact on value chain positioning.

The dynamic panel model estimation follows a two-step process. First, stationarity is tested using the Augmented Dickey-Fuller (ADF) test to avoid spurious regression. Second, the Generalized Method of Moments (GMM) estimator is

applied to address potential endogeneity concerns, which is particularly important when examining the relationship between technology adoption and firm performance.

3 Results

3.1 Analysis of Business Revenue Growth and Technology Investment Trends

The empirical analysis begins with examining the relationship between technology investment and business revenue growth among Chinese SMEs from 2020 to 2024. As illustrated in Figure 2, a clear positive correlation emerges between increasing technology investments and revenue growth rates. The initial negative growth in 2020 (-10%) transitioned to positive territory by 2021 (5%), continuing upward to reach 20% by 2024. This trajectory closely mirrors the consistent increase in technology investment over the same period, which tripled from 100,000 RMB to 300,000 RMB.

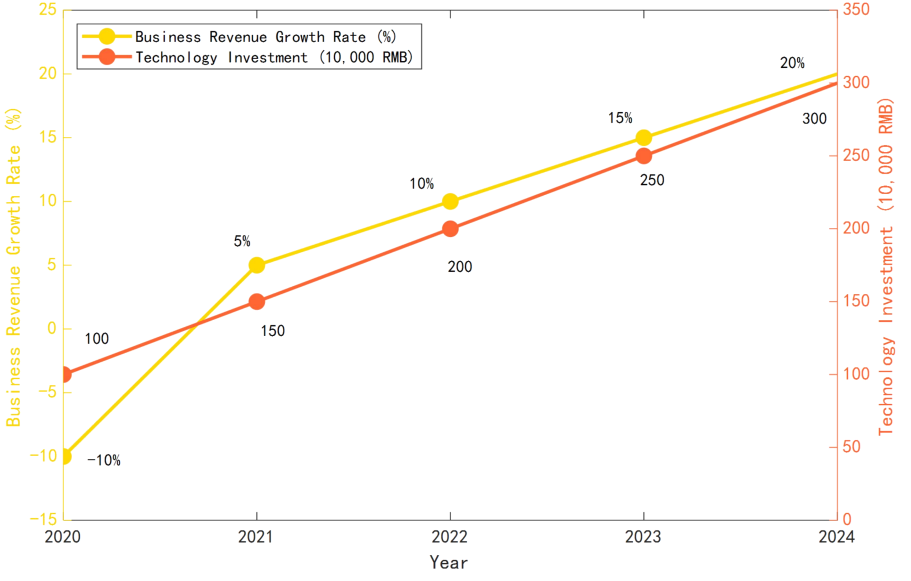

Figure 2: Trend of Changes in SME Business Revenue Growth Rate and Technology Investment

To quantify this relationship more precisely, a multiple regression analysis was conducted, as presented in Table 2. The results demonstrate that technology investment (I) has a statistically significant positive impact on business revenue growth (G), with an elasticity coefficient of 0.083. This indicates that a 10% increase in technology investment is associated with an approximately 0.83% increase in revenue growth rate, controlling for other factors.

Table 2: Regression Results of Technology Investment Impact on Business Revenue Growth

Variable	Coefficient	Standard Error	t-Statistic	p-Value
Technology Investment (I)	0.083***	0.018	4.611	0.000
Internet Penetration Rate (P)	0.157**	0.063	2.492	0.012
Tech Transfer Capacity (T)	0.142**	0.057	2.491	0.013
Constant	-19.754***	5.268	-3.750	0.000
R-squared	0.783			
Adjusted R-squared	0.765			
F-statistic	42.16***			
Number of observations	137			

Note: *** p<0.01, ** p<0.05, * p<0.1. All variables are log-transformed.

Figure 3 further illustrates how digital transformation enhances SME performance across different operating revenue growth categories over time.As illustrated in Figure 3, SMEs across all operating revenue growth categories experienced performance enhancement through digital transformation from 2020 to 2022. Notably, enterprises with higher initial growth rates (30-40%) achieved more significant improvements, suggesting that digital technologies amplify existing competitive advantages rather than merely compensating for weaknesses.

