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The Impact of Digital Transformation in Manufacturing on Firm Performance: A Deleveraging Perspective

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Abstract. In the digital economy era, digital technologies such as cloud computing and artificial intelligence have brought both opportunities and challenges to enterprises. Understanding how digital transformation impacts business operations and the specific mechanisms involved is of great reference significance for companies. This study, based on a panel data of A-share listed manufacturing companies from 2010 to 2020 and adopting a deleveraging perspective, proposes hypotheses, constructs regression models, and conducts empirical analysis. The findings confirm that digital transformation in manufacturing can effectively enhance corporate performance. In this process, enterprise leverage plays an intermediary role. By leveraging digital technologies, manufacturing companies can effectively mitigate information asymmetry, improve information utilization efficiency and operational efficiency, and reduce risks through deleveraging, thereby enhancing their overall performance.

Keywords: manufacturing, corporate performance, digital transformation, deleveraging

1. Introduction

Over the past few years, with the rapid development of the global economy, many Chinese enterprises have achieved significant growth through various factors and means, among which leveraging is a crucial one. Many companies have utilized financial leverage to address capital shortages, reduce the proportion of equity capital, thereby increasing their return on investment, significantly boosting profitability, and enhancing market competitiveness. However, leverage is a "double-edged sword." While it brings high profits to enterprises, it also substantially increases the risks they face. The involvement of capital means higher debt risks for companies, and poor management could accelerate bankruptcy. Furthermore, high leverage can also lead to difficulties in financing and reduced operational freedom for enterprises. Therefore, how to wield this "double-edged sword" of leverage, balance corporate leverage levels, maximize its benefits, and minimize risks is an important topic for every enterprise to consider. In recent years, with the rapid development of digital technologies, their applications in enterprises have become increasingly widespread and mature, becoming a key means to facilitate innovative development, business model optimization, and transformation and upgrading of enterprises. Through the digital transformation of internal management using technologies such as big data and cloud computing, enterprises have achieved intelligent production and efficient management, significantly increasing their revenue and enhancing their competitiveness. Then, can digital transformation help enterprises balance their leverage levels and thus achieve performance growth? Resolving this important issue will undoubtedly provide direction and reference for the transformation and development of enterprises, holding significant practical implications.

Currently, scholars both domestically and internationally have conducted relevant research on the correlation between digital transformation and firm performance. However, few have approached this topic from a deleveraging perspective, and even fewer have studied it in conjunction with the characteristics of a specific industry. Therefore, this paper focuses on the manufacturing industry, taking into account industry characteristics and firm-specific traits. It proposes tailored metrics for digital transformation, firm performance, and corporate leverage specifically for manufacturing enterprises. By constructing a model for empirical analysis, the paper explores the relationships and specific pathways among these three elements, providing guidance for enterprises seeking development and for governments supporting enterprise growth.

2. Literature Review

2.1. Literature Review

With the rapid development of the global digital economy, an increasing number of academic studies have focused on the impact of the degree of enterprise digital transformation on firm performance. Different scholars have reached varying conclusions through theoretical and empirical research, and some have introduced the concept of enterprise leverage to investigate its effect in this context.

Regarding research on how enterprise digital transformation affects firm performance, the academic community generally believes that the degree of digital transformation positively promotes firm performance. For example, Xie Lijuan argues that enterprises can leverage digital technologies to precisely identify customer needs, intelligently store and process vast amounts of consumer and product transaction information, analyze consumer preferences, and adjust product strategies to precisely match customer demands, thereby enhancing performance [1]. Liu Yi et al. focused their research on the impact of enterprise digital transformation on production and operation activities, proposing that digital technologies can enable enterprises to achieve intelligent manufacturing systems, precisely control production processes and product quality, and realize large-scale, intelligent, and customized production [2]. Yi Luxia et al. found that as the degree of enterprise digital transformation deepens, the level of information asymmetry between the enterprise and the outside world gradually decreases [3]. Simultaneously, the level of information sharing and the efficiency of information transmission within the enterprise also significantly improve, reducing resistance and internal friction in enterprise management activities and leading to significant performance growth. Yuhao N et al. believe that enterprises can effectively promote capital structure adjustment through digital transformation means, dynamically correcting deviations between the actual and target values of the enterprise's capital structure, and thus optimizing firm performance [4]. Meng Tao et al. argue that by focusing on user value and deploying digital transformation, enterprises can leverage digital technologies to construct and optimize organizational structures, engage in market development activities, and reorganize resource allocation, thereby enhancing firm performance [5]. Slightly differing from the conclusions of the aforementioned scholars, Liu Shuchun et al. compared the input-output ratios of enterprise digital transformation at different development stages and found that during the initial stage of digital transformation, large-scale digital investments do not improve production and operation efficiency; instead, they may have a negative impact [6]. Wu Jie et al. divided the degree of enterprise digital transformation into depth and breadth dimensions and, through empirical research, confirmed that the depth of digital transformation has a significant positive effect on firm performance [7]. However, the impact of the breadth of digital transformation on firm performance follows an "inverted U-shaped" curve. In the early stages of digital transformation, digital technologies do positively promote firm performance, but when the degree of transformation reaches a certain level, further investment can have some negative effects on performance.

In studying the mechanism of how enterprise digital transformation affects firm performance, some scholars have also identified and proposed the effect of enterprise leverage. They believe that digital means can significantly reduce the level of leverage resistance in enterprise operations, thereby effectively improving operational performance. Enterprise leverage refers to the extent to which an enterprise uses debt and equity when raising funds, truly reflecting the level of risk the enterprise faces and influencing its stability. Typically, enterprise operating leverage, financial leverage, and combined leverage are used to reflect the level of enterprise leverage. Operating leverage refers to the ratio of fixed costs to variable costs in an enterprise; high operating leverage implies high fixed costs and increased operational risk. Financial leverage represents the ratio of debt funds to equity in an enterprise; high financial leverage implies high debt, increasing the possibility of gains but also significantly elevating financial risk. Combined leverage is the sum of operating and financial leverage, indicating the overall risk faced by the enterprise. Qi Yudong and Cai Chengwei proposed in their research that digital technologies such as cloud computing, big data, and blockchain can effectively assist enterprises in managing production and operation information in a large-scale, scientific, and efficient manner, helping to avoid unreasonable management behaviors, reduce operational decision-making risks, and thus lower management costs and mitigate operating leverage [9]. Du Shanzhong and Ma Lianfu believe that digital technologies can effectively alleviate information asymmetry between enterprises and the external environment, assist enterprises in storing and processing vast amounts of data, improve information utilization and transmission efficiency, and to some extent, reduce financing costs, thereby lowering financial leverage and enterprise risk and enhancing firm performance [8]. Hu Yuanlin et al., through empirical analysis of the joint effect of operating and financial leverage in the process of digital transformation affecting firm performance, confirmed the mediating effect of combined leverage. Enterprise digital transformation helps achieve a balance between operating and financial leverage, enabling better risk management and maximizing operational benefits with limited resources [10].

2.2. Hypothesis

To investigate the relationship between digital transformation in the manufacturing industry and firm performance, as well as the role of corporate leverage in this context, based on the aforementioned theoretical foundations, this paper proposes the following hypotheses:

H1: Digital transformation has a significant positive impact on the performance of manufacturing firms.

H2: Corporate leverage mediates the effect of digital transformation on enhancing the performance of manufacturing firms.

H2a: Operating leverage mediates the effect of digital transformation on enhancing the performance of manufacturing firms.

H2b: Financial leverage mediates the effect of digital transformation on enhancing the performance of manufacturing firms.

H2c: Combined leverage (operating and financial) mediates the effect of digital transformation on enhancing the performance of manufacturing firms.

3. Methodology

3.1. Variable Selection

This study, referring to previous research by Yi Luxia et al. [3], Meng Tao et al. [5], Wu Jie et al.[7], and others, selects firm performance (BP) as the dependent variable and digital transformation (DT) as the independent variable. It introduces operating leverage (OL), financial leverage (FL), and combined leverage (CL) as mediator variables. Additionally, firm size (BS), years of establishment (AG), nature of controlling shareholder (CS), debt-to-asset ratio (DA), and regional location of the firm (RG) are taken as control variables. The specific measurement methods for each indicator are shown in Table 1.

Table 1. Definition of Variable Indicators

Variable		Symbol	Measure of Indicators
Dependent Variable	Business Performance	BP	The firm's performance is measured through a weighted average of various aspects, including accounts receivable, net profit, cost control, market share, brand strength, innovation capability, and customer satisfaction.
Independent Variable	Digital Transformation	DT	Referring to the national standard "Information Technology Service - Digital Transformation - Maturity Model and Assessment" (GB/T 43439-2023), the digital transformation maturity is divided into five levels: Initial, Basic, Integrated, Optimized, and Leading, based on the corresponding requirements of 7 capability domains and 29 capability subdomains. These levels are assigned values from 1 to 5 respectively.
Mediator Variable	Operating Leverage	OL	Measured by the Operating Leverage Ratio
	Financial Leverage	FL	Comprehensively measured by debt ratio, debt-to-asset ratio, interest coverage ratio, and financial leverage ratio
	Combined Leverage	CL	Operating Leverage Ratio * Financial Leverage Ratio
Control Variable	Business Size	BS	The natural logarithm of total assets of an enterprise
	Age	AG	The number of years since the establishment of the enterprise
	Nature of Controlling Shareholder	CS	"1" represents state-owned enterprises, and "0" represents non-state-owned enterprises.
	Debt-to-Asset Ratio	DA	Total liabilities / Total assets × 100%
	Region	RG	Based on the level of economic development, China's regions are often divided into the Eastern region, Central region, Western region, and Northeastern region, represented by 1, 2, 3, and 4 respectively.

3.2. Model Construction

To test the validity of the hypotheses H1, H2a, H2b, and H2c proposed earlier, this study constructs the following models for examination in sequence, where BP is the dependent variable, DT is the independent variable, and OL, FL, CL are the mediator variables.

$$BP_{i,t}=\alpha_0+\alpha_1 DT_{i,t}+\alpha_2 BS_{i,t}+\alpha_3 AG_{i,t}+\alpha_4 CS_{i,t}+\alpha_5 DA_{i,t}+\alpha_6 RG_{i,t}+\varepsilon_{i,t} \quad (1)$$

$$BP_{i,t}=\beta_0+\beta_1 DT_{i,t}+\beta_2 OL_{i,t}+\beta_3 BS_{i,t}+\beta_4 AG_{i,t}+\beta_5 CS_{i,t}+\beta_6 DA_{i,t}+\beta_7 RG_{i,t}+\varepsilon_{i,t} \quad (2)$$

$$BP_{i,t}=\gamma_0+\gamma_1 DT_{i,t}+\gamma_2 FL_{i,t}+\gamma_3 BS_{i,t}+\gamma_4 AG_{i,t}+\gamma_5 CS_{i,t}+\gamma_6 DA_{i,t}+\gamma_7 RG_{i,t}+\varepsilon_{i,t} \quad (3)$$

$$BP_{i,t}=\delta_0+\delta_1 DT_{i,t}+\delta_2 CL_{i,t}+\delta_3 BS_{i,t}+\delta_4 AG_{i,t}+\delta_5 CS_{i,t}+\delta_6 DA_{i,t}+\delta_7 RG_{i,t}+\varepsilon_{i,t} \quad (4)$$

3.3. Data Source

This study focuses on the digital transformation of manufacturing enterprises, taking A-share listed manufacturing companies as the research objects. Relevant data from the eleven years spanning 2010 to 2020 were extracted, screened, and processed to obtain panel data. The relevant data were sourced from the annual reports of the respective companies and the official website of the Shanghai Stock Exchange.

4. Empirical Results

4.1. Descriptive statistics

The descriptive statistics results are shown in Table 2, which reveal that the selected listed manufacturing companies exhibit varying levels of operating performance and degrees of digital transformation. Additionally, there are also differing levels of corporate leverage among the sample companies.

Table 2. Descriptive Statistics Results

Variables	Mean	S D	Minimum	Median	Maximum
BP	2.698	1.2592	0.761	1.876	8.774
DT	2.137	1.3525	1.000	1.775	4.000
OL	1.788	1.3088	0.779	1.126	7.321
FL	1.871	0.8516	0.867	1.087	4.878
CL	2.811	0.2293	1.023	1.239	17.395
BS	1.390	0.8372	0.314	1.034	6.599
AG	6.503	3.2183	1.707	2.679	15.658
CS	0.743	0.4363	0.000	0.453	1.000
DA	0.572	0.3081	0.343	0.499	0.726
RG	2.351	1.9205	1.000	2.013	4.000

4.2. Baseline Regression Analysis

The empirical model test results for the impact of digital transformation on the operating performance of manufacturing enterprises are shown in Table 3. It can be seen that the coefficient for the degree of digital transformation (DT) is 0.806, which is significant at the 1% level. This indicates that the degree of digital transformation in manufacturing enterprises can significantly affect their operating performance. By undergoing digital transformation, enterprises can effectively improve their operating performance and promote sustained development. In other words, Hypothesis H1 is confirmed. By introducing digital technologies for activities such as adjusting business models, integrating and optimizing business processes, and implementing intelligent manufacturing, manufacturing enterprises can achieve precise identification of target markets and customers, intelligent matching of business models to market demand, enhanced internal information transfer efficiency, and efficient collaboration among departments. Ultimately, this leads to strategic improvements in enterprise value, revenue growth, and operating efficiency.

Table 3. Baseline Regression Results

Variables	Dependent Variable: BP Model (1)
DT	0.806***
	(0.364)
BS	1.702***
	(8.267)
AG	-0.792
	(-0.241)
CS	0.681
	(0.305)

Table 3. (continued).

DA	2.191***
	(1.851)
RG	2.117**
	(0.845)
Constant term	14.287***
	(5.048)
DW Statistic	1.509
Adjusted R-squared	0.708
F-value	30.12***

Note: Significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively.

4.3. Results of the Mediation Effect Test

Table 4 presents the regression results of the mediation effect test, which introduces operating leverage (OL), financial leverage (FL), and combined leverage (CL) into the model for testing, respectively.

The results of Model (2) demonstrate the effectiveness of operating leverage. The coefficients for the corresponding variables DT and OL are 0.841 and -1.962, respectively, and both are significant at the 1% level. This indicates that in the path where digital transformation positively promotes the operating performance of manufacturing enterprises, the mediation effect of operating leverage is confirmed. Through digital transformation, manufacturing enterprises can effectively reduce their operating leverage, thereby enhancing their operating performance. Hypothesis H2a is thus supported. By implementing various digital transformation measures, manufacturing enterprises can achieve scientific and efficient decision-making, effectively reduce business risks, enhance risk management capabilities, improve the efficiency of business operations and innovation capabilities, leading to a significant reduction in operating leverage and subsequently improving the overall performance of the enterprise.

The results of Model (3) confirm the mediation effect of financial leverage. The coefficients for the corresponding variables DT and FL are 1.071 and -0.795, respectively, and both are significant at the 1% level. This indicates that digital transformation in manufacturing enterprises can reduce financial leverage to a certain extent, and the reduction in financial leverage can further enhance the operating performance of the enterprise. Therefore, Hypothesis H2b is established. As previously demonstrated, Hypothesis H2a is also supported. Through the application of digital technologies, manufacturing enterprises can effectively reduce information asymmetry and inefficient information transmission between the enterprise and the external environment, as well as among various internal organizations. This optimizes the financing environment and structure, lowers financing and agency costs, and alleviates financial leverage, thereby promoting an improvement in the enterprise's operating performance.

The regression results of Model (4) demonstrate the mediation effect of the firm's combined leverage (CL). The coefficients for the corresponding variables DT and CL are 0.967 and -0.991, respectively, and both are significant at the 1% level. This indicates that in the pathway where digital transformation significantly affects the operating performance of manufacturing enterprises, the combined leverage exerts its mediation effect by jointly influencing and balancing the operating leverage and financial leverage. Therefore, Hypothesis H2c is established. The business strategy of an enterprise determines the operating risks it faces, while its capital structure determines the financial risks. Together, these constitute the overall risk of the enterprise. By balancing the operating leverage and financial leverage, the enterprise can control its overall risk, effectively utilizing the combined leverage to maintain risk management and subsequently enhance operating performance.

Table 4. Results of The Mediation Effect Mechanism Test

Variables	Dependent Variable: BP		
	Model (2)	Model (3)	Model (4)
DT	0.841***	1.071***	0.967***
	(8.532)	(9.419)	(9.94)
OL	-1.962***		
	(-6.253)		
FL		-0.795***	
		(-7.091)	
CL			-0.991***
			(-12.612)

Table 4. (continued).

BS	1.98***	2.21***	2.309***
	(4.923)	(3.988)	(5.371)
AG	-0.743	-0.952	-0.673
	(-2.263)	(-2.143)	(-1.878)
CS	1.638	1.747	1.425
	(1.455)	(2.156)	(1.386)
DA	1.587***	1.361***	1.48***
	(8.712)	(7.179)	(12.633)
RG	0.375**	0.372**	0.474**
	(3.525)	(5.234)	(4.275)
Constant term	0.658***	0.581***	0.555***
	(8.611)	(8.301)	(7.5)
DW Statistic	2.524	3.729	1.521
Adjusted R-squared	0.572	0.479	0.844
F-value	25.12***	35.12***	19.12***

Note: Significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively.

5. Conclusions and Recommendations

Based on a comprehensive analysis of research on enterprise digital transformation and business performance, this paper focuses on the manufacturing industry and utilizes data from A-share listed manufacturing companies to propose hypotheses and construct models to analyze the relationship between the degree of digital transformation and the level of business performance in manufacturing enterprises. The study also examines the underlying mechanisms from the perspective of deleveraging. The empirical results confirm that digital transformation in manufacturing enterprises does indeed contribute to improving business performance to a certain extent, with enterprise leverage playing a significant mediation effect. By leveraging digital technologies, manufacturing enterprises can reduce information asymmetry between the enterprise and the external environment, as well as among internal organizations, thereby enhancing information utilization efficiency, production efficiency, and operational efficiency. This, in turn, alleviates operating and financial leverage, lowers enterprise risk levels, and ultimately improves business efficiency, fostering sustainable enterprise development.

Based on the above research conclusions, this paper proposes the following two insights and recommendations. First, for manufacturing enterprises, it is recommended to tailor digital transformation strategies and tactics that align with their development goals, taking into account their own characteristics and the environmental context. By leveraging digital technologies such as artificial intelligence, blockchain, cloud computing, and big data, enterprises can optimize their production and manufacturing processes, enhance production efficiency, improve collaborative management and decision-making efficiency. The advantages of digital technologies should be fully utilized to eliminate information asymmetry both within and outside the enterprise, assist enterprises in matching the best financing policies and solutions, alleviate financing constraints, and reduce financial and operating leverage. This will help achieve controllable and gradual reduction of enterprise risks, thereby leading to business growth, improved operating performance, and the realization of strategic goals, ensuring stable and sustainable enterprise development. Second, for governments, it is recommended to issue policies that incentivize enterprises to accelerate their digital transformation efforts. Policies and digital technology support should be tailored to enterprises at different stages, providing a foundational public infrastructure for digital transformation that facilitates technology sharing and data interoperability among enterprises and industries. Financial subsidies and tax incentives should be used to encourage enterprises to embark on the path of digital transformation, promoting the active utilization of digital technologies to strengthen innovation activities. This will foster a healthy competitive environment of sustainable innovation and development, promote stable enterprise growth, and enhance enterprise competitiveness.

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