



HOW FIRM'S DIGITAL TRANSFORMATION INFLUENCE ITS INNOVATION PERFORMANCE: EMPIRICAL EVIDENCE FROM CHINA

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Abstract

In recent years, firms across industries have increasingly adopted digital technologies to boost their competitive edge and innovation. Despite this growing focus, there is a lack of empirical studies examining the impact of digital transformation on innovation performance in Chinese manufacturing firms. This study uses a fixed effect model to investigate the impact of digital transformation on the innovation performance of 3,678 Chinese manufacturing firms from 2016 to 2023. Our findings indicate that digital transformation significantly enhances innovation performance, with a regression coefficient of 4.146 ($p < 0.01$), suggesting a 41.5% improvement in innovation output for firms adopting digital technologies. Consistent results were observed across control variables such as firm size, total assets, and firm age. Furthermore, the research explores the role of government subsidies, indicating that while these subsidies may hinder digital transformation efforts, they significantly affect innovation performance when controlling for other variables. This dual focus on digital transformation and government subsidies is novel, as it provides a comprehensive understanding of how both factors interact and affect innovation in the context of Chinese manufacturing. Overall, this research highlights the crucial role of digital transformation in fostering innovation and calls for policymakers to strategically refine subsidy programs to better support firms' innovation objectives. For firms undergoing digital transformation, it is recommended that they strategically invest in digital technologies that align with their innovation goals to achieve a competitive edge in an increasingly dynamic technological landscape. However, this study is limited by its focus on Chinese manufacturing firms, which may not fully capture the dynamics of digital transformation in other industries or regions. Future research should explore the relationship between digital transformation, government support, and innovation performance across diverse industries and geographic contexts.

Keywords: Digital transformation, innovation performance, government subsidy, manufacturing firms, China manufacturing firms, fixed effect model, empirical analysis



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1.0 INTRODUCTION

The digital age has ushered in transformative changes across various sectors, with firms increasingly embracing digital technologies to enhance their competitive edge and innovation capabilities. These technologies have significantly promoted firm innovation by optimizing resource allocation, strengthening inter-firm linkages, blurring organizational boundaries, and reducing innovation costs (Cefis et al., 2023; Lo & Lee, 2024). Digital transformation integrates digital technologies into all business areas, fundamentally altering operations and value delivery (Vial, 2019). It represents profound organizational change through creative digital adoption, optimizing operations, and exploring new business models to boost innovation (Gong & Ribiere, 2021; Nambisan, 2017).

Digital transformation is revolutionizing industries globally, with Chinese manufacturing companies leading the shift. Driven by the "Made in China 2025 (中国制造 2025)" initiative, these firms are investing heavily in digital transformation to enhance productivity, innovation, and global competitiveness. The goal is to move from being the "world's factory" for low-cost goods to an "innovation-driven" model producing advanced, high-value products. According to the 20th National Congress of the Communist Party of China (CPC), the Chinese government decided to further deepen comprehensive reform and advance Chinese-style modernization before 2029, which also includes the reform of firm digital transformation. This strategic initiative underscores the importance placed on digital technologies to drive future growth and maintain global competitiveness.

A significant number of studies have analyzed the economic impact and strategic importance of digital transformation (L. Chen et al., 2018; Jiang & Wang, 2024; Z. Wang & Yang, 2024).

Despite the potential benefits, some companies remain uncertain about their business value due to the substantial costs involved (Guo & Xu, 2021). The investment required for digital transformation initiatives can be significant, and firms must carefully weigh the benefits against the expenses. This cautious approach reflects the need for a thorough understanding of the costs, risks, and expected returns associated with digital transformation. However, the business value of digital technologies has gained widespread recognition in the field of information systems research. Extensive studies (L. Chen et al., 2018; P. Chen & Kim, 2023; Guo & Xu, 2021; Merín-Rodrigáñez et al., 2024) on IT valuation demonstrate that investing in or utilizing digital technologies can significantly enhance organizational performance, including both operational and financial aspects. Notably, the role of digital technologies in facilitating internal operations within companies has been a focal point of interest in information systems research.