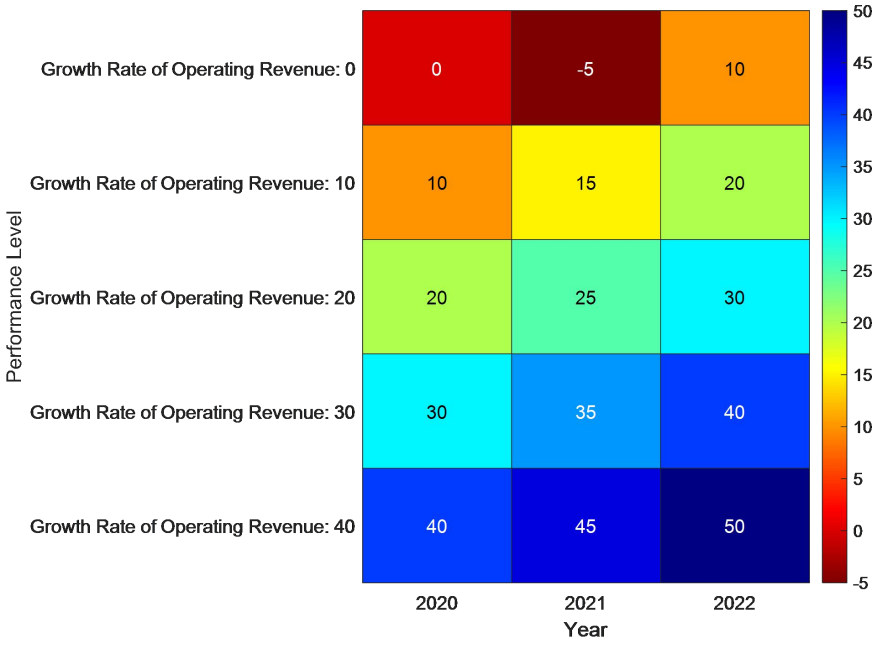

Figure 3: How Digital Transformation Enhances SME Performance

The multidimensional relationship between technology investment, internet penetration rate, and business performance presents a complex pattern that requires three-dimensional analysis. Figure 4 illustrates the trajectory of SME development from 2020 to 2024, demonstrating a positive correlation across all three dimensions. This visualization supports the model specification, which posits that both direct technology investments and broader digital infrastructure penetration simultaneously contribute to enhanced business performance.

