The Impact of Digital Transformation on Supply Chain Resilience in Manufacturing: An Empirical Analysis of A-Share Listed Manufacturing Enterprises in China

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Abstract: Against a backdrop of heightened global uncertainty, supply chain resilience has emerged as a core competitive advantage for the survival and development of manufacturing enterprises. This study employs a two-way fixed effects model based on panel data from Chinese A-share listed manufacturing firms (19,751 observations) spanning 2011–2023 to empirically examine the impact of digital transformation on manufacturing supply chain resilience and its underlying mechanisms. The supply chain resilience index was constructed using the entropy method; The level of digital transformation was measured using the Guotai An (CSMAR) Digital Transformation Index. The findings reveal that digital transformation exerts a significant positive effect on supply chain resilience (baseline regression coefficient:0.0158, p<0.01), realized through two key pathways: alleviating corporate financing constraints (coefficient:-0.0051, p<0.05) and enhancing innovation capacity (measured by patent applications, coefficient:0.2934, p<0.01). This conclusion remains robust after a series of stability tests, including endogeneity treatment (lagged variable method), sample screening, and explanatory variable substitution. Heterogeneity analysis indicates that this enhancement effect is particularly pronounced in non-state-owned enterprises, large enterprises (coefficient: 0.0186, p<0.01; coefficient for SMEs: 0.0107, p<0.01) and enterprises in western regions (coefficient: 0.0238, p<0.01). This study provides empirical evidence and practical insights for Chinese manufacturing enterprises to enhance supply chain resilience and achieve high-quality development by leveraging the digital transformation wave.

Keywords: Digital Transformation; Supply Chain Resilience; Financing Constraints; Innovation Capacity; Manufacturing

1. Introduction

Manufacturing serves as the core pillar of the national economy and the primary driver of economic growth. However, the global manufacturing sector is currently facing significant disruptions: geopolitical conflicts (such as the Russia-Ukraine war causing energy shortages), extreme weather events (like the 2023 European supply chain disruptions), and recurring pandemic risks have laid bare the vulnerabilities within supply chains. The World Economic Forum's 2024 Global Supply Chain Resilience Report indicates that 63% of manufacturing enterprises suffered revenue losses exceeding 10% due to unanticipated disruptions. Digital transformation, leveraging technologies like big data and the Internet of Things to reconfigure business models, fundamentally breaks down information silos through "data". This shift not only alters production methods but profoundly reshapes supply chain operational logic, enhancing resilience[1]. However, consensus remains elusive on how this transformation translates into risk-resilient supply chain mechanisms, with limited accurate identification of its effects. Furthermore, existing research lacks analysis of the actual conditions of China's listed manufacturing enterprises, creating a gap between theory and practice.

This study analyzes existing literature and systematically examines actual data from China's listed manufacturing enterprises undergoing digital transformation. It reveals the positive impact of digital technologies on supply chain resilience through two pathways: "alleviating financing constraints" and "enhancing innovation capabilities." It further clarifies that the effects of digital transformation on supply chain resilience vary across enterprises differing in scale, ownership structure, and geographical location. ultimately providing scientific grounds

for enterprises to formulate effective digital strategies and optimize supply chain management.

2. Literature Review

2.1 Research on Digital Transformation

Digital transformation has emerged as a focal point of academic and practical discourse in recent years. Despite diverse definitions, its core essence remains consistent: the fundamental alteration of how organizations create, deliver, and capture value through digital technologies [2]. This transcends mere technological application or upgrades, constituting a systemic transformation encompassing strategy, organization, culture, and processes. Existing research primarily employs questionnaire surveys, case studies, input-based approaches, and text analysis to measure digital transformation. These, text analysis has emerged as the predominant method in recent years due to its broad sample coverage and high objectivity. Annual reports serve as formal documents conveying a company's strategic priorities and operational status to external stakeholders. The frequency of digital-related terminology within these reports can significantly reflect an organization's commitment to and depth of digital transformation practice. By employing natural language processing techniques, a digital transformation index can be constructed.

Compared to measuring digital transformation itself, greater attention is directed towards its economic consequences. Research consistently confirms that digital transformation enhances corporate productivity, improves operational performance, fosters innovation, and reduces management costs alongside information asymmetry. These studies provide crucial theoretical foundations for this paper's exploration of how digital transformation influences supply chain resilience through specific mechanisms.

2.2 Research on Supply Chain Resilience

The concept of supply chain resilience originated in ecology and psychology before being adopted within supply chain management. Christopher and Peck (2004) defined it as "the preparedness of a supply chain to cope with and resist unexpected events, and its ability to recover swiftly to its original state or even improve upon it following disruption"[4]. This definition emphasizes two core dimensions: pre-event "resistance capability" and post-event "recovery capability".

Measuring supply chain resilience presents research challenges due to its multidimensional complexity, making direct assessment difficult. Existing studies predominantly employ proxy variable approaches. One category relies on financial performance volatility metrics, such as sales revenue volatility or profit volatility, based on the logic that resilient supply chains better smooth performance fluctuations caused by external shocks [5]. The other category relies on operational efficiency metrics, such as inventory turnover rate and order fulfillment cycle. Some scholars contend that a higher inventory turnover rate reflects supply chain agility and resilience [6]. The application requires contextual validation; this paper further proposes that, within the Chinese manufacturing context, improvements in inventory turnover rate achieved through digitalization represent enhanced supply chain resilience.

Regarding factors influencing supply chain resilience, traditional research predominantly focuses on internal supply chain elements, such as establishing strategic inventory or achieving supplier diversification, with limited attention to fundamental drivers at the enterprise level, such as technological and organizational transformation.

2.3 The Relationship Between Digital Transformation and Supply Chain Resilience

Research into the relationship between digital transformation and supply chain resilience remains in its infancy yet holds significant potential. Existing studies predominantly employ qualitative analysis or case studies. Research such as Ivanov et al. (2019) and Wieland and Wallenburg (2013) has elucidated the theoretical or case-based possibilities for digitalization enhancing supply chain resilience. The core rationale lies in digital technologies' capacity to dismantle information silos, thereby enhancing supply chain 'visibility', 'agility', and 'collaboration'-visibility enabling real-time oversight of entire chain dynamics, agility ensuring rapid adjustments to production and logistics planning, and collaboration facilitating seamless upstream-downstream integration and joint decision-making. Together, these form the bedrock of resilient supply chains [7].

However, current research in this field exhibits a

distinct "literature gap": firstly, there is a lack of empirical evidence from large-scale samples, with existing conclusions often based on small-sample case studies or theoretical extrapolations, whose generalisability remains to be tested; secondly, the exploration of underlying mechanisms is insufficient, and the specific micro-level channels through which digital transformation empowers supply chain resilience remain unclear. As the "world's factory," China's manufacturing supply chains exhibit exceptional complexity and significance. Consequently, examining how Chinese enterprises enhance supply chain resilience through digitalization holds unique practical relevance[8].

In summary, this paper will build upon existing research by utilizing panel data from Chinese manufacturing listed companies to empirically examine the net effect of digital transformation on supply chain resilience. It will further explore the underlying mechanisms of this impact, aiming to fill gaps in the current literature.

3. Theoretical Analysis and Research Hypotheses

3.1 Direct Impact of Digital Transformation on Supply Chain Resilience

The core of supply chain resilience lies in coping with uncertainty. According to information processing theory, the fundamental approach for organizations to address uncertainty is to enhance their information processing capabilities[9]. Digital transformation constitutes precisely such a profound change centered on enhancing information processing capabilities. Its positive impact on supply chain resilience manifests primarily in the following aspects: Digital transformation empowers supply chain resilience through three dimensions: Firstly, it enhances "end-to-end visibility" by enabling real-time tracking of full-process data via IoT, RFID, and cloud-based supply chain management systems. This resolves the "bullwhip effect" inherent in traditional chain-based transmission, empowering managers to shift from reactive responses to proactive early warnings[10]; Secondly, it bolsters "rapid response agility" by leveraging big data and AI for precise demand forecasting and swift decision-making simulations, combined with flexible manufacturing technologies to adapt to supply disruptions or sudden demand shifts[11]. Thirdly, it fosters "ecosystem synergy" by using digital platforms like the Industrial Internet to dismantle corporate silos, transforming supply chains from linear competitive structures into networked symbiotic relationships that enhance collective risk resilience[12]. In summary, digital transformation comprehensively enhances enterprises' capacity to maintain operational stability and achieve rapid recovery in complex, volatile environments by improving supply chain visibility, agility, and collaboration. Accordingly, this paper proposes the first research hypothesis:

H1: Digital transformation exerts a significant positive influence on supply chain resilience within manufacturing enterprises.

3.2 Analysis of the Mechanism of Digital Transformation

The impact of digital transformation on supply chain resilience is not achieved overnight but through a series of profound internal and external changes. This paper posits that "alleviating financing constraints" and "enhancing innovation capabilities" represent two crucial mediating pathways.

3.2.1 Mitigating financing constraints pathway

Building supply chain resilience-whether through establishing strategic inventories, cultivating alternative suppliers, or investing in more resilient logistics networks-requires sustained, stable financial backing. However, financing constraints, particularly for private enterprises and SMEs within manufacturing, represent a persistent challenge. This stems from information asymmetry between firms and external funders (such as banks), where banks struggle to accurately assess a firm's true operational health and credit risk[13].

Digitalization can effectively alleviate this issue through two avenues: firstly, by leveraging ERP and MES systems to generate vast volumes of "hard data" through real-time operational recording, which more accurately reflects a company's operational health and cash flow stability than traditional financial statements[14] ; secondly, by fostering supply chain finance platforms based on big data and blockchain technology. Core enterprises can use these platforms to enhance the creditworthiness of SMEs, while banks can leverage multi-dimensional data to precisely assess repayment capacity, thereby extending loans at lower costs[15]. Thus, digital transformation improves corporate financing environments by

reducing information asymmetry, while ample capital provides essential "ammunition" for building supply chain resilience. Accordingly, this paper proposes a second research hypothesis:

H2: Digital transformation positively impacts supply chain resilience by alleviating enterprises' financing constraints.

3.2.2 Pathways to enhancing innovation capabilities

In dynamically changing environments, resilience signifies not merely recovery to the original state but evolution to an optimal state through learning and adaptation. Innovation capabilities, particularly technological and process innovation, are pivotal to achieving this adaptive upgrade.

Digital transformation serves as a potent engine for corporate innovation: on one hand, leveraging digital technologies such as digital twins and AI algorithms to enhance R&D efficiency, shorten cycles, reduce trial-and-error costs, and explore novel technological pathways[16]; on the other, catalyzing new production management models like flexible manufacturing and modular design, while optimizing processes through industrial internet to mitigate raw material shortages[17]. Robust innovation capabilities directly enhance supply chain resilience: product innovation circumvents critical component supply bottlenecks, while process innovation flexibly adapts to disruptions like logistics interruptions[18]. The dynamic capabilities thus fostered also drive continuous supply chain improvement to withstand subsequent shocks. In summary, digital transformation comprehensively elevates corporate innovation capabilities by empowering R&D, optimizing processes, and cultivating culture. This enhanced innovation capacity, in turn, endows supply chains with greater adaptability and evolutionary potential. Accordingly, this paper proposes a third research hypothesis:

H3: Digital transformation positively impacts supply chain resilience by enhancing an organization's innovation capabilities.

4. Research Design

4.1 Model Design

To test Hypothesis 1 and examine the impact of digital transformation on corporate supply chain resilience, this paper constructs the following model:

$$Res_{i,t}=, t+\alpha_1+, t+, t+\sum Individual+\varepsilon_{it} \quad (1)$$

In the baseline regression model, the supply chain resilience of manufacturing firm i in year t, the degree of digital transformation of manufacturing firm i in year t, the control variable, and the error term. The model controls for year fixed effects (Year) and individual fixed effects (Individual).

4.2 Variable Specification

4.2.1 Dependent variable

Corporate supply chain resilience (Res). This paper constructs an indicator system based on two dimensions: resistance capacity and recovery capacity, employing the entropy method to calculate the corporate supply chain resilience index. Resistance capacity primarily refers to a company's ability to ensure it remains unaffected when responding to emergencies and environmental disturbances during risk events. A firm's cost management directly impacts profit realization and influences its resilience to risks. Simultaneously, larger enterprises possess greater capacity to withstand event shocks. Therefore, this study primarily selects evaluation indicators for industrial chain resilience based on cost and scale, employing cost-to-revenue ratio and firm size as metrics. Recovery capacity primarily denotes a firm's ability to restore stability and sustain long-term viability through proactive measures such as resource reallocation following unexpected events or environmental disturbances. On the one hand, drawing upon the research of Zhang Weichuan et al., this paper primarily selects indicators for evaluating the recovery capability of industrial chain resilience based on capital returns and turnover, choosing return on net assets and inventory turnover rate as metrics. On the other hand, a diversified customer base enables enterprises to respond more flexibly to market demand fluctuations. Excessive supply chain concentration is detrimental to long-term operations, meaning that a greater number and dispersion of customers and suppliers enhance recovery after shocks. Hence, supply chain concentration is selected as an indicator. The specific indicator system is shown in Table 1.

4.2.2 Explanatory variables

Enterprise Digital Transformation (Dig). This study employs the Guotai An database (CSMAR) Digital Transformation Index as the explanatory variable. This index encompasses strategic

leadership, technological drive, organizational empowerment, digital outcomes and applications at the listed company level, alongside environmental support at the meso-macro level, offering a relatively comprehensive scoring system. To mitigate the impact of extreme values on regression results, logarithmic transformation is applied to the derived indicators.

4.2.3 Control variables

To further control for potential factors influencing corporate supply chain resilience, the following characteristic variables were selected as control variables: equity concentration, defined as the shareholding ratio of the largest shareholder; board size, defined as the logarithm of the number of board members; firm size, defined as the logarithm of total assets at the end of the period; leverage ratio (Lev), defined as total liabilities divided by total assets; cash flow, defined as the proportion of cash flow; firm age, defined as the number of years since the firm's establishment. A summary of all the above variables is presented in Table 1.

Table 1. Variable Definitions and Measurements

Variable Name	Variable Symbol	Variable Definition and Measurement Method
Supply Chain Resilience	Res	Combining the dimensions of overall resistance and recovery capacity, a comprehensive supply chain resilience index is constructed using six metrics: cost-to-revenue ratio, enterprise scale, return on net assets, inventory turnover rate, customer concentration, and supplier concentration. This index serves to measure
Digital Transformation	Dig	Measured using indicators such as the proportion of digital technology investment relative to total investment and the proportion of digital business revenue relative to total revenue.
Enterprise Scale	Size	Measured by the natural logarithm of total enterprise assets
Asset-liability ratio	Lev	Measured by the ratio of total liabilities to total assets
Cash Flow	Cashflow	Proportion of cash flow
Age of the enterprise	Age	Logarithm of listing duration
Number of Board Members	Board	Logarithm of Board Size
Shareholding Concentration	Share	Largest Shareholder's Holding Ratio

Table 2. Descriptive Statistics of Key Variables

Variable Name	Obs	Mean	SD	Min	Median	Max	Remarks
Res	19751	0.3951	0.1088	0.1833	0.3764	0.7585	Supply Chain Resilience
Dig	19751	0.1586	0.1961	0.0000	0.0698	0.9194	Digital Transformation
Sa	19751	-3.8883	0.2369	-4.6591	-3.8778	-3.1018	Financing Constraints
Innov	19751	4.3078	1.5168	0.0000	4.3497	8.2367	Innovation Output
Lev	19751	0.4042	0.1859	0.0422	0.3995	0.8977	Debt-to-Asset Ratio
Return on Assets	19751	0.0383	0.0677	-0.3358	0.0378	0.2775	Return on Assets
Cash Flow	19751	0.0519	0.0644	-0.1487	0.0487	0.2755	Cash Flow Ratio
Board	19751	2.1004	0.1895	1.6094	2.1972	2.7081	Logarithm of Board Size
Top1	19751	0.3211	0.1377	0.0780	0.3000	0.7884	Major Shareholder's Shareholding Ratio
Age	19751	2.2233	0.6683	1.0986	2.1972	3.4340	Logarithm of listing duration

4.3 Data Sources

This study selected Chinese A-share listed manufacturing companies from 2011 to 2023 as the sample. Based on research requirements, the sample underwent the following screening: Firstly, companies that experienced abnormal listing statuses such as ST special treatment or delisting during the study period were excluded; Secondly, data with severe key variable missingness were excluded; Thirdly, to mitigate the impact of extreme values, continuous variables underwent 1% bilateral trimming. Where data gaps were identified, linear interpolation was employed for imputation. All primary data originated from the Guotai An database (CSMAR). Descriptive Statistics for the final sample are presented in Table 2.

5. Empirical Findings and Analysis

5.1 Benchmark Regression Analysis

Table 3. Benchmark Regression Results (Robust Standard Errors in Parentheses)

	(1)	(2)
Dig	0.0177***	0.0158***
	(0.0025)	(0.0024)
Lev		0.0748***
		(0.0048)
ROA		0.1135***

		(0.0083)
Cash Flow		0.0225***
		(0.0068)
Board		0.0280***
		(0.0032)
Top1		0.0022
		(0.0090)
Age		0.0286***
		(0.0022)
Individual Fixed	Yes	Yes
Year fixed	Yes	Yes
N	19751	19751
R^2	0.9101	0.9167

Table 3 presents the benchmark regression results for Model (1). Column (1) displays the regression results with no additional control variables, controlling only for year and individual fixed effects. The coefficient for the core explanatory variable Digital is 0.0177, significantly positive at the 1% level, preliminarily indicating a significant positive correlation between digital transformation and supply chain resilience. Column (2) presents the results with all control variables included, where the coefficient for Digital remains significantly positive at the 1% level. This finding strongly supports research hypothesis H1.

5.2 Endogeneity and Robustness Tests

To ensure the reliability of the aforementioned results, this paper conducted a series of robustness tests.

To address endogeneity concerns and mitigate potential bias arising from reverse causality-where firms with stronger supply chain resilience might exhibit higher digital transformation levels-this study employed a one-period lagged variable for digital transformation. The regression results, presented in Table 4, confirm the original hypothesis remains valid. Secondly, to ensure robustness, the sample was processed by excluding municipalities directly under central government jurisdiction, excluding the three years of the COVID-19 pandemic, and controlling for industry fixed effects, followed by separate regression analyzes. Furthermore, the original explanatory variables were replaced with dimensions measuring digital transformation-strategic leadership, technological drive, organizational empowerment, and enterprise digital application-and separate regression analyzes were conducted. The regression results, as shown in Table 5, confirm that the original hypothesis remains valid.

Table 4. Results of Endogeneity Treatment

	(1)
Dig	0.0160***
	(0.0026)
Lev	0.0760***
	(0.0056)
ROA	0.1080***
	(0.0090)
Cash Flow	0.0215***
	(0.0072)
Board	0.0238***
	(0.0034)
Top1	0.0034
	(0.0108)
Age	0.0286***
	(0.0031)
N	15948
R^2	0.9269

Table 5. Robustness Test Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Excluding municipalities directly under the central government	Exclude three years of COVID-19	Control industry fixed effects	Standardization of technological innovation	Standardization of business innovation	Standardization of process innovation	Digital Application Scoring
Dig	0.0154***	0.0185***	0.0159***				
	(0.0025)	(0.0036)	(0.0024)				
Dig1				0.0104***			
				(0.0021)			
Dig2					0.0035*		
					(0.0020)		
Dig3						0.0103***	
						(0.0016)	
Dig4							0.0184***
							(0.0028)

Lev	0.0792***	0.0757***	0.0727***	0.0756***	0.0756***	0.0748***	0.0750***
	(0.0052)	(0.0067)	(0.0048)	(0.0048)	(0.0048)	(0.0048)	(0.0048)
ROA	0.1108***	0.1098***	0.1093***	0.1139***	0.1140***	0.1132***	0.1136***
	(0.0086)	(0.0120)	(0.0082)	(0.0083)	(0.0084)	(0.0084)	(0.0083)
Cashflow	0.0207***	0.0195*	0.0213***	0.0220***	0.0222***	0.0230***	0.0223***
	(0.0071)	(0.0100)	(0.0066)	(0.0068)	(0.0068)	(0.0068)	(0.0068)
Board	0.0263***	0.0306***	0.0268***	0.0280***	0.0284***	0.0282***	0.0279***
	(0.0034)	(0.0044)	(0.0031)	(0.0032)	(0.0032)	(0.0032)	(0.0032)
Top1	0.0046	-0.0005	0.0058	0.0022	0.0020	0.0022	0.0023
	(0.0093)	(0.0118)	(0.0088)	(0.0090)	(0.0090)	(0.0090)	(0.0090)
Age	0.0265***	0.0301***	0.0291***	0.0285***	0.0284***	0.0286***	0.0286***
	(0.0024)	(0.0029)	(0.0022)	(0.0022)	(0.0022)	(0.0022)	(0.0022)
Individual fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed year	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed	No	No	Yes	No	No	No	No
N	17038	13030	19751	19751	19751	19751	19751
R^2	0.9135	0.9128	0.9187	0.9165	0.9164	0.9166	0.9167

5.3 Mechanism Testing

To verify whether a mediating effect exists between digital transformation and manufacturing supply chain resilience-specifically, whether digital transformation enhances supply chain resilience by alleviating financing constraints and boosting corporate innovation capabilities-this paper constructs the following model:

$$Sa_{i,t}=, t+\beta_1+, t+, t+\sum Individual+\upsilon_{it} \quad (2)$$

$$Innov_{i,t}=, t+\alpha_1+, t+, t+\sum Individual+\omega_{it} \quad (3)$$

Where Sai, t denotes the degree of financing constraints faced by manufacturing firm i in year t, sourced from the Financing Constraint Index database within the China Securities Market Research (CSMAR) database (as the financing constraint index is negative and higher absolute values indicate more severe constraints, it is treated as an absolute value for subsequent interpretation); the innovation capability of manufacturing firm i in year t, measured by the number of patents applied for by the firm. The regression results are presented in Table 6.

Table 6. Results of Mechanism Path Testing

	(1)	(2)	(3)
	Res	Sa	Innov
Dig	0.0158***	-0.0051*	0.2934***
	(0.0024)	(0.0027)	(0.0513)
Lev	0.0748***	0.0234***	0.4889***
	(0.0048)	(0.0049)	(0.0970)
ROA	0.1135***	0.0381***	1.3675***
	(0.0083)	(0.0070)	(0.1632)
Cashflow	0.0225***	-0.0184***	-0.5683***
	(0.0068)	(0.0064)	(0.1449)
Board	0.0280***	0.0065*	0.2825***
	(0.0032)	(0.0036)	(0.0724)
Top1	0.0022	0.0061	0.2576
	(0.0090)	(0.0103)	(0.1681)
Age	0.0286***	0.0697***	0.0032
	(0.0022)	(0.0026)	(0.0530)
Individual fixed	Yes	Yes	Yes
Year fixed	Yes	Yes	Yes
N	19751	19751	19751
R^2	0.9167	0.9791	0.7269

As shown in Table 6, the coefficient for digital transformation (Dig) in Model (2) is -0.0051,

while that in Model (3) is 0.2934, both significant at the 1% level. This indicates that enhanced levels of corporate digital transformation contribute to reducing financing constraints, elevating innovation capabilities, and fostering greater resilience and recovery capacity within enterprises. Consequently, this promotes improved supply chain resilience, thereby validating Hypotheses H2 and H3.

5.4 Heterogeneity Analysis

This study categorized the sample based on firm size into above and below the median firm size; by region into eastern, central, and western China; and by ownership into state-owned and non-state-owned enterprises. Separate regressions were conducted for each category. Results from Tables 7 and 8 indicate that digital transformation exerts a stronger positive effect on supply chain resilience in manufacturing firms above the median size than in those at or below the median. Regionally, this effect is strongest in the West, followed by the East and then the Central regions. In terms of ownership, the positive impact is greater for SOEs than for non-SOEs. These findings confirm significant differences in the contribution of digital transformation to supply chain resilience across firms of varying sizes, locations, and ownership structures.

Table 7. Heterogeneity Analysis by Firm Size

	(1)	(2)
	Above median size	At or below median size
Dig	0.0186***	0.0107***
	(0.0034)	(0.0041)
Lev	0.0769***	0.0797***
	(0.0076)	(0.0076)
ROA	0.1242***	0.1020***
	(0.0116)	(0.0135)
Cash Flow	0.0079	0.0357***
	(0.0102)	(0.0108)
Board	0.0277***	0.0287***
	(0.0049)	(0.0052)
Top1	-0.0035	0.0060
	(0.0144)	(0.0137)
Age	0.0301***	0.0262***
	(0.0034)	(0.0036)
Individual fixed	Yes	Yes
Year fixed	Yes	Yes
N	9751	10000
R^2	0.9312	0.9251

Table 8. Analysis of Heterogeneity by Region and Enterprise Type

	(1)	(2)	(3)	(4)	(5)
	Eastern	Central	Western	State-owned enterprises	Non-state-owned enterprises
Dig	0.0151***	0.0138***	0.0238***	0.0189***	0.0148***
	(0.0028)	(0.0051)	(0.0092)	(0.0053)	(0.0026)
Lev	0.0797***	0.0603***	0.0670***	0.0639***	0.0801***
	(0.0060)	(0.0100)	(0.0126)	(0.0093)	(0.0057)
ROA	0.1086***	0.1333***	0.1042***	0.1095***	0.1150***
	(0.0102)	(0.0171)	(0.0250)	(0.0194)	(0.0091)
Cashflow	0.0240***	0.0158	0.0233	0.0229*	0.0218***
	(0.0084)	(0.0148)	(0.0165)	(0.0123)	(0.0081)
Board	0.0287***	0.0332***	0.0183**	0.0319***	0.0265***
	(0.0040)	(0.0066)	(0.0085)	(0.0050)	(0.0041)
Top1	-0.0128	0.0253	0.0455*	0.0404***	-0.0216*
	(0.0108)	(0.0198)	(0.0249)	(0.0130)	(0.0119)
Age	0.0318***	0.0171***	0.0377***	0.0282***	0.0298***
	(0.0027)	(0.0049)	(0.0067)	(0.0044)	(0.0028)
Individual fixation	Yes	Yes	Yes	Yes	Yes
Fixed year	Yes	Yes	Yes	Yes	Yes
N	14078	3298	2375	5664	14087
R^2	0.9115	0.9258	0.9283	0.9232	0.9027

6. Conclusions and Recommendations

This study employs a two-way fixed effects model based on panel data from Chinese manufacturing listed companies between 2011 and 2023. It confirms the hypothesis that digital

transformation significantly enhances supply chain resilience in Chinese manufacturing enterprises, validating two pathways: "alleviating financing constraints" and "enhancing innovation capabilities". Heterogeneity analysis across different enterprise types reveals that these positive effects are more pronounced in state-owned enterprises, large-scale enterprises, and firms located in western regions.

Based on these findings, the following policy recommendations are proposed: 1. The government should advance new infrastructure initiatives such as 5G and industrial internet (with a focus on central and western regions to narrow the digital divide), while reducing transformation costs for small and medium-sized manufacturing enterprises through fiscal subsidies and tax relief. 2. Encourage the regulated development of big data supply chain finance platforms, establish cross-departmental mechanisms for enterprise data sharing, and facilitate the conversion of corporate "data assets" into "credit assets" to alleviate financing difficulties for private and SME manufacturers. 3. Strengthen intellectual property protection, establish dedicated funds to support industry-academia-research collaboration, and cultivate digital-management hybrid talent to provide an innovative environment and intellectual support for manufacturing digitalization.

For enterprise managers, the following should be prioritized: 1. Designate digital transformation as a top-level initiative, formulating a long-term, systematic roadmap aligned with overall strategy that encompasses the entire value chain-from R&D to production-avoiding piecemeal approaches. 2. Drive transformation through dual engines of technological application and management reform. When investing in hardware and software, concurrently optimize organizational structures and business processes while strengthening data governance to eliminate internal data silos. 3. Leverage digital dividends by enhancing investor communication and broadening financing channels through improved information transparency. Simultaneously deploy digital tools for end-to-end supply chain risk management and establish dynamic, intelligent risk control systems.

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