Despite the growing recognition of digital transformation's benefits, there is a significant gap in empirical research on how it specifically influences innovation performance in Chinese manufacturing firms, particularly in relation to government subsidies (Merín-Rodrigáñez et al., 2024; Z. Wang & Yang, 2024; Zhang et al., 2024). This research seeks to fill this gap in two main strands: 1) exploring the impact of digital transformation on innovation performance and 2) examining the role of government subsidies in this process. The objectives of this study are to understand the relationship between digital transformation and innovation performance in Chinese manufacturing firms and to investigate the influence of government subsidies in this context. The research questions are as follows: 1) How does digital transformation affect the innovation performance of Chinese

manufacturing firms? 2) What role do government subsidies play in enhancing innovation performance in this sector?

First, by exploring how digital degree affects firms' innovation performance, it sheds light on the policy influence on digital degree and innovation. Although prior studies have extensively explored how government policy affect innovation of China, the influence of government policies have been largely overlooked. Second, this paper enhances the innovation research framework by offering insights for companies, particularly those in China's manufacturing sector, on implementing digital transformation to boost their innovation performance.

While the focus of digital transformation has primarily been on the manufacturing sector in China, the insights gained from these trends can be applied to industries worldwide. As digital innovation becomes a priority in other economies, the results of this study could provide useful guidance for firms in different regions aiming to strengthen their innovation capabilities and competitive edge.

The paper is structured as follows. The second section briefly describes the theoretical framework for this study. The third section describes the data and methodology used. Section 4 shows the results and hypothesis testing. The last section discusses the implications and limitations to conclude the paper.

2.0 LITERATURE REVIEW

2.1 Digital Transformation

The advancement of the digital economy necessitates that enterprises adjust to the challenges introduced by digital technology. Drawing on the theory of dynamic capabilities, the digital transformation of enterprises involves employing digital concepts and technologies to boost market competitiveness and respond to swiftly changing market

conditions (L. Chen et al., 2018). Digital transformation is a comprehensive process that integrates digital technologies into all aspects of a business, fundamentally altering how businesses operate and deliver value to customers (Vial, 2019). With the progress of the digital economy, an increasing number of businesses are actively adopting digital technology to enable change and adapt to emerging innovation trends (Hung et al., 2023).

Prior research on digital transformation and enterprise innovation has highlighted multiple dimensions (Bresciani et al., 2021; L. Chen et al., 2018; Hinings et al., 2018; B. Wang et al., 2024). Firstly, digital transformation accelerates innovation in business models. Secondly, it promotes innovation in organizational management. Thirdly, it drives innovation in operational logic and business process management, including areas like inventory and value chain management. Lastly, digital transformation fosters innovation in enterprise infrastructure and institutional foundations, as digitalization reshapes organizations' resources and capabilities.

2.2 Innovation Performance

Schumpeter (1934) posits that innovation allows entrepreneurial firms to achieve rents by temporarily establishing a monopoly, and he views ongoing innovation activity as the primary driver of sustained entrepreneurial success. According to the process understanding, it is common to distinguish between factors that serve as inputs in the innovation process (such as financial resources allocated to innovation tasks or the number of personnel engaged in R&D) and factors that serve as outputs of the innovation process (such as the number of patents, new services, products, or manufacturing processes).

Innovation performance refers to the outcomes of innovation activities within a firm. It can be measured through various indicators such as the number of new products developed, R&D

expenditure, patent filings, and improvements in production processes (Geroski, 1996). Innovation performance is crucial for maintaining competitive advantage and long-term success in today's rapidly changing business environment. However, allocating more inputs to the innovation process does not necessarily ensure innovation outcomes, as the development of innovation is complex and fraught with high risks (Rosenbusch et al., 2011).

2.3 Digital Transformation and Innovation

Previous research indicates that firms with higher levels of digital maturity tend to exhibit stronger innovation outcomes, as they are better equipped to exploit digital technologies for creative problem-solving and innovation (Nambisan et al., 2019). L. Chen et al. (2018) proposed that digital transformation can enhance enterprise innovation through four distinct pathways. Digital transformation enhances enterprise innovation through several key mechanisms (B. Wang et al., 2024; Yang et al., 2024). It increases information transparency by optimizing processes, improving data sharing, and reducing search and transaction costs. Additionally, digital tools help manage operational risks, improving decision-making, resource allocation, and access to financing, which encourages enterprises to take more risks in innovation (Goldfarb & Tucker, 2019; Urbinati et al., 2020). From the perspective of Dynamic Capability Theory (Teece, 2010), these mechanisms highlight how firms leverage their dynamic capabilities—such as sensing, seizing, and reconfiguring—to harness digital technologies. By sensing new opportunities, seizing digital tools to enhance operational processes, and reconfiguring their internal resources and capabilities, firms can foster innovation and improve performance in response to the evolving digital landscape.