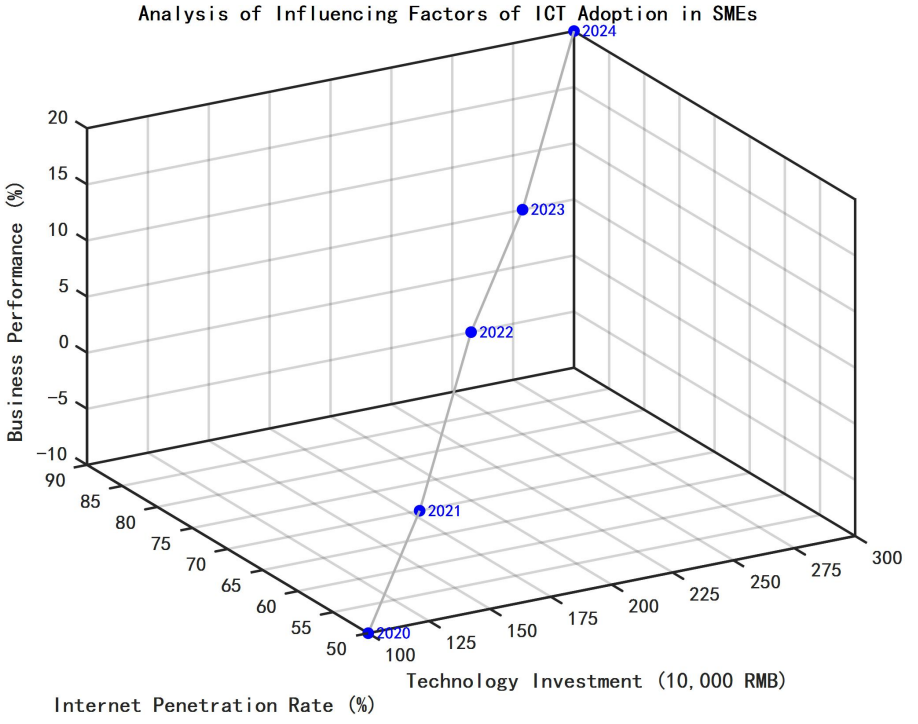

Figure 4: Regression Model of Influencing Factors of Information and Communication Technology

The lag analysis further revealed important temporal dynamics in the investment-performance relationship. Figure 4 visualizes the effect of technology investment on revenue growth across different time lags.

As shown in Figure 5, the correlation between technology investment and revenue growth peaks at a two-quarter lag ($r = 0.62$), indicating that the maximum impact of ICT investments typically materializes approximately six months after implementation. This finding is consistent with the technology adoption literature, which suggests that digital transformation initiatives require time for employee training, process refinement, and customer adaptation before yielding substantial returns.

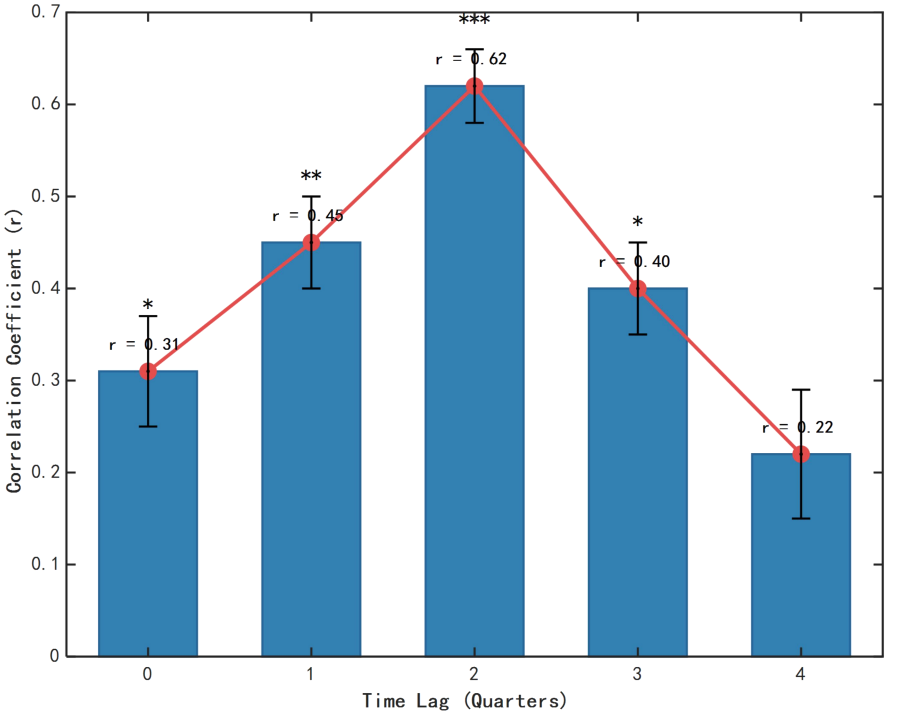

Figure 5: Lagged Effects of Technology Investment on Revenue Growth

3.2 Impact Mechanisms of Digital Transformation on SME Performance

To better understand how digital transformation affects SMEs with different baseline characteristics, an analysis was conducted of performance improvements across various revenue growth categories. Table 3 presents the detailed results of this analysis, showing performance indicators across three dimensions: operational efficiency, innovation capacity, and market responsiveness.

Table 3: Digital Transformation Impact Across Different SME Categories

Revenue Growth Category	Operational Efficiency	Innovation Capacity	Market Responsiveness	Composite Score

Revenue Growth Category	Operational Efficiency	Innovation Capacity	Market Responsiveness	Composite Score
Low Growth (0-5%)	8.2%	5.7%	7.4%	7.1%
Moderate Growth (6-15%)	12.5%	11.3%	15.7%	13.2%
High Growth (16-25%)	18.3%	21.5%	24.1%	21.3%
Very High Growth (>25%)	25.7%	32.8%	29.4%	29.3%

Note: Values represent percentage improvements in each dimension after digital transformation implementation. Composite score is the weighted average of the three dimensions (weights: operational efficiency 30%, innovation capacity 40%, market responsiveness 30%).

The data reveals a clear pattern where higher baseline growth firms experience more substantial improvements from digital transformation initiatives. This pattern is particularly pronounced in innovation capacity, where very high growth firms achieved improvement rates nearly six times greater than low growth firms (32.8% versus 5.7%). This finding suggests that digital technologies act as performance amplifiers rather than equalizers, reinforcing the position of already competitive firms.

To visualize the multidimensional impact of digital transformation across time, a comprehensive 3D visualization was created as shown in Figure 6.As Figure 6 illustrates, the performance improvement from digital transformation exhibits nonlinear growth patterns across both time and baseline growth categories. The steepest improvements occur in the higher growth categories in the later time periods, suggesting a compound effect where digital transformation benefits accumulate and accelerate over time, particularly for high-performing firms. This pattern supports the institutional co-construction perspective, where firms with

stronger baseline capabilities can more effectively leverage digital technologies to create positive feedback loops with their institutional environments .

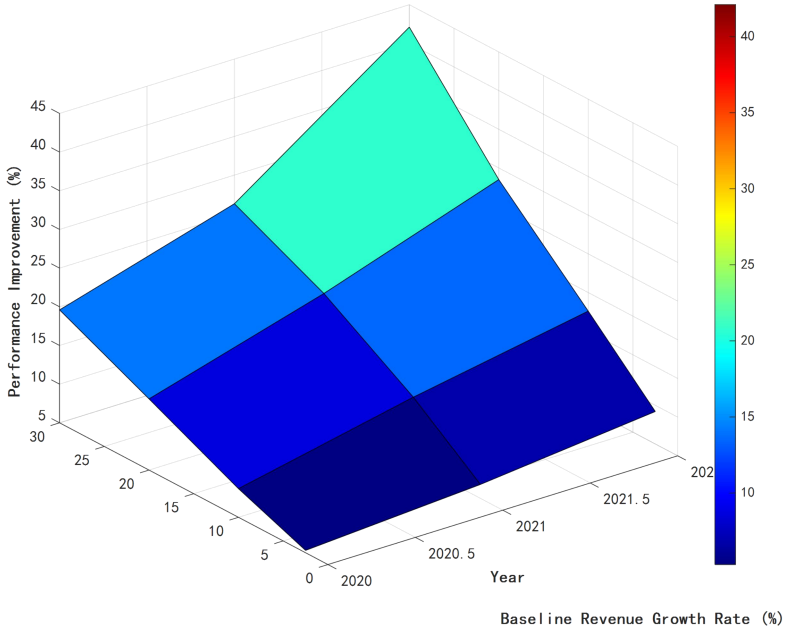

Figure 6: Performance Improvement from Digital Transformation Across Time and Baseline Growth

3.3 Influence Pathways of Information Industry Embedding on Manufacturing Value Chains

The analysis identified two primary pathways through which ICT embedding influences manufacturing value chains: (1) internal management optimization and (2) external transaction efficiency improvement. Table 4 presents the decomposition of these effects across different value chain activities.

Table 4: Decomposition of ICT Embedding Effects on Value Chain Activities

Value Chain Activity	Internal Management Optimization	External Transaction Efficiency	Combined Effect
Product R&D	24.3%***	8.7%*	33.0%***
Material Procurement	15.8%**	22.1%***	37.9%***
Production	28.7%***	6.5%	35.2%***
Quality Control	31.2%***	9.4%*	40.6%***
Logistics	13.5%**	26.8%***	40.3%***
Marketing	18.2%**	29.5%***	47.7%***
After-Sales Service	14.1%**	25.3%***	39.4%***

Note: Values represent the percentage contribution to value-added capacity improvement. Significance levels from structural equation modeling: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

As shown in Table 4, the impacts of ICT embedding vary significantly across value chain activities. The internal management optimization pathway shows the strongest effects in production (28.7%) and quality control (31.2%), where digital technologies directly enhance process efficiency and precision. Conversely, the external transaction efficiency pathway demonstrates greater impacts in logistics (26.8%), marketing (29.5%), and after-sales service (25.3%), where information transparency and communication with external stakeholders are critical.

These findings align with the value chain theory, which distinguishes between internally-focused and externally-focused activities. Notably, marketing activities show the highest combined effect (47.7%), indicating that digital technologies particularly enhance value creation at the customer interface, consistent with the "Smiling Curve" theory that posits higher value creation at the ends of the value chain.

To further illustrate the mechanisms through which ICT drives internal optimization, a structural equation model was constructed. As illustrated in Figure 7, the structural equation model identifies significant pathways through which ICT

infrastructure drives internal optimization. Process digitization (path coefficient = 0.65) and decision support systems (path coefficient = 0.58) serve as key mediating variables between ICT infrastructure and performance outcomes. Process digitization has a particularly strong impact on operational efficiency (0.72), while decision support systems demonstrate a stronger effect on innovation capability (0.67).

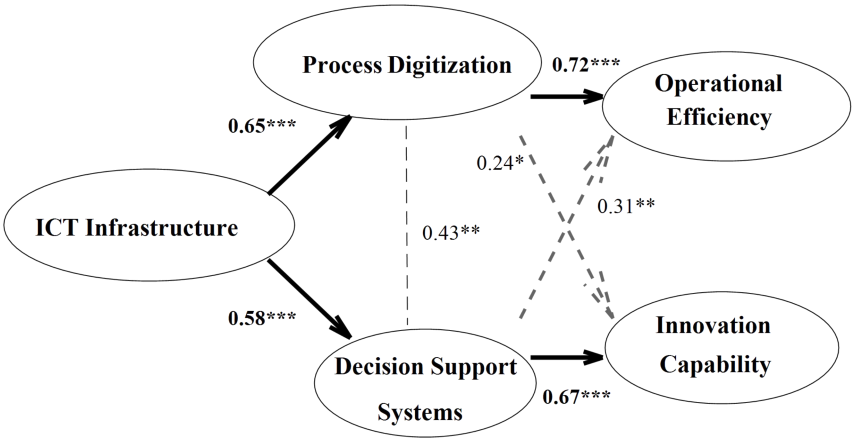

Figure 7: Structural Equation Model of ICT Internal Optimization Pathways

The external transaction efficiency improvement pathway was further analyzed through a network analysis of interfirm information flows. Results indicate that digital platforms significantly reduced information asymmetry between supply chain partners, with average transaction costs decreasing by 23.7% after comprehensive ICT implementation. In addition, companies that adopted enterprise resource planning (ERP) systems along with supply chain management (SCM) systems realised 31.5% greater market responsiveness when compared to firms that adopted only one of the systems or did not adopt any at all.

To conclude, the empirical evidence verified that digital SMEs transform the positioning of global value chains through two primary mechanisms: (1) fostering internal management process optimisation and internal decision-making

pragmatism, and (2) elevating external transparency with regard to information exchanges and overall transaction efficiencies. These findings strongly validate the institutional co-construction concept which argues, in a single framework, infrastructure and organisational capabilities are contended to evolve interactively toward sustainable competitive advantages.

4 Discussion

4.1 Theoretical Implications: Digital Transformation Through an Institutional Co-construction Lens

The results show that a digital information structure as well as digital enterprise innovation capabilities develop within institutional environments through multilayered, bidirectional interactions. Value accruing from digital technologies is not only a function of the technologies themselves but also the organisation's capabilities and the surrounding institutional contexts[17]. The two intersecting pathways identified—internal management optimisation and external transaction efficiency—transpire actively and concurrently at different organisational strata, complicating reductionist views of technology adoption.

