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Digital transformation and firm performance among Chinese manufacturing firms: A moderated-mediation model

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ABSTRACT

This paper examines how digital transformation (DT) influences the performance of Chinese manufacturing firms within the context of industrial upgrading. It considers both the short-term and long-term effects of DT and the mechanisms through which these effects unfold. Using panel data from A-share listed manufacturing firms between 2014 and 2023, the study develops a moderated mediation model in which resource allocation (RA) and innovation capability (INC) serve as mediators, while internal control (ICON) moderates the mediation paths. The findings reveal that DT has the most significant and apparent impact on firm performance, with a cumulative effect: the more intensive the DT efforts, the greater the benefits. RA exerts a direct influence on short-term performance (FPS), while INC plays a critical role in driving long-term performance (FPL). ICON demonstrates a two-pronged effect: it amplifies the efficiency impact of RA on FPS while constraining INC's flexibility in the short term, but over time, it fosters FPL through innovation transformation. These findings suggest that firms can benefit most from DT when digital initiatives are aligned with governance and resource allocation and combined with efforts to build innovation capability. Such alignment not only translates short-term efficiency gains into immediate improvements but also ensures lasting competitiveness through sustained innovation.

Contribution/ Originality: This study constructs a moderated mediation framework linking DT, RA, INC, and ICON. By distinguishing FPS and FPL, it demonstrates how governance and capability factors jointly influence firm outcomes. The evidence contributes to understanding DT in manufacturing and offers guidance for both managers and policymakers.

1. INTRODUCTION

And digitalization in China is doing well recently, and it is also transforming China's economy and industrial changes. It was up to 2023 and reached 53.9 trillion RMB, which occupied the proportion of 42.8% of GDP, and it is also the world's second-largest manufacturing sector under these circumstances; This is a fully-fledged Digital Transformation (DT). More than 100 million are currently connected through the industrial network, and more than 30% of lines have added smart elements to their production line.

As for some technologies like artificial intelligence, big data, and the Internet of Things, they have become a reality. They are used extensively to help manufacturers utilize their resources more efficiently. At the national strategy level, initiatives such as Made in China 2025 and the 14th Five-Year Plan for the Digital Economy support digital growth, which is a top priority. Combining these efforts makes China a better environment for China's

Manufacturing Firms (CMFs) worldwide and opens new avenues for the Chinese industry to grow in a smart, rapid, and environmentally sustainable manner.

China's manufacturing speed of the DT trend is fast. Too many great businesses are rushing to digital tools, keeping up with such a giant world. For DT, it is the main path (Niu, Wen, Wang, & Li, 2023). The report claims that DT will cut info gaps, improve RA, make ops better (Guo & Xu, 2021; Zhao, Wang, & Li, 2021), reduce business risk, and encourage creation and long-term growth. With the increase being adopted, it is time for smarter manufacturing.

And the results of DT on CMFs also show mixed results. One big issue is technical. Many businesses get in touch with suppliers to acquire large tech. The core process remains unaffected by what it can do, so change is patchy. Small and medium enterprises are taking a significant hit, with no funds, no technology, and no talented staff members. How will they progress? Supply chain shake-up is possible, as is environmental pressure (Shahi & Sinha, 2021; Zhang, Xu, & Ma, 2022). Many supply networks are not robust, so they are affected by global events and market fluctuations. At the same time, due to the setting of carbon reduction targets and the regulation of energy utilization, it is difficult to sustain growth (Hsu, Zeng, Chang, & Cai, 2022). Fourth, the business is squeezed by an increase in competition from home market problems. Domestic markets are extremely full with little chance and competition. So, all of these other different things combined together are what make the difference in the DT promises versus how most companies are finding themselves worse off than promised by the DT.

Managerial Studies have provided useful descriptions of these issues, and the economic modelling literature does not fully capture the complicated nature that DT has on enterprise performance. Existing empirical studies treat DT as if it were merely a sudden shock and do not consider the relationship between DT and internal governance structures. Additionally, approaches such as RA, INC, and other econometric methods do not differentiate between FPS and FPL, which are the same DT but have different economic impacts depending on their price.

And we're not reaping the digital transformation benefits we thought we were, so it's like it just reinforces all these other problems and how important it is for us to know how digital transformation impacts businesses. In the digital world, all of these tools are useful, not necessarily to improve (RA), but maybe to improve INC and let a company be more responsive to the outside world (Peter, Pradhan, & Mbohwa, 2023). Not sure. Then let's see what happens to performance with these two routes. If there actually is anything through that DT can improve, maybe it's something theoretical or beneficial in real-time. To explore the internal logic of the DT is in order to help CMFs who want to jump the technology hurdle, get over the risk to the supply chain, and be able to cope with more intense competition.

And also, as the digital economy becomes more prevalent, ICON plays a significant part in the DT process for a manufacturing firm (Lu, Zhan, & Xiao, 2019). A good ICON framework holds a stable and safe working environment, and it makes the performance of the mechanism link between DT and FP possible. To have strong internal controls allows a company to use DT more (technology/knowledge benefit), and then the company will do well (Huijiao, 2021).

Though important, it is unclear how ICON interacts with DT and FP. Research on DT, ICON, and FP often focuses on these aspects in isolation, lacking an integrative approach that connects them. Furthermore, investigations into the mechanisms through which DT influences enterprise performance, particularly from the dual perspectives of innovation (dynamic) and RA (static) are even more limited. Such an integrative approach is critical for understanding how these dimensions collectively drive organizational success in a digital economy.

This study focuses on the CMF to explore the impact pathways of DT on firm performance. It further examines how ICON moderates this process. To achieve this, a three-level mechanism equation is constructed. The first level investigates the direct effects of DT on FPS and FPL. The second level examines the mediating roles of RA and INC in the relationship between DT and firm performance. The third level analyzes the moderating effects of ICON on these mediating pathways. Building on this design, this study advances the economic modelling literature by developing a moderated mediation framework that jointly captures direct, mediating, and moderating effects of DT. It contributes by distinguishing short- and long-term performance outcomes and by integrating RA, INC, and ICON into a unified empirical analysis. The findings enrich digital economy theory and provide actionable implications for both policymakers and managers.

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

2.1. Impact of DT on FP in CMF

Murray (1989) categorized FP into two distinct dimensions: one centered on efficiency, which tends to manifest in the short term, and another focused on adaptability, which reflects a company's longer-term capacity to navigate change. Under this view, FPS captures immediate financial and operational indicators, such as quarterly profits or annual output. FPL, on the other hand, reflects a firm's ongoing ability to maintain competitiveness, adapt strategically, drive innovation, and make the most of its internal resources over time (Si, Xu, & Chen, 2020).

In the context of CMF, improvements in FPS are often linked to the practical application of digital technologies aimed at boosting efficiency and cutting costs. In the early stages of DT, firms typically adopt solutions like smart marketing platforms, automation tools, and real-time analytics. These tools help streamline operations, improve RA, reduce customer acquisition costs, and deliver more personalized services. The result is a measurable uptick in productivity and a quicker response to market demands, factors that collectively contribute to better short-term outcomes (Song & Yang, 2024).

DT contributes to FP not only in the short term but also in ways that continue to unfold over time. Its long-lasting effect lies in the foundation it builds for ongoing innovation and operational refinement (Leng, He, & Kang, 2023). Rather than offering one-off gains, DT helps create a dynamic ecosystem where firms can steadily accumulate practical experience, integrate and repurpose internal resources, and deepen their capacity for innovation. Within this environment, companies are also able to adjust business processes more effectively and foster stronger, more resilient customer relationships. As a result, firms can sustain competitive advantages and achieve long-term profitability (Chukwudi, 2024; Ha, Huong, & Thanh, 2022). Technologies such as big data, artificial intelligence, and IoT fundamentally reshape operating equations, resulting in optimized production, sales, and service processes. This transformation ultimately strengthens FPL (Liu, Zhao, Kamioka, & Nakamura, 2021).

In practice, conflicts sometimes arise between a firm's FPS and FPL. The ability to strategically sacrifice FPS to achieve sustainable long-term growth is a critical determinant of a firm's success. Enterprises must balance short-term profitability with long-term strategic investments to ensure that the pursuit of immediate gains does not overshadow the essential investments and planning required for future development (Souder, Bromiley, Mitchell, & Reilly, 2017).

DT transcends traditional notions of digital technology investment; it encompasses a comprehensive reconfiguration of a firm's vision, business processes, organizational capabilities, structure, and culture. This implies that the primary costs of DT extend beyond technology acquisition and implementation, manifesting instead in the integration and management expenses incurred during the business and organizational transformation process (Hanelt, Bohnsack, Marz, & Antunes Marante, 2021). Compared to traditional IT utilization equations, DT involves distinctly different patterns of benefits and costs. These shifts introduce uncertainties regarding DT's impact on organizational performance, further highlighting its inherent complexity and challenges.

Thus, while DT may impose short-term financial pressures, its long-term benefits, including enhanced innovation capacity and market competitiveness, are expected to outweigh these initial challenges. Accordingly, this study posits the following hypotheses:

H_{1a}: DT has a significant positive impact on FPS in CMF.

H_{1b}: DT has a significant positive impact on FPL in CMF.

2.2. Mechanisms Linking DT to FP

The resource-based theory posits that a firm's competitive advantage stems from the acquisition, allocation, and optimization of core resources (Barney et al., 2011). DT helps firms bring data and technology together in ways that improve how resources are used and managed. Supporting more precise, responsive management practices leads to clear improvements in internal efficiency and daily operations (Rosyidah, Djatmika, Wardoyo, Restuningdiah, & Soetjipto, 2024). At the same time, dynamic capabilities theory emphasizes that firms must constantly build and adjust their innovation abilities if they want to stay competitive in a changing market. In China's manufacturing sector, many of those older firms have been struggling with inefficient resource use and a poor innovation system for quite a while. Companies can use digital tools to save money, make good use of resources, and develop better products by doing things differently, working differently, and selling to different people (Fang & Yuan, 2025).

This study has taken the theories above and looked at are two main ways digital transformation impacts firm performance: RA improvement and INC improvement. Based on the resource-based theory, which emphasizes stable internal resources, and the dynamic capability theory, which emphasizes adaptability and innovation, we explain the contribution of digital transformation to the CMF. These two approaches, one focused on structure, the other on changeability, demonstrate how digital technology enables rapid progress in small increments while building substantial long-term outcomes. It provides a comprehensive view, allowing understanding of digital transformation and offering guidance to businesses seeking to leverage digital tools to enhance their performance.

2.2.1. INC as a Mediator

Innovation ecosystems became a new way for companies to do R&D (Huwei & Shengyun, 2022). Digital tools are making it possible for companies to produce products faster, reduce costs, and increase efficiency. Take smart production lines and real-time data tracking for better manufacturing. It is more likely to adapt to changes and get products out faster. This kind of improvement can satisfy customers; it is also beneficial in the short term (Abdallah, Shehab, & Al-Ashaab, 2021).

And even 1,000 years from now, DT will help manufacturers stay ahead of the game and earn money for many centuries to come. It's time for another change or fine-tuning; it's not just a little change. DT creates big changes to how an organization works (Zhao, Sun, Zhao, & Xing, 2022). Technology and product expertise, customers' network resources, cooperation, and coordination make the company more flexible and powerful for adapting to a fast-changing market and growth. Over time, these integrative changes will result in gains, allowing companies to create even more value than everything they have improved on all by themselves. Therefore, DT is always a constant improvement (Zhao et al., 2022).

2.2.2. RA as a Mediator

RA terms: Digital tech usages cause changes in the core strategic resource structure, which can assist businesses in realizing strategic transformation and improving the efficiency of human, funds, and material allocation and use (Adama, Popoola, Okeke, & Akinoso, 2024).

In the short term, DT significantly improves operational efficiency and market responsiveness in manufacturing firms through resource optimization. Automation technologies and real-time data analytics allow precise scheduling of production resources, reducing downtime and improving productivity. These technologies also enable firms to respond quickly to market demands (Bayram, Springer, Garvey, & Özdemir, 2020). Smart systems optimize inventory management and logistics coordination, reducing operational costs, improving cash flow, and boosting short-term profitability. Furthermore, digital tools enhance team collaboration and streamline business processes, providing firms with a competitive first-mover advantage (Chikezie, Godwin, Adams, Ifeanyi, & Chukwunweike, 2024).

In the long term, DT promotes industrial upgrading and sustainable development through ongoing resource optimization (Kumari, 2021, 2022). Digital technologies support in-depth analysis of markets and competitive environments, facilitating the strategic allocation of resources and transforming business equations (Nguyen, 2022). Data-driven decision-making continuously enhances operational efficiency, minimizes resource waste, and reduces environmental costs. These efforts strengthen market competitiveness and build an ecosystem focused on innovation and efficient resource utilization. As a result, firms achieve stable profitability and long-term sustainability.

DT exerts a mediating effect through RA and INC. It optimizes the dynamic allocation and efficient utilization of resources while driving continuous technological and process innovation. This mechanism not only enhances short-term operational efficiency and market responsiveness but also fosters long-term innovation ecosystems and strategic resource integration. Consequently, it strengthens firms' sustainable development capacity and competitive advantage. Based on this, we propose hypotheses H2a, H2b, H2c, and H2d.

H_{2a}: INC mediates the positive relationship between DT and FPS.

H_{2b}: INC mediates the positive relationship between DT and FPL.

H_{2c}: RA mediates the positive relationship between DT and FPS.

H_{2d}: RA mediates the positive relationship between DT and FPL.

2.3. Moderating Role of ICON

ICON refers to a series of policies and procedures designed by firms to achieve organizational objectives. It ensures efficient operations, asset protection, and the accuracy of financial information. Within the relationship between DT and FP, ICON plays a critical moderating role (Boulhaga, Bouri, Elamer, & Ibrahim, 2023; Chen, Yang, Zhang, & Zhou, 2020).

2.3.1. ICON's Moderation of INC

In terms of INC, an effective ICON that resources are focused on high-potential innovation projects. It achieves this through standardized budget approvals and dynamic monitoring. This enables the management of innovation strategies in DT to align closely with strategic objectives (Luo, Xiong, & Liu, 2024; Masoud & Basahel, 2023). As a result, enterprises can accelerate the application of digital technologies in research and development, reducing the time required for innovation outcomes to materialize. This improves the efficiency of innovation processes and product quality, allowing firms to launch new products or improve existing ones more rapidly. ICON also helps to identify and address problems in a timely manner, increasing the success rate and efficiency of innovation projects, thereby enhancing financial performance. Additionally, it establishes clear performance evaluation and incentive mechanisms, motivating employees to engage in innovative activities and further strengthening the firm's innovation capabilities (Sousa-Zomer, Neely, & Martinez, 2020). This enhanced innovation capacity contributes to improved FPS in the short term by enabling firms to quickly adapt to market changes and customer needs. ICON helps strengthen the DT process by improving both the efficiency and quality of innovation efforts. It enhances FPS by making innovation activities more focused and effective, allowing firms to generate practical outcomes from new ideas more quickly (Bresciani, Huarng, Malhotra, & Ferraris, 2021; He & Su, 2022; Wang, Wang, Deng, & Wang, 2023).

In the short run, DT is a business creation trip. To turn research and innovation into productivity will require time, not an instant. That's a fair amount of time. I can help, ICON, as far as knowledge flow and internal flow. So we make sure that new resources are directed towards projects that will have a long-lasting appeal in the market, or we could say that we would have a high chance of receiving continuous rewards over a longer duration of time. It can promote the accumulation and leap of core technology, so as to improve the innovation ability of the company, so that FPL (Wu & Zeng, 2022). It can be beneficial to have a strong framework system to manage all intellectual property risks when their technology leaks or is stolen. This can reduce ambiguity in innovation throughout digital transformation (DT) and ensure the firm continuously implements its strategy. All these mechanisms together contribute to the improvement of FPL (Gong, Yao, & Zan, 2023; Metreveli, 2024).

ICON makes the process of innovation management and risk reduction in DT more effective. In the short term, it enhances the efficiency and speed of innovation outcomes, while in the long term, it ensures the protection and application of innovation achievements. This dual role supports sustained performance growth and enhances the competitive advantage of manufacturing firms. Based on this analysis, we propose hypotheses H3a and H3b.

2.3.2. ICON's Moderation of RA

In terms of RA, effective ICON ensures that management remains focused on maximizing organizational interests. It motivates managerial efficiency and reduces the risk of resource misallocation caused by management's deliberate avoidance of strategic transformation risks. This enhances the role of digital technologies in optimizing RA (Aguilera, Niroula, & Zhang, 2023).

ICON systems, with standardized management processes and stringent RA mechanisms, regulate the input-output efficiency of enterprise resources, ensuring their effective and rational utilization (Lu, 2021). DT requires substantial resource investments, including capital, technology, and human resources, often involving cross-departmental collaboration.

ICON, through measures such as budget control, cost management, and RA, ensures the rapid concentration of critical resources on high-yield projects, accelerating resource utilization efficiency. Dynamic monitoring mechanisms promptly identify issues such as resource waste and inefficient allocation, effectively reducing operational costs (Li, 2020). These measures enable enterprises to leverage digital technologies more efficiently, improve productivity, and enhance market responsiveness, thereby boosting FPS. Additionally, with timely risk alerts and response mechanisms, firms can adjust RA processes more effectively, ensuring both safety and efficiency (Liu, Pan, Lin, Wang, & Zhang, 2024; Zhang, Pan, Meng, & Wang, 2023). This risk management capability helps stabilize operations and mitigate performance fluctuations caused by resource misallocation (He & Shi, 2023).

In the context of DT, ICON amplifies the impact of RA on FPL through strategic resource planning, enhanced resource integration, and improved efficiency in allocating strategic resources (Su, Zhang, Ge, & Chen, 2022). ICON ensures the prioritization of resources for competitive technology development and high-value-added sectors, driving technological accumulation and market expansion. By strengthening resource integration, ICON optimizes supply chain collaboration and industrial chain layouts, enhancing firms' resilience to market fluctuations. The dynamic adjustment of strategic R&D ensures alignment between resource utilization and long-term organizational objectives, further improving sustainability (Chen, Lee, Hui, & Qian, 2023). Through systematic resource management, ICON significantly enhances FPL during DT, laying a solid foundation for sustainable value creation.

In DT, ICON drives FPS by improving resource utilization efficiency and conversion speed. Over the long term, it promotes strategic RA and integration, strengthening sustainability and FPL. Based on this analysis, we propose hypotheses H3c and H3d.

H_{3a}: ICON strengthens the impact of DT on INC, enhancing FPS.

H_{3b}: ICON strengthens the impact of DT on INC, enhancing FPL.

H_{3c}: ICON strengthens the impact of DT on RA, enhancing FPS.

H_{3d}: ICON strengthens the impact of DT on RA, enhancing FPL.

Grounded in the resource-based theory and dynamic capabilities perspective, this study proposes a mediating pathway through which digital transformation (DT) influences enterprise performance via RA and innovation capability (INC). Additionally, it explores the moderating role of ICON in this pathway. As the independent variable, DT impacts FPS and FPL through the mediating effects of RA and INC. Simultaneously, ICON functions as a moderating variable, either strengthening or weakening the effects of DT on RA and INC, thereby indirectly influencing enterprise performance. To illustrate this framework, this study constructs a research hypothesis equation, as shown in Figure 1.

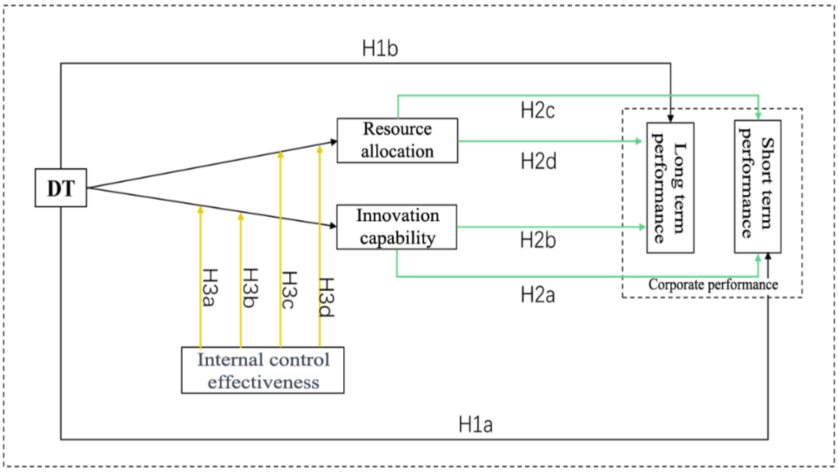

Figure 1. Research hypotheses.

3. RESEARCH DESIGN

3.1. Variable Definitions and Measurement

3.1.1. Core Explanatory Variable

1. Independent Variables

The independent variable, DT, is quantified using a keyword-based analysis of corporate annual reports. Keywords such as smart manufacturing and industrial internet are employed to construct a measurable index. This study adopts the comprehensive DT evaluation index, as developed by Zhao et al. (2021), to assess the extent of DT.

2. Dependent Variables

This study employs Return on Assets (ROA) as the dependent variable to measure FP. ROA effectively reflects a company's efficiency in generating profits from its assets and serves as a key indicator of operational efficiency and resource utilization. As a financial metric, ROA is both straightforward and convenient, facilitating cross-company comparisons (Haji & Mohd Ghazali, 2018; Pucci, Simoni, & Zanni, 2015; Soda, Oroud, & Makhlouf, 2021). FP is captured through two dependent variables: FPS and FPL.

- FPS: Measured using the change in ROA within one year, reflecting the firm's short-term profitability and operational efficiency. The one-year horizon captures the immediate outcomes of managerial and operational adjustments, consistent with common practice in performance studies.
- FPL: Measured using ROA lagged by three years, capturing the firm's capacity for sustained profitability and competitive advantage over an extended period (Horváthová, 2012; Wibbens & Siggelkow, 2020). The three-year horizon captures the delayed but lasting effects of innovation, strategic investment, and resource reallocation, thus representing long-term performance.

3.1.2. Other Variables

1. Mediating Variables

- RA: Measured by the total asset turnover ratio, calculated as operating revenue divided by average total assets. This metric indicates the efficiency of resource utilization (Modi & Mishra, 2011; Tutcu et al., 2024).
- INC: Measured by the R&D expense ratio, calculated as R&D expenditures divided by operating revenue, reflecting the firm's investment in innovation (Ghazal, Aziz, Tabash, & Drachal, 2024; Jiang, Su, Hu, Yin, & Chang, 2024).

2. Moderating Variable

- ICON: Measured using the DIBO index, a comprehensive and systematic indicator of ICON quality in Chinese firms. The DIBO index evaluates ICON's effectiveness across dimensions such as compliance, risk management, and operational efficiency (Liu, 2017; Shu, Chen, & Lin, 2018).

3. Control Variables

To account for potential confounding factors, several control variables are included (Dalwai, Mohammadi, & Satrovic, 2024; Kalyani & Annamalai, 2024; Putri, Martusa, & Meythi, 2024).

- Firm Age (Age): Years since the company's establishment.
- Cash Holdings (Cash): Proportion of cash and cash equivalents in total assets.
- Ownership Concentration (Top 10): Sum of shareholdings by the top 10 shareholders.
- Market Competition (HHI): Measured using the Herfindahl-Hirschman Index (HHI).
- Industry and Year Effects: Controlled through dummy variables for industry and year.

Data for these variables is sourced from the CSMAR and Wind databases.

A summary of variable definitions and measurements is provided in Table 1.

Table 1. Variable declaration.

Variable type	Abbreviation	Description	Measurement
Dependent variable	FPL	FPL	ROA delayed by 3 years
	FPS	FPS	ROA
Explanatory variable	DT	DT	Zhao Chenyu DT Index (2021)
Mediating variables	RA	RA	Total asset turnover ratio
	INC	INC	R&D expenses/Operating revenue
Moderating variable	ICON	ICON	DIBO index
Control variables	Age	Firm age	Years since the company went public +1
	Top10	Ownership concentration	Top 10 shareholders' shares/Total shares
	Cash	Cash holdings	Proportion of cash and cash equivalents in total assets
	HHI	Market competition level	Herfindahl-Hirschman Index
Dummy variable	Year	Year	Year dummy variable
	Ind	Industry	Industry dummy variable

3.2. Statistical Equation

3.2.1. Direct Effects

The direct effect of DT on FPS and FPL is estimated using a two-way fixed-effects regression framework.

$$FP_{it} = \alpha_0 + \alpha_1 DT_{it} + Ind_i + Year_m + \varepsilon_{it} \quad (1)$$

$$FPS_{it} = \beta_0 + \beta_1 DT_{it} + \beta_2 control_{it} + Ind_m + Year_t + \varepsilon_{it} \quad (2)$$

$$FPL_{it} = \gamma_0 + \gamma_1 DT_{it} + \gamma_2 control_{it} + Ind_m + Year_t + \varepsilon_{it} \quad (3)$$

Here, i represents the firm, and t represents the year. Given the lagged impact of DT, the dependent variable FP is lagged by one period to denote FPS (ROA_{it+1}), reflecting FPS. Similarly, FP is lagged by three periods to denote FPL (ROA_{it+3}), capturing FPL. The variable DT_{it} represents the DT level of firm i in year t and serves as the core explanatory variable. To control for potential confounding effects, key control variables are included: $control_{it}$. These encompass age, top10, cash, and HHI. Additionally, Yeart and Indm denote year and industry fixed effects, while ε_{it} captures random disturbances, including unobservable firm- and time-specific factors.

- Equation 1: A baseline regression includes only the core variable DT and fixed effects. This setup tests the direct effect of DT on the performance of CMF without additional controls.
- Equations 2 and 3: Building upon Equation 1, these Equations introduce control variables to examine the FPS and FPL impacts of DT under controlled conditions. Equation 2 tests hypothesis H1a, while Equation 3 validates hypothesis H1b.

3.2.2. Moderated Mediation Effect

$$M_{it} = \lambda_0 + \lambda_1 DT_{it} + \lambda_2 control_{it} + Ind_m + Year_t + \varepsilon_{it} \quad (4)$$

$$FPS_{it} = \vartheta_0 + \vartheta_1 DT_{it} + \vartheta_2 M_{it} + \vartheta_3 control_{it} + Ind_m + Year_t + \varepsilon_{it} \quad (5)$$

$$FPL_{it} = \kappa_0 + \kappa_1 DT_{it} + \kappa_2 M_{it} + \kappa_3 control_{it} + Ind_m + Year_t + \varepsilon_{it} \quad (6)$$

$$M_{it} = \tau_0 + \tau_1 DT_{it} + \tau_2 ICON_{it} + \tau_3 DT_{it} * ICON_{it} + \tau_4 control_{it} + Ind_m + Year_t + \varepsilon_{it} \quad (7)$$

$$FPS_{it} = \varrho_0 + \varrho_1 DT_{it} + \varrho_2 ICON_{it} + \varrho_3 M_{it} + \varrho_4 DT_{it} * ICON_{it} + \varrho_5 control_{it} + Ind_m + Year_t + \varepsilon_{it} \quad (8)$$

$$FPL_{it} = \chi_0 + \chi_1 DT_{it} + \chi_2 ICON_{it} + \chi_3 M_{it} + \chi_4 DT_{it} * ICON_{it} + \chi_6 control_{it} + Ind_m + Year_t + \varepsilon_{it} \quad (9)$$

In this analysis, *Mit* serves as the mediating variable, representing either *INC* or *RA*. By introducing *INC* and *RA* as mediators, the equations explore the mechanisms through which *DT* influences *FPS* and *FPL*. Additionally, *ICON* is incorporated as a moderating variable to examine its role in adjusting the mediation pathways.

The interaction term *DTit×ICONit* is employed to analyze how *ICON* moderates the impact of *DT* on the mediators (*INC* or *RA*) and their subsequent influence on FP. Control variables, as well as fixed effects for industry and year, are included to enhance equation robustness.

- Equations 5 and 6: These Equations test hypotheses H2a, H2b, H2c, and H2d, focusing on the mediation pathways.
- Equations 8 and 9: These Equations evaluate hypotheses H3a, H3b, H3c, and H3d, specifically addressing the moderating role of ICON in the mediation process.

This analytical framework enables a comprehensive understanding of both direct and conditional indirect effects while ensuring robust and reliable results through rigorous equation design.

3.3. Data Sources and Description

This study focuses on Chinese A-share listed manufacturing firms. To enhance the accuracy of empirical analysis, the raw data were processed as follows:

- Firms with substantial missing values for key variables were excluded.
- Manufacturing firms that completed IPOs during the observation period were removed.
- Firms classified as ST, ST* with special treatment, or delisted during the observation period were excluded.
- To mitigate the impact of outliers, all relevant variables were winsorized at the 1st and 99th percentiles.

Following these rigorous data-filtering steps, the final dataset comprises 13,995 observations from 2,425 listed firms over the period 2014–2023. Industry coverage follows the CSRC's manufacturing classification (Category C), which is divided into 8 major sub-sectors and 18 minor classes. For example, the sample covers Equipment and Machinery (C3) as well as Pharmaceuticals and Bioproducts (C8), alongside other representative categories of both traditional and high-tech manufacturing. The descriptive statistics for the primary variables are presented in Table 2.

Data preprocessing was conducted using Stata 17, ensuring the robustness of the analysis and the reliability of the results.

Table 2. Descriptive statistics.

Variable	Obs.	Mean	Std. dev.	Min.	Max.
FPS	12,838	4.874	7.133	(24.951)	24.933
FPL	8,484	4.911	6.860	(24.097)	24.112
DT	13,995	1.394	0.287	0.527	1.916
RA	13,995	0.605	0.308	0.093	1.721
INC	13,995	0.037	0.047	0.000	0.332
ICON	13,995	6.149	1.401	0.000	6.677
Age	13,995	9.684	7.366	1.000	28.000
HHI	13,995	15.109	11.602	4.119	67.336
Cash	13,995	20.738	13.934	2.303	73.402
Top10	13,995	57.463	14.440	23.790	89.350

Table 3. Baseline regression result.

Variable	(1)	(2)	(3)
	FP	FPS	FPL
DT	1.680***	1.463***	2.250***
	(5.39)	(6.27)	(7.86)
Age		-0.144***	-0.212***
		(-16.75)	(-21.19)
HHI		0.00904	0.0434***
		(0.81)	(3.00)
Cash		0.123***	0.104***
		(28.49)	(19.60)
Top10		0.0900***	0.0897***
		(20.42)	(17.53)
_cons	1.704***	-4.124***	-4.049***
	(3.24)	(-8.22)	(-6.80)
YEAR FE	Yes	Yes	Yes
IND FE	Yes	Yes	Yes
N	13994	12838	8484
R^2	0.028	0.190	0.202
adj. R^2	0.026	0.189	0.200

Note: t-statistics in parentheses. ***, denote statistical significance at the 1% level.

4. EMPIRICAL RESULTS AND ANALYSIS

4.1. Analysis of Baseline Results

Table 3 presents the results of the baseline regression analysis. Column (1) shows the direct effect of DT on FP, corresponding to Equation 1. Columns (2) and (3) incorporate control variables, including age, HHI, cash, and top10, corresponding to Equations 2 and 3, respectively.

The findings indicate that DT has a significant positive impact on FP, FPS, and FPL in Chinese listed manufacturing firms. Notably, the effect on FPL is the strongest, with a coefficient of 2.250 (t=7.86, p<0.01), which is substantially higher than the coefficients for FPS (1.463, t=6.45, p<0.01) and FPL (1.680, t=7.02, p<0.01). This means that a one-unit increase in DT is associated with an average increase of 1.463 units in FPS and 2.250 units in FPL, highlighting DT's stronger role in enhancing long-term profitability. This suggests that DT plays a more prominent role in enhancing FPL.

The explanatory power of the equations, as reflected in R^2 and adjusted R^2, improves progressively. The adjusted R^2 for FPL (0.048) is higher than that for FPS (0.037) and FP (0.026), demonstrating that DT has a stronger explanatory effect on FPL.

The inclusion of Ind and Year fixed effects further enhances the equation's robustness. Additionally, all t-values are statistically significant at the p<0.01 level, reinforcing the significant role of DT in improving FP.

These results provide robust support for hypotheses *H1a* and *H1b*.

4.2. Endogeneity Test

To address potential endogeneity issues in the equation, this study employs the System Generalized Method of Moments (System GMM) and Two-Stage Least Squares (2SLS) methods for endogeneity testing. The results are presented in Table 4.

Table 4. Endogeneity test.

Variable	Two-Stage Least Squares				System GMM	
	1	2	3	4	5	6
	DT	EPS	DT	EPL	EPS	EPL
DT		11.99*		11.66*	8.529*	48.92
		-2.95		-1.84	-1.77	-2.3
L.meanDT	0.633*					
	-6.99					
L3.meanDT			0.394*			
			-4.41			
L.EPS					0.37	
					-2.51	
L.EPL						0.164
						-0.36
Controls	Yes	Yes	Yes	Yes	Yes	Yes
YEAR FE	Yes	Yes	Yes	Yes	Yes	Yes
IND FE	Yes	Yes	Yes	Yes	Yes	Yes
N	11549	11548	7611	7610	10412	6647
R^2	0.231	0.035	0.201	0.064	0	0
adj. R^2	0.229	0.033	0.198	0.061	0.207	0.425
Under identification test	48.824 (0.000)		19.507 (0.000)			
Weak test	48.91 (16.38)		19.493 (16.38)			
Sargan test	0.0000		0.0000			
AR(1)					0.000	0.000
AR(2)					0.207	0.425
Hansen *test*					0.14	0.888

Note: t-statistics in parentheses. *, denote statistical significance at the 10% level.

- Two-Stage Least Squares: From Columns (1) and (3), the underidentification test, weak identification test, and Sargan statistic test results (all $p<0.01$) confirm that the instrumental variables are identifiable. The Cragg-Donald Wald F-statistic exceeds the critical value at the 10% level, validating the use of strong instrumental variables. The Sargan test value equals 0, indicating no overidentification issues. Regression results show that DT significantly and positively impacts FPS and FPL ($p<0.01$), confirming robustness after addressing endogeneity.
- System GMM: In Columns (5) and (6), the AR(1) test rejects the null hypothesis, while AR(2) and Hansen tests accept it, confirming no autocorrelation and no overidentification of instruments. The System GMM equation incorporates lagged dependent variables, effectively addressing bidirectional causality and endogeneity. Results consistently show DT's significant positive effect on FPS and FPL, aligning with baseline findings.

4.3. Robustness Tests

This study conducts robustness tests through dependent variable substitution, sample modification, and the addition of control variables. Table 5 summarizes the findings.

- Dependent Variable Substitution: Columns (1) and (2) replace ROA with ROIC, generating EPS1 and EPL1 by lagging one and three periods. Results show that DT has a significant positive effect on EPS1 and EPL1 at the 5% level, consistent with baseline results.
- Sample modification: Columns (3) and (4) exclude 2020 data, revealing that DT significantly positively affects FPS and FPL at the 1% level, aligning with baseline findings.
- Adding control variables: columns (5) and (6) incorporate debt-to-asset ratio (DAR) and book-to-market ratio (BM). DT remains significantly positive, with coefficients of 2.203 and 2.707. DAR and BM negatively impact dependent variables, consistent with economic theory.

Table 5. Robustness test.

Variable	Replacing the dependent variable		Modifying the sample composition		Adding control variables	
	(1)	(2)	(3)	(4)	(5)	(6)
	EPS1 (ROIC)	EPL1 (ROIC)	FPS	FPL	FPS	FPL
DT	0.0327* -4.77	0.0438* -5.11	1.516* -6.25	2.276* -7.02	2.203* -9.72	2.707* -9.44
DAR					-8.063* (-30.12)	-4.012* (-13.26)
BM					-3.420* (-12.79)	-1.862* (-5.99)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
YEAR FE	Yes	Yes	Yes	Yes	Yes	Yes
IND FE	Yes	Yes	Yes	Yes	Yes	Yes
N	11542	7605	11117	6944	12660	8433
R^2	0.034	0.033	0.184	0.191	0.259	0.223
adj. R^2	0.032	0.03	0.183	0.188	0.258	0.22

Note: t-statistics in parentheses. *, denote statistical significance at the 10% level.

4.4. Analysis of Moderated Mediation Results

Table 6 summarizes the results of the moderated mediation analysis, illustrating the effects of DT under ICON's moderation on EPS, EPL, and the mediating variables (RA and INC). The results demonstrate notable complexity.

Table 6. Test analysis of moderated mediation effects.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	INC	FPS	INC	FPL	RA	FPS	RA	FPL
DT	0.0130* -7.43	-4.501* (-15.09)	0.0187* -8.87	-1.762* (-5.01)	-0.0691* (-5.04)	-4.364* (-14.90)	-0.0829* (-5.04)	-1.483* (-4.24)
RA						4.263* -22.6		1.610* -6.96
INC		-12.14* (-8.08)		7.735* -4.29				
c.ICON#c.DT	-0.00103* (-5.94)	0.909* -30.81	-0.00117* (-6.19)	0.589* -18.71	0.0216* -15.95	0.829* -28.35	0.0208* -14.14	0.546* -17.22
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
YEAR FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IND FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	12838	12838	8484	8484	12838	12838	8484	8484
R^2	0.413	0.251	0.334	0.234	0.129	0.276	0.133	0.237
adj. R^2	0.412	0.25	0.332	0.232	0.127	0.275	0.131	0.235

Note: t-statistics in parentheses. *, denote statistical significance at the 10% level.

From Columns (1) and (2), the direct effect of DT on INC is significantly positive (0.0130, $p<0.01$), while the direct effect of INC on FPS is significantly negative (-12.14, $p<0.01$). Based on the DT → INC → FPS mediation pathway, the indirect effect of DT through INC remains significant, supporting H2a. The interaction term c.ICON#c.DT has a significant positive moderating effect on FPS (0.909, $p<0.01$), indicating that ICON positively moderates the relationship between DT and INC. However, this moderating effect does not completely offset the negative impact of INC on FPS. Thus, H3a is partially supported, confirming the existence of ICON's positive moderating role, though its impact on improving FPS is limited.

Columns (3) and (4) further explore DT's impact on FPL. The direct effect of DT on INC remains significantly positive (0.0187, $p<0.01$), and the direct effect of INC on FPL is also significantly positive (7.735, $p<0.01$). Thus, the DT → INC → FPL mediation pathway is significant, supporting H2b. The interaction term c.ICON#c.DT shows a significant positive moderating effect on FPL (0.589, $p<0.01$), enhancing this pathway. However, the negative moderating effect of ICON on DT and INC (Column 1, -0.00103, p<0.01) partially reduces DT's direct impact on INC. Therefore, H3b is partially supported.

Columns (5) and (6) demonstrate that the direct effect of DT on RA is significantly negative (-0.0691, p<0.01), while the direct effect of RA on FPS is significantly positive (4.263, p<0.01). The interaction term c.ICON#c.DT has a significant positive moderating effect on FPS (0.0216, p<0.01). This indicates that ICON effectively mitigates the negative impact of DT on RA and amplifies RA's positive contribution to FPS. Therefore, the DT → RA → FPS pathway is significant, supporting both H2c and H3c.

Columns (7) and (8) show that the direct effect of DT on RA is significantly negative (-0.0829, p<0.01), while the direct effect of RA on FPL is significantly positive (1.610, p<0.01). The DT → RA → FPL mediation pathway is significant, supporting H2d. The interaction term c.ICON#c.DT exhibits a significant positive moderating effect on FPL (0.0208, p<0.01), further strengthening this pathway. This confirms that ICON significantly enhances RA's positive impact on FPL. Therefore, H3d is fully supported.

The Equation results indicate that H2b, H2c, and H2d are fully supported, while H2a is partially supported. This demonstrates that DT significantly impacts EPS and EPL through INC and RA. INC shows certain negative effects in the short-term pathway but remains significant overall through its indirect effects. In the long-term pathway, INC exhibits a positive contribution. RA demonstrates significant positive effects in both short-term and long-term pathways.

Meanwhile, the equation results indicate that H3a and H3b are partially supported, while H3c and H3d are fully supported. ICON shows a significant positive moderating effect in the pathways involving DT, RA, and INC on FP. However, its negative moderating effect on INC limits its full potential in the H3a and H3b pathways.

Table 7. Moderated mediation effect test results.

ICON level	DT→RA→FPS			DT→RA→FPL		
	Mediation effect	Std. err.	95% confidence interval	Mediation effect	Std. err.	95% confidence interval
High level	-0.3404	0.0679	[-0.4734, -0.2074]	-0.3404	0.0576	[-0.4533, -0.2275]
Low level	-0.338	0.0733	[-0.4817, -0.1943]	-0.338	0.0653	[-0.4659, -0.2101]
	DT→INC→FPS			DT→INC→FPL		
	Mediation effect	Std. err.	95% confidence interval	Mediation effect	Std. err.	95% confidence interval
High level	-0.3404	0.0449	[-0.4284, -0.2524]	-0.3404	0.0653	[-0.4684, -0.2125]
Low level	-0.338	0.047	[-0.4302, -0.2458]	-0.338	0.0686	[-0.4724, -0.2035]

Moderated Mediation Effect Test. The moderated mediation effects were analyzed using the Bootstrap method with 5,000 resamples and a 95% confidence interval. Table 7 indicate that the indirect effect of DT on FPS through RA is significant under both high (−0.3404-0.3404−0.3404, 95% CI [−0.4734,−0.2074][-0.4734, -0.2074][−0.4734,−0.2074]) and low levels of ICON (−0.338-0.338−0.338, 95% CI [−0.4817,−0.1943][-0.4817, -0.1943][−0.4817,−0.1943]). Similarly, for FPL, the indirect effect through RA remains significant under high (−0.3404-0.3404−0.3404, 95% CI [−0.4533,−0.2275][-0.4533, -0.2275][−0.4533,−0.2275]) and low levels of ICON (−0.338-0.338−0.338, 95% CI [−0.4659,−0.2101][-0.4659, -0.2101][−0.4659,−0.2101]).

Additionally, the indirect effects of DT on FPS and FPL through INC are statistically significant across both high and low ICON levels. These findings strongly support hypotheses H3a, H3b, H3c, and H3d, confirming the robustness of ICON's moderating role in the mediated pathways.

5. DISCUSSION

In the context of China's manufacturing industry transformation, DT has become a critical tool for improving FP. Supported by the 14th Five-Year Plan for Digital Economy Development, CMF have widely adopted smart technologies, big data analytics, and information systems. These efforts have significantly improved production efficiency and reduced operational costs in the short term (Cheng et al., 2023). Additionally, DT has strengthened its long-term competitiveness through technological accumulation and market expansion (Ningsih & Tjahjono, 2024). Thus, H1 is fully supported.

CMF has gradually recognized the critical roles of INC and RA in enhancing performance during DT (Liu & Wang, 2023). However, their effects show distinct differences between the short and long term. In the short term, the high resource investment required for INC often increases costs, creating a negative impact on FPS. This effect is particularly evident in technology-intensive industries. Over the long term, however, INC significantly enhances competitiveness through technology accumulation and the transformation of innovative outcomes (Firdaussiah, Sutjipto, & Febrianta, 2024; Yang, Kheng, & Jaafar, 2024). DT empowers innovation by enabling firms to develop high-value-added products, expand into new markets, and strengthen their global competitiveness. These observations suggest that the resource pressures of INC in the short term eventually translate into long-term value, validating H2a and H2b.

RA demonstrates significant positive effects on both short- and long-term performance. In the short term, RA serves as a key driver of performance improvement, particularly in resource-constrained regions. By optimizing resource allocation, firms can enhance production efficiency and reduce operational costs, leading to rapid improvements in FPS. Additionally, RA optimization facilitates supply chain coordination and improves production capabilities, laying a foundation for sustainable FPL. These practices confirm the critical role of RA in driving performance in both the short and long term, supporting H2c and H2d.

ICON plays a significant moderating role in the pathways through which DT impacts firm performance. In the INC pathway, ICON exhibits a dual effect, restricting flexibility in the short term while promoting long-term benefits. Short-term constraints arise from strict management practices that may limit the agility of innovation, particularly when resource distribution is constrained. Over the long term, however, ICON enhances the positive impact of INC on FPL by standardizing innovation management, facilitating outcome transformation, and protecting intellectual property (Li, Tang, Zhou, & Yang, 2023). This enables firms to more effectively translate research and development into market competitiveness (H3a and H3b hold true).

In the RA pathway, ICON's moderating role is notably positive. Through real-time data monitoring, cost analysis, and budget optimization, ICON mitigates the resource adjustment costs associated with the early stages of DT. It amplifies RA's contributions to both short- and long-term performance, which are validated (Nezhad et al., 2024) (H3c and H3d are validated).

In summary, DT significantly enhances short- and long-term performance in CMF through INC and RA, with ICON amplifying these effects. INC primarily contributes to long-term performance, while RA plays a crucial role in both the short and long term. ICON further strengthens the performance effects of DT, validating H1, H2, and H3. These findings highlight the temporal differences and functional roles of INC and RA while emphasizing ICON's balancing role in digital transformation. They provide valuable theoretical and practical insights for the transformation and upgrading of Chinese manufacturing firms.

6. CONCLUSION AND IMPLICATIONS

6.1. Research Conclusions

DT has been found to improve both FPS and FPL, with its impact more evident on FPL. This suggests that while DT helps firms boost FPS by enhancing operational efficiency, its deeper value lies in strengthening long-term competitiveness through the gradual build-up of technology and the formation of innovation-driven ecosystems. Endogeneity control, robust test. After the endogeneity control, the positive impact of DT is still valid.

RA and INC are the key mechanisms through which DT influences FP, but they do so in different ways. The focal point is mostly relying on better resource utilization and reducing operational costs in the short term. However, INC shows one more aspect: in the short term, it will take a lot of power, which will not be able to do this, and it will drop FPS. Nevertheless, it still plays a significant role in helping FPL, as firms can put together their technology and enter new areas, which is better for the long run.

ICON exhibits dual moderating effects on the two pathways between DT and FP. In the RA pathway, ICON mitigates the initial resource adjustment costs of DT and amplifies RA's positive impact on both FPS and FPL. In the INC pathway, strict ICON management limits the flexibility of innovation activities in the short term. However, by facilitating the standardized transformation of innovation outcomes, ICON ultimately enhances the long-term contribution of INC to FPL.

6.2. Implications

Strengthen the strategic role of DT. DT significantly enhances both FPS and FPL, with a particularly strong contribution to long-term competitiveness. Manufacturing firms should prioritize DT as a core strategy, leveraging technological upgrades and process optimization to achieve short-term efficiency gains while building digital ecosystems to sustain long-term growth.

Optimize RA for FPS. RA plays a critical role in boosting FPS, highlighting the importance of resource optimization in operational success. Firms should adopt intelligent production tools and lean management techniques to maximize resource efficiency (Kolasani, 2023; Yu, Zhang, Cao, & Kazancoglu, 2021). Policymakers can facilitate regional resource-sharing platforms to support resource-constrained areas, reducing costs and enhancing market competitiveness.

Focus on INC for FPL. INC significantly contributes to FPL, emphasizing the need for long-term innovation investment. Firms should develop efficient innovation management systems, streamline processes, and implement incentive mechanisms to enhance technology commercialization (Degtyarev, 2024). Governments can foster collaborative innovation within industrial clusters, promoting knowledge sharing and accelerating the transformation of innovation outcomes.

Establish Dynamic ICON. ICON is pivotal in both short-term and long-term pathways. In the RA pathway, internal controls should leverage real-time monitoring and budgeting tools to improve resource allocation efficiency. In the INC pathway, balancing strict governance with flexibility in innovation activities is essential to ensure that innovation outcomes are effectively translated into long-term competitiveness.

Extend insights to other Asian economies. Beyond China, the findings offer policy implications for other Asian economies undergoing rapid digital transformation. Economies such as Vietnam, India, and Indonesia face similar challenges in balancing resource optimization and innovation-driven growth. Policymakers in these countries can draw lessons from the Chinese experience by strengthening digital infrastructure, promoting innovation ecosystems, and establishing robust governance mechanisms to ensure that digital transformation contributes to both short-term efficiency and long-term competitiveness.

6.3. Contributions

Advancing Moderated Mediation Analysis. This study employs a moderated mediation equation to validate the role of ICON in moderating the effects of DT on FP through RA and INC. It deepens the understanding of the interaction between mediating and moderating variables.

Revealing the dual role of ICON. The study unveils ICON's dual attributes and their temporal dynamics. In the RA pathway, ICON reduces resource adjustment costs. In the INC pathway it restricts short-term innovation flexibility but enhances competitiveness over time by facilitating the structured transformation of innovation outcomes.

Providing dual perspectives on performance. By examining both FPS and FPL, this research reveals the differentiated roles of RA and INC in achieving short-term and long-term performance goals. It offers theoretical guidance for firms to balance short-term efficiency with long-term strategic objectives.

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