2.4 Digital Transformation and Government Subsidy

Prior research on digital transformation and enterprise innovation has identified several aspects. Digital transformation enhances innovation in business models, organizational management, and operational processes as well as fostering innovation. Meanwhile, several studies indicated that government subsidy plays a crucial role in promoting innovation within enterprises (M. Li et al., 2023; B. Wang et al., 2024; Yang et al., 2024).

Government subsidies can enhance output by supplying firms with innovation resources and aiding in the reduction of R&D costs and risks, thereby bolstering their innovation efforts (Wu et al., 2021). Wan & Ding, (2024) suggests that government subsidies, particularly R&D subsidies, play a critical role in stimulating enterprise innovation. Shinkle & Suchard (2018) observed that government subsidies enhance the external investment accessible to firms, thereby facilitating their innovation output.

However, the effectiveness of government subsidies in driving transformation is not universal across industries. A study on China's coal companies found that government subsidies do not significantly impact their transformation (X. Li & Wu, 2024). The research suggests that while subsidies provide financial support, structural constraints, regulatory complexities, and firms' reliance on traditional energy sources hinder substantial transformation. This finding highlights that the impact of government subsidies on innovation and transformation is context-dependent, varying across industries and organizational structures.

A critical gap in the literature lies in the understanding of how government subsidies should be allocated to truly foster innovation. It is essential to recognize that government

subsidies should not merely be directed at supporting R&D or production; rather, the focus should be on supporting innovation (Wu et al., 2021). The allocation of subsidies must prioritize the capacity for transformative change in enterprise innovation. Therefore, while subsidies may enhance digital transformation and innovation in some sectors, their role in fostering substantial change in others remains debatable. A more nuanced approach is needed to evaluate the appropriate allocation and strategic use of subsidies to encourage long-term innovation across diverse industries.

3.0 METHODOLOGY

3.1 Data and Sample

This study empirically examines the impact of firms' digital transformation on their innovation performance using data from manufacturing companies in China from 2016 to 2023. Our

final sample consists of 3,678 firms with 29,424 firm-year observations, distributed across 48 industries (Figure 1). The data was sourced from the Wind database in the range of Chinese Mainland listed companies. Data measurement and its definition are shown in Table 1. The data from 2016 to 2023 was selected due to improved data completeness and accuracy in these years, ensuring a more robust and reliable analysis.

To ensure data quality and reliability, we carefully addressed missing values by implementing appropriate data-cleaning procedures. Firms with excessive missing data were excluded from the final sample, while reasonable interpolation methods were applied where necessary to maintain data integrity without introducing bias. This approach ensures that our analysis remains robust and reflective of actual industry trends.

Table 1. Data measurement and definition

Variables	Symbol	Definition
Dependent variable	lnpatent	Patent book value (logarithm)
Independent variable	dig degree	Software value divided by of total assets (logarithm)
	lnsoftware	Software value (logarithm)
Mechanism	Lgovsub	Government subsidy (logarithm)
Control variables	Lnemployment	Employment (logarithm)
	lntotalasset	Total assets (logarithm)
	lnage	Company age (logarithm)

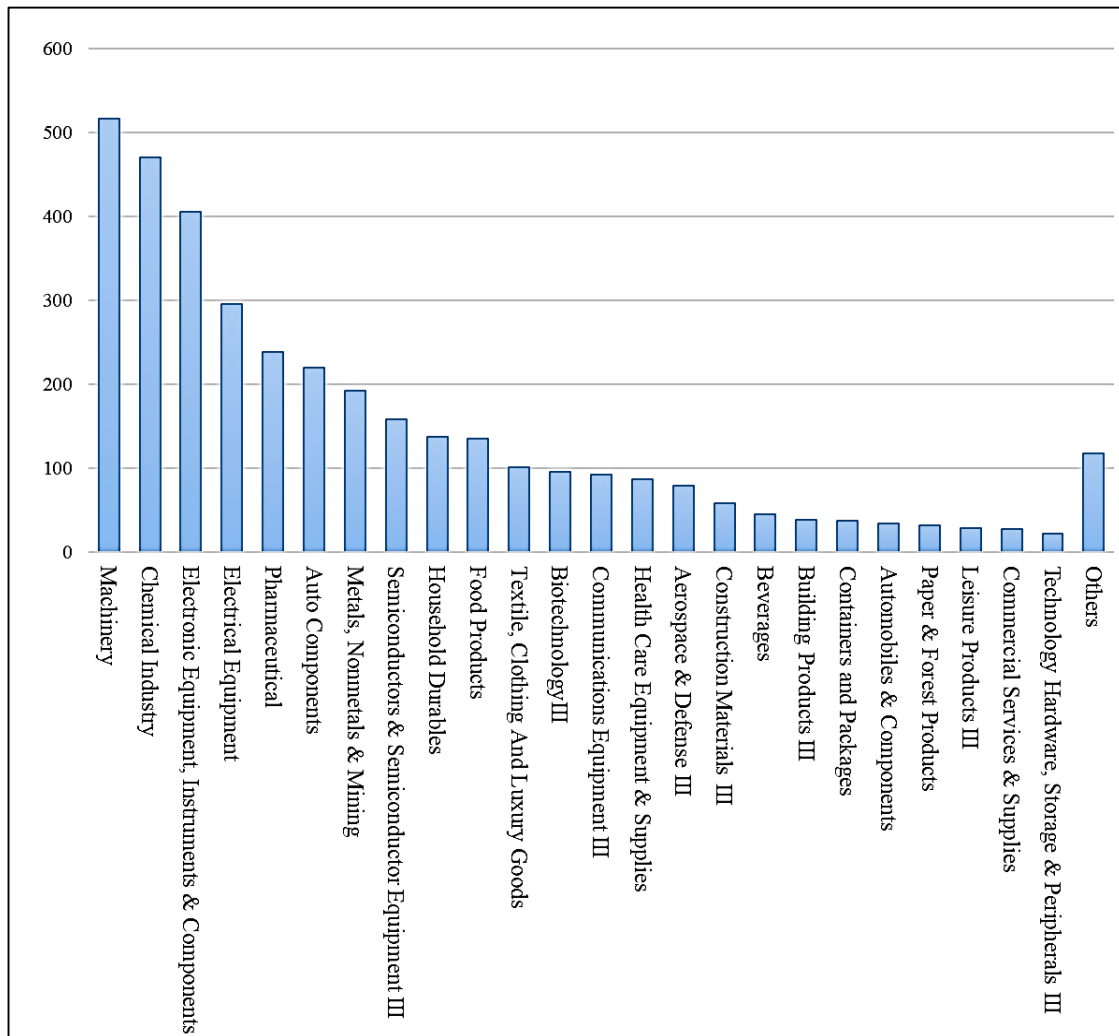


Figure 1. Industry Distribution

1.1 Variables

3.2.1. Digital transformation

Most of studies measured the digital transformation by analyzing frequency of keywords related to digital transformation from annual report. However, this study defined the digital transformation from the digital degree of the firm by divided natural logarithm of software book value by natural logarithm of total assets. Digital transformation underscores the influence of information technology (IT) on an organization's structure, routines,

information flow, and its ability to adapt to and incorporate IT (Vial, 2019).

Software book value represents the investment in software, which is a key aspect of digital infrastructure. The book value of software encompasses the cost of acquiring, developing, and maintaining software, reflecting a company's commitment to digital tools and technologies. By dividing the software book value by total assets, the digital degree captures the relative scale of a company's investment in digital assets compared to its overall resource base. This proportional measure indicates the extent to

which a company prioritizes digital transformation relative to its entire portfolio of assets. A higher digital degree suggests a greater emphasis on digital capabilities, signaling a more advanced stage of digital transformation.

3.2.2. Innovation performance

Innovation performance is dependent variable of this research. Innovation performance is a critical indicator of a company's ability to generate new ideas, processes, products, or services that contribute to its competitive advantage and long-term growth. In this study, innovation performance is measured by the patent right book value, which represents the monetary valuation of the patents held by the company. Patents are a tangible outcome of a company's innovation activities, reflecting its output or success in developing new and proprietary technologies, processes, or products (L. Chen et al., 2018). The book value of patents, which accounts for the cost associated with acquiring, developing, and maintaining these patents, provides a quantifiable measure of this innovation output.

$$\ln patent_{it} = \alpha + \beta_1 dig_degree_{it} + \varepsilon_{it} \quad (1)$$

$$\ln patent_{it} = \alpha + \beta_1 dig_degree_{it} + \beta_2 \ln employment_{it} + \beta_3 \ln totalasset_{it} + \beta_4 \ln age_{it} + \varepsilon_{it} \quad (2)$$

$$\ln patent_{it} = \alpha + \beta_1 dig_degree_{it} + \beta_2 \ln employment_{it} + \beta_3 \ln totalasset_{it} + \beta_4 \ln age_{it} + Year_t + Ind_i + \varepsilon_{it} \quad (3)$$

4.0 RESULTS AND DISCUSSIONS

4.1 Descriptive Statistics

Table 2. Descriptive Statistics presents the summary statistics for several variables across a sample of 29,424 observations. These statistics include the number of observations (N), mean, standard deviation

3.2.3. Control Variables

Control variables are chosen based on previous literature (Merín-Rodríguez et al., 2024; Zhang et al., 2024; Zhou, 2021). Factors that may affect firm's innovation performance are; firm size as the logarithm of the total number of employees, as larger firms are generally more inclined to invest in digital transformation and innovation performance. We accounted for firm age by measuring it as the logarithm of the number of years since the company's founding. More experienced firms may benefit from accumulated learning, leading to increased efficiency and superior performance.

1.2 Model Design

For the purpose of this study, a baseline regression model is constructed as demonstrated in Equation (1). Equation (2) is added to with control variables. According to Hausman test, we use fixed effect model to evaluate the relationship between digital transformation and innovation performance which is shown in model (3).

(Std. Dev.), minimum (Min), and maximum (Max) values for each variable.

The variable $\ln employment$ represents the logarithm of employment within the sample. With an average value of 7.244 and a standard deviation of 1.277, the spread of employment levels is relatively moderate. The minimum and maximum values, 2.485

and 13.464 respectively, indicate a broad range of employment levels within the dataset. *Intotalasset* captures the logarithm of total assets. The mean value is 12.38, suggesting a substantial size of total assets on

average—the standard deviation of 1.429 points to variability in total asset sizes among the entities. The range, from 6.166 to 18.427, shows significant diversity in asset holdings.

Table 2. Descriptive Statistics

	N	Mean	Std. Dev.	Min	Max
<i>lnemployment</i>	29424	7.244	1.277	2.485	13.464
<i>Intotalasset</i>	29424	12.38	1.429	6.166	18.427
<i>lnpatent</i>	29424	1.557	2.923	0	13.121
<i>lnsoftware</i>	29424	2.947	3.172	0	12.142
<i>dig_degree</i>	29424	.227	.239	0	.804
<i>lngovsub</i>	29424	15.031	4.428	0	22.468

The *lnpatent* variable measures the logarithm of the number of patents. The mean is 1.557, with a high standard deviation of 2.923, indicating considerable disparity in patent counts. For *lnsoftware*, representing the logarithm of software investments, the mean is 2.947 with a standard deviation of 3.172. This high standard deviation, along with the wide range from 0 to 12.142, suggests a wide variation in software investment among the sampled entities.

The *dig_degree* variable reflects the degree of digitalization. With a mean of 0.227 and a standard deviation of 0.239, the digital degree varies across entities, though not extremely. The range from 0 to 0.804 shows that while some entities are less digitized, others have higher digital degrees. The *lngovsub* variable measures the logarithm of government subsidies. The mean is 15.031, with a standard deviation of 4.428, indicating moderate variability. The minimum value is 0, and the maximum is 22.468, showing a wide range of government subsidy levels.

1.3 Basic Regression Result

Table 3 presents the regression results for 3 models mentioned above. Column (1) presents the baseline regression result for digital transformation and innovation performance without any control variables and fixed effects. The result shows that digital transformation has positive significant at 1% level with coefficient of 4.190 to innovation performance, indicating that for every increase of 1 unit digital transformation, the innovation performance will increase 4.190 unit. The R^2 showed 0.117, means that the independent variable of digital transