



Can digital transformation enable distressed manufacturing SMEs turnaround? The mediating role of supply chain resilience

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Abstract

Introduction. This study examines how digital transformation affects the turnaround performance of manufacturing small and medium-sized enterprises (SMEs) under financial distress. While digital transformation is widely regarded as a critical driver of competitiveness, its role in the recovery of distressed firms remains insufficiently understood.

Method. We draw on data from financially distressed manufacturing SMEs and develop an empirical framework to assess the relationship between digital transformation, supply chain resilience, and turnaround performance.

Analysis. A quantitative analysis was conducted on a dataset comprising 436 manufacturing SMEs in financial distress. Using Stata, we tested the nonlinear effects of digital transformation and examined the mediating role of supply chain resilience.

Results. The findings reveal an inverted U-shaped relationship between digital transformation and turnaround performance. Specifically, moderate levels of digital transformation enhance supply chain resilience, which in turn facilitates effective turnaround, whereas excessive transformation reduces resilience and impedes recovery.

Conclusion. This study contributes to digital transformation and crisis management research by demonstrating its dual impact on SMEs' turnaround. It identifies supply chain resilience as the key mechanism linking digital transformation to recovery and offers insights for managers to balance digital investment with organisational adaptability.

Introduction

Due to inherent resource and scale disadvantages, manufacturing small and medium-sized enterprises (SMEs) are currently facing significant financial decline. Research on manufacturing SMEs' recovery from decline emphasises two strategies: retrenchment to improve efficiency and strategic initiatives to explore new opportunities ([Rico et al., 2021](#); [Oliveira Saraiva et al., 2024](#)).

To address the financial distress of SMEs, many researchers promoted digital transformation as a valuable strategic action to enhance financial performance ([Parker et al., 2023](#); [Mandviwalla & Flanagan, 2021](#)).

Prior studies largely affirm the positive impact of digital transformation on SMEs' performance ([Skare et al., 2023](#); [Aghazadeh et al., 2024](#)). However, these findings are mainly derived from high-performing or fast-growing SMEs. While the manufacturing SMEs in financial distress, can digital transformation act as the strategic action still enable them to turnaround?

Clarifying the mechanisms through which digital transformation enables financially distressed manufacturing SMEs to achieve turnaround is essential. Prior studies emphasise internal factors, such as operating costs and management expenses ([Guo et al., 2023](#)). Considering SMEs' vulnerability to supply chain shocks ([Miklian & Hoelscher, 2022](#)), this study extends beyond firm-level factors by selecting supply chain resilience as the mediating variable to examine the strategic role of digital transformation in SMEs' turnaround.

According to *Fortune*, the average lifespan of SMEs is only 2.5 years in China. Chinese manufacturing SMEs, however, make a significant contribution to global economic growth. This study therefore examines financially distressed Chinese manufacturing SMEs. Our analysis identifies an inverted U-shaped relationship between digital transformation and turnaround performance. The findings extend SMEs' turnaround research by demonstrating the dual effects of digital transformation and highlighting supply chain resilience as the mediating mechanism.

Hypothesis development

Digital transformation effect on manufacturing SMEs' turnaround performance

Enterprise digital transformation is a gradual restructuring of organisational structures, business models, processes, and services through digital technologies ([Vial, 2021](#)). Unlike prior studies focusing solely on its facilitating role, this study examines both the positive and negative effects of digital transformation on the turnaround performance of financially distressed manufacturing SMEs using an inverted U-shaped model. The following sections interpret this curve by integrating diminishing returns and escalating costs from socio-technical systems theory.

Socio-technical systems theory posits that social and technical systems are interdependent and co-evolve ([Appelbaum, 1997](#)), requiring the integration of social factors and technical elements in system design ([Sony & Naik, 2020](#)). Accordingly, digital transformation is a socio-technical process ([Autio et al., 2018](#); [Münch et al., 2022](#)). For financially distressed SMEs, success depends not only on adopting digital technologies but also on complementary assets such as organisational and human capital ([Eller et al., 2020](#)). Digitalisation can initially improve productivity and innovation ([Huang & Lin, 2024](#); [Hu & Lu, 2024](#)), however, as transformation progresses, marginal benefits diminish while costs of complementary assets—such as employee training and managerial restructuring—increase, leading to diminishing returns.

At low levels of digital transformation, its inhibiting effect is minimal while the facilitating effect dominates. In the initial stage, financially distressed manufacturing SMEs typically adopt technologies such as big data, AI, and 5G to collect operational data ([Battistoni et al., 2023](#)). This yields substantial benefits, including improved efficiency, cost reduction, and market expansion, thereby enhancing performance ([Li et al., 2018](#)).

However, as digital transformation progresses, the managerial benefits may gradually decrease because the low-hanging fruits of the initial stage have already been harvested, leading to diminishing returns.

At higher levels of digital transformation, inhibiting effects outweigh facilitating ones. Successive technology upgrades yield diminishing returns while restructuring, software updates, and digital skills training drive up costs (Hu et al., 2024). Financially distressed SMEs thus confront technological complexities (Battistoni et al., 2023) and the 'productivity paradox' (Brynjolfsson et al., 2020), where heavy digital investment fails to deliver expected gains, ultimately reducing performance.

Thus, we propose the hypothesis:

Hypothesis 1: The relationship between digital transformation and the turnaround performance of manufacturing SMEs in financial distress exhibits an inverted U-shaped pattern.

The mediating role of supply chain resilience

Digital transformation and supply chain resilience

Information processing theory examines how individuals and organisations collect, interpret, and utilise information to make decisions and take actions (Kmetz, 2018). According to information processing theory, digital transformation simultaneously exerts the dual effects of information transmission (Lu et al., 2024) and information overload (Müller et al., 2023) for the distressed manufacturing SMEs.

In the initial stages, the benefits of improved information transmission and processing efficiency outweigh potential drawbacks. The adoption of digital technologies and intelligent systems enables buyers and suppliers to streamline communication and coordination (Núñez-Merino et al., 2020), reducing information delays, enhancing decision-making agility, and strengthening supply chain adaptability (Sadeghi et al., 2024). Thus, at lower levels of digital transformation, the turnaround performance of distressed manufacturing SMEs improves.

As digital transformation advances, adverse effects from information overload and asymmetry may outweigh positive outcomes. High levels of digitalisation exacerbate these challenges, hindering accurate data access and effective decision-making (Nudurupati et al., 2024). Consequently, manufacturing SMEs experience reduced market sensitivity and weakened supply chain resilience, leading to negative consequences that surpass initial benefits.

Therefore, through the lens of information processing theory, the relationship between digital transformation and supply chain resilience can be understood as exhibiting an inverted U-shape.

Thus, we propose the hypothesis:

Hypothesis 2: The relationship between digital transformation and supply chain resilience exhibits an inverted U-shaped pattern.

Supply chain resilience and manufacturing SMEs' turnaround performance

According to dynamic capability theory, a resilient supply chain equips financially distressed manufacturing SMEs with adaptability to disruptions and proactive risk mitigation (Safari et al., 2024). It enables rapid responses to shocks such as natural disasters, economic downturns, or supply interruptions, ensuring continuity and minimising losses (Pertheban et al., 2023). It also supports risk management through supplier diversification, contingency planning, and enhanced visibility, thereby reducing vulnerability and safeguarding operations (Munir et al., 2024).

From the standpoint of the Resource-Based View (RBV), supply chain resilience both preserves resources and facilitates their flow, thereby strengthening the operational capabilities of

manufacturing SMEs (Kamalahmadi & Parast, 2016). First, by preventing resource losses and ensuring business continuity, resilience enhances overall performance (Li et al., 2022). Second, it accelerates resource flow and reduces inventory, substantially improving operational efficiency.

Thus, we propose the hypothesis:

Hypothesis 3: Supply chain resilience exerts a positive impact on the turnaround performance of financial distressed manufacturing SMEs.

Research design

Data and sample

Manufacturing SMEs are defined following the Chinese Ministry of Industry and Information Technology (2011) as firms with fewer than 1,000 employees and annual sales revenue under 300 million yuan (Jiang & Wang, 2024). The sample comprises listed manufacturing SMEs in financial distress between 2011 and 2023, identified by an Altman Z-score below 1.8 (Altman et al., 2017). To avoid duplication, only the first occurrence of distress is considered, and firms with incomplete data are excluded. The final dataset consists of 436 SMEs and 2,104 firm-year observations, sourced from the CSMAR database (<http://data.csmar.com/>).

Model specification

The model below depicts the relationship between digital transformation and the turnaround performance of manufacturing SMEs in financial distress.

$$ROA_{i,t} = \alpha_0 + \alpha_1 Digital_{i,t} + \alpha_2 Digital_{i,t}^2 + \delta X_{i,t} + \sum Year + \varepsilon_{i,t} \quad (1)$$

In the formula, ‘*i*’ represents the company, ‘*t*’ denotes the specific time period, and ‘ ε ’ represents the error term. In particular, $ROA_{i,t}$ signifies the turnaround performance of company *i* during year *t*. $Digital_{i,t}$ denotes the digital transformation level of company *i* in year *t*, while $Digital_{i,t}^2$ denotes a squared term. To take into consideration additional variables that can affect the connections under study, a set of control variables is also provided.

Variables

Explanatory variable

Digital transformation (*Digital*) is the explanatory variable. Combining the measurement of Shang et al. (2023) and the phases in the SME digital alignment model proposed by Canhoto et al. (2021), we quantify digital transformation through using text analysis. Unlike previous studies that focus on specific terms like blockchain or cloud computing in annual reports, our approach categorises digital transformation into three stages—informatisation, digitalisation, and intelligentisation—customising a set of keywords for each stage based on its unique characteristics.

ChatGPT-3 proficiently discerns contextual associations among words and generates appropriate synonyms as per instructions (Leippold, 2023). In this study, ChatGPT is employed to refine the existing word segmentation dictionary, significantly improving the accuracy of text data extracted from corporate annual reports.

The keyword spectrum for the digital transformation of manufacturing SMEs is provided in Appendix Table A1.

(2) Explained variable

The turnaround performance of manufacturing SMEs experiencing financial distress is the dependent variable. Following Wang & Bai (2024), we use return on assets (ROA) as a proxy to measure the turnaround performance of manufacturing SMEs in financial distress, a method previously used in turnaround research (Schmitt & Raisch, 2013).

Mediating variable

For financially distressed manufacturing SMEs, supply chain resilience denotes the ability to withstand, adapt to, and evolve in response to disruptions. Following [Jia & Li \(2024\)](#), we define SCR as the average resilience of upstream and downstream activities.

Control variables

The main control variables are *Age*, *Top*, *Peo*, *LnPay* and *FS*. The definitions of variables and English symbols are detailed in Appendix Table A2.

Results

Descriptive statistics

Table 1 displays the descriptive statistics. The turnaround performance variable (ROA) shows a wide range from -3.551 to 5.170, indicating significant variability in the turnaround performance of the manufacturing SMEs in our dataset. In contrast, the digital transformation variable (*Digital*) has a mean of 0.988 and a median of 0.532, signalling notable differences in digital transformation levels among the sampled firms.

	N	Mean	Sd	Min	Median	Max
ROA	2104.000	0.026	0.575	-3.551	0.026	5.170
<i>Digital</i>	2104.000	0.988	1.193	0.000	0.532	9.039
SCR	2104.000	0.402	0.421	0.000	0.303	5.396
<i>Age</i>	2104.000	2.635	0.522	0.693	2.708	3.497
<i>Top</i>	2104.000	28.214	13.156	2.120	25.975	82.700
<i>Peo</i>	2104.000	3.403	0.350	1.245	3.442	4.261
<i>LnPay</i>	2104.000	14.872	0.725	11.695	14.867	17.226
<i>FS</i>	2104.000	1.197	2.072	0.005	0.944	61.837

Table 1. Descriptive statistics.

Baseline regression analysis

We begin with a regression analysis using Model 1, clustering robust standard errors to address potential heteroscedasticity. The findings presented in Table 2 confirm the hypothesis 1, which demonstrated an ‘inverted U-shaped’ relationship between digital transformation and the turnaround performance for manufacturing SMEs in financial distress.

VARIABLES	ROA
<i>Digital</i>	0.120** (2.185)
<i>Digital</i> ²	-0.020*** (-2.961)
Controls	Yes
Year	Yes
Constant	-0.997 (-1.226)
Observations	2104.000
R-squared	0.048

Table 2. Regression results. (Note: *** p<0.01, ** p<0.05, * p<0.1; t-statistics in parentheses)

Mechanism test

Table 3 presents the results of our mechanism test. Column 1 shows that digital transformation of SMEs has an inverted U-shaped relationship with supply chain resilience. The results supported Hypothesis 2. Furthermore, Column 2 indicates that supply chain resilience has a significant

positive impact on the turnaround performance of financially distressed manufacturing SMEs, thereby supporting Hypothesis 3.

VARIABLES	(1) SCR	(2) ROA
SCR		0.618*** (-7.92)
Digital	0.086*** (-2.95)	0.067 (1.30)
Digital ²	-0.012*** (2.95)	-0.013** (-1.97)
Controls	Yes	Yes
Year	Yes	Yes
Constant	0.923 (1.60)	-0.426 (-0.53)
Observations	2104.000	2104.000
R-squared	0.118	0.131

Table 3. Mechanism test.

Robustness check

Replacing the independent variable

Acknowledging the potential exaggeration of digitalisation levels in the annual reports of some manufacturing SMEs, our research adopts the methodology proposed by [Zhang et al. \(2021\)](#), using the proportion of digital technology-related components to total intangible assets disclosed in companies' year-end financial reports to re-measured digital transformation (*Digital2*). The results are shown in Column 1 of Table 4.

Incorporating omitted variables

To minimise measurement errors due to omitted variables, research, and development intensity (RD) is introduced as a control variable to test the robustness of the results. RD can influence a firm's performance ([Leung & Sharma, 2021](#)); therefore, it is measured as R&D expenses to total sales and includes it as a control variable in Model 1. The results are presented in Column 2 of Table 4.

Winsorisation

To reduce the effect of outliers on the regression results, the data was winsorised at the 1% upper and lower percentiles. The results are displayed in Column 3 of Table 4.

VARIABLES	(1) ROA	(2) ROA	(3) ROA
Digital		0.121** (2.198)	0.120** (2.185)
Digital ²		-0.020*** (-2.943)	-0.020*** (-2.961)
Digital2	0.373** (2.372)		
Digital2 ²	-0.257*** (-3.215)		
Controls	Yes	Yes	Yes
Year	Yes	Yes	Yes
Constant	-0.895 (-1.093)	-0.775 (-0.936)	-0.997 (-1.226)
Observations	2104.000	2088.000	2104.000
R-squared	0.045	0.067	0.048

Table 4. Robustness test.

Endogeneity test

In order to address potential endogeneity issues arising from reciprocal causation, our study utilises a numerical instrumental variable (IV) approach. Following [Zhang et al. \(2024\)](#), this study uses the average digital transformation level of other firms within the same industry and year as IV, which meets the requirements of relevance and exogeneity. We re-estimate the model by using the two-stage least squares method (2SLS). Results in Table 5 show that the F statistics in the regression results exceed 10, indicating that our model meets the criterion for strong instruments.

The inverted U-shaped association between digital transformation and the turnaround performance for manufacturing SMEs financially distressed remains intact, according to the second-stage regression. Notably, the results suggests that even after the incorporation of instrumental variables, the research conclusions remain consistent with the earlier findings.

VARIABLES	Digital 1st Stage	Digital ²	ROA 2nd Stage
Digital			0.103** (2.16)
Digital ²			-0.024** (-2.52)
IV	0.786*** (4.94)	-3.337** (-2.68)	
IV ²	0.234*** (3.30)	3.519*** (6.27)	
Controls	Yes	Yes	Yes
Year	Yes	Yes	Yes
Constant	-0.214 (-0.63)	-0.838 (-0.35)	-0.771 (-2.22)
Observations	2104.000	2104.000	2104.000
R-squared	0.686	0.492	0.040
Adj R-squared	0.684	0.488	
F-statistics	125.98	31.88	

Table 5. Endogeneity test.

Heterogeneity analysis

Ownership heterogeneity test

The capacity of manufacturing SMEs to recover from a decline can vary considerably based on their ownership structure. Thus, we analyse two groups: privately-owned enterprises (POEs) and state-owned enterprises (SOEs). Column 1 in table 6 indicates that digital transformation has a significant impact on improving turnaround performance for POEs. Column 2 shows that the inverted U-shaped relationship between the two variables does not exhibit statistical significance in SOEs.

SOEs benefit from government-appointed executives and privileged access to resources ([Zhang et al., 2022](#)), which enables them to withstand financial distress through conventional advantages, thereby reducing the incremental value of digital transformation. In contrast, POEs, constrained by limited resources, treat digital transformation as a strategic necessity to enhance supply chain efficiency and strengthen resilience to external shocks.

(2) Regional digital economy level heterogeneity test

The sampled manufacturing SMEs are dispersed across different regions in the country, where the level of digital economy varies significantly. Therefore, the median is used to separate the sample into two groups: low regional digital economy level (DEI Low) and high regional digital economy level (DEI High). Column 3 in table 6 shows a significant impact in low digital economy regions, while column 4 in table 6 shows no significant inverted U-shaped association in regions with a high digital economy in high digital digital economy regions.

In regions with a developed digital economy, mature logistics and e-commerce infrastructures reduce the marginal benefits of internal digital transformation, weakening its inverted U-shaped effect on distressed SMEs ([Wang & Li, 2024](#)). By contrast, in less developed regions, where information silos and inefficient supply chains prevail ([Peng et al., 2022](#)), digital transformation markedly strengthens supply chain resilience and turnaround performance. Yet, at advanced stages, limited absorptive capacity in such regions constrains further performance gains.

VARIABLES	(1) POEs	(2) SOEs	(3) DEI Low	(4) DEI High
Digital	0.069** (2.00)	0.065 (1.28)	0.158*** (3.57)	0.010 (0.27)
Digital ²	-0.015** (-2.55)	-0.017 (-1.24)	-0.027*** (-3.67)	-0.006 (-0.96)
Controls	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Constant	-1.110*** (-3.14)	-0.413 (-0.90)	-1.142*** (-2.79)	-0.953** (-2.50)
Observations	1333.000	771.000	1047.000	1057.000
R-squared	0.055	0.051	0.049	0.059

Table 6. Heterogeneity analysis.

Conclusion and implications

This study investigates the impact underlying digital transformation's role in the turnaround performance of financially distressed manufacturing SMEs, revealing an inverted U-shaped curve, particularly in regions with less developed digital economies or in privately-owned enterprises. Moreover, the results of our mechanism test further show that enterprise digital transformation, through influencing supply chain resilience, can significantly impact financially distressed manufacturing SMEs' turnaround performance.

This paper also provides several implications for financially distressed manufacturing SMEs. First, they should adopt a balanced approach to digitalisation, ensuring they leverage its benefits without overextending their resources. Second, it is crucial for them to strengthen their supply chain resilience to navigate external disruptions effectively.

This study has two limitations: first, the text analysis used to assess digital transformation in manufacturing SMEs is influenced by keyword selection and text samples; second, the measurement of supply chain resilience, due to limited secondary data, does not fully capture its diversity and stability. Future research will address these issues by using survey questionnaires to obtain more accurate quantitative data on the digital transformation and supply chain resilience of manufacturing SMEs in financial distress.

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Appendix A

Informationisation stage
informationisation, information technology, information security, information network, information industry, information management, information website, flow of information, Information Harbor, cyber-physical systems, management information system, knowledge management, electronic information, telecommunication, communication network, satellite communication, communication satellite, hardware and software, key technologies, core technologies, technological transformation, computing technology, high technology, high-tech innovation, digital technology, mobile internet, internet mobile, internet application, internet technology, internet protocol, interconnection, cyberspace, network infrastructure, network services, network equipment, network coverage, service network, networked television, service network, monitoring network, radio frequency, wireless network, government website, one-network connection, network formation, portal website, gateway, interconnected, wireless, broadband access, application software, mobile payment, third-party payment, multimedia, base station, domain name, electronic report form, electronic record, remote
Digitalisation stage
digitalisation, differential privacy technology, distributed computing, fusion architecture, billion-level concurrency, multi-party secure computation, technological empowerment, data network, data platform, data science, data centre, data sharing, data security, database, data processing, data mining, data analysis, data management, data services, data flow, data empowerment, data computation, data storage, data application, data assets, Intelligence digitisation, digital control, digital communication, digital network, digital intelligence, digital terminal, digital television, digital creativity, digitised business, digital marketing, digitised supply chain, cryptocurrency, fintech, quantitative finance, cloud computing, stream computing, graph computing, in-memory computing, cognitive computing, brain-like computing, green computing, computer, server, processor, numerical control, development tools, terminal products, electronic products, big data, text mining, data visualisation, heterogeneous data, relational database, public data, application data, internet of things (IoT), open banking, cloud ecology, cloud service, cloud platform, cloud storage, cloud business, blockchain, platformisation, application scenarios, algorithm, coding, internet+, internet solutions, internet thinking, internet action, internet business, internet marketing, telemedicine, online education, unmanned retail, live streaming, subscription-based services, platform economy, cross-media, integrated circuit, industry 4.0, new industrialisation, ecological collaboration, navigation system, terminal screen, integrated interoperability, shared platform, industrial chain platform, ecological alliance, technological co-creation, digital talent, digital tools
Intelligentisation stage
Artificial intelligence(AI), intelligentisation, smart wearables, intelligent transportation, intelligent healthcare, intelligent customer service, smart home, robo-advisory services, smart cultural tourism, intelligent environmental protection, smart grid, smart agriculture, intelligent marketing, smart devices, smart network, intelligent manufacturing, smart technology, smart terminals, intelligent supply chain, intelligent algorithms, smart financial contracts, intelligent energy, business intelligence (BI), commercial intelligence (CI), virtualisation, virtual reality (VR), augmented reality (AR), mixed reality (MR), human-computer interaction (HCI), robots/robotics, automation/control technology, automatic control, image understanding, investment decision support system, smart data analysis, machine learning, deep learning, semantic search, biometric technology, facial recognition, speech recognition, identity verification/authentication, autonomous driving/self-driving cars, natural language processing, machine learning internet, smart production

Table A1. Keyword spectrum of digital transformation.

Symbol	Variables	Definitions
ROA	Return on Assets	The ratio of net income to average total assets

<i>Digital</i>	Digital Transformation	The ratio of the frequency of keywords in digital transformation to the length of the entire text multiplied by 100
SCR	Supply chain resilience	The mean of upstream and downstream resilience
<i>Age</i>	Listing years	Ln (Current year - enterprise's establishment year+1)
<i>Top</i>	Ownership concentration	The shareholding ratio of the largest shareholder
<i>Peo</i>	Number of employees	Ln (Number of employees in the company)
<i>LnPay</i>	Executive Compensation	Ln (Total annual executive compensation)
FS	Financial Slack	The ratio of current assets to total liabilities

Table A2. Variable definitions.