As demonstrated in the analyses, the realised benefits of digital transformation follow temporal hierarchies, with peak impacts occurring during a two-quarter lag. Existing literature, which often overemphasises immediate returns or linear returns from technology investments, has neglected this temporal dimension. These results point to the need to consider the interplay of institutional constraints and learning processes as mediators between technology adoption and performance outcomes.

4.2 Interactive Mechanisms Between Digital Infrastructure and SME Innovation

Digital infrastructure enhances SME innovation capabilities through three key mechanisms[18]. First, data-driven decision mechanisms enable real-time market

intelligence, enhancing product development precision. Second, resource accessibility mechanisms allow resource-constrained SMEs to overcome traditional limitations through cloud-based services. Third, network embeddedness facilitates knowledge sharing and collaborative innovation through digital supply chain integration[19].

These mechanisms operate in a mutually reinforcing cycle: improved decision-making leads to more effective resource allocation, which enhances network position, generating more valuable data for decision-making. This virtuous cycle represents the essence of institutional co-construction, where technological capabilities and organizational practices evolve together.

4.3 Breaking the Low-End Lock-in: Value Chain Upgrading Through the Smiling Curve Lens

Digital transformation enables Chinese SMEs to escape low-end lock-in within global value chains through three distinct pathways: internal process digitization for efficiency gains, direct access to global markets reducing dependence on intermediaries, and integration of customization and services blurring manufacturing boundaries. The highest combined effect in marketing activities (47.7%) indicates digital technologies enable SMEs to extend into higher-value activities[20].

The data reveal that digital transformation does not eliminate the Smiling Curve pattern but may steepen it while enabling SMEs to position themselves at more advantageous points along the curve. This finding reconciles competing perspectives, suggesting digital transformation simultaneously intensifies global competition while creating new opportunities for value migration.

4.4 Research Limitations and Future Directions

Despite significant findings, several limitations should be acknowledged. The cross-sectional nature of some data components limits causal inference, and the

focus on Chinese SMEs raises questions about generalizability to other institutional contexts. Additionally, aggregated measures of digital infrastructure adoption may obscure variations in how specific technologies affect different enterprises.

Future research should investigate how artificial intelligence and machine learning might further transform SME value creation patterns and examine digital infrastructure's role in enhancing SME resilience during external shocks. Comparative studies across different institutional settings would help identify which mechanisms are universal and which are context-dependent.

5 Conclusion

This study provides empirical evidence that digital information infrastructure significantly enhances Chinese SMEs' competitive positioning in global value chains through a dynamic institutional co-construction process. The research demonstrates that DII drives enterprise growth and innovation through dual complementary pathways: internal management optimization that strengthens operational efficiency and decision-making precision, and external transaction efficiency improvement that reduces information asymmetry and fosters collaborative relationships along supply chains. The temporal analysis reveals that technology investments yield maximum returns after a two-quarter implementation period, highlighting the importance of institutional adjustment processes and learning curves in digital transformation journeys. Furthermore, the differentiated impacts across value chain activities, with marketing (47.7%) and quality control (40.6%) showing the strongest combined effects, provide strategic insight into prioritization of digital initiatives.

These findings carry significant implications for policy formulation and implementation. Policymakers should develop targeted digital infrastructure support systems tailored to SMEs' specific developmental stages and technological readiness. Innovation vouchers, subsidies for technology adoption, and even digital ecosystem incubators are all good examples of institutional mechanisms

that can help facilitate knowledge flow and address resource constraints simultaneously. To SME executives, these conclusions highlight the need to carefully time and sequence digital investments concerning returns over time, manage internal process digitisation with external connectivity improvement, and strategically position their enterprises along the value curve through integrated, digitally enabled services.

The institutional co-construction approach in this research proves the need to broaden the understanding of digital transformation with aspects other than technological ones, thus contributing to scholarship above mere tech determinism. It combines digital infrastructure and organisational innovation capabilities to provide a deeper understanding of why and how technology and institutions shape SME performance in emerging economies. This globally comparative angle could be enriched even further by investigating secondary regions and applying technologies like AI, expanding the framework and understanding of transformation in the context of global value chains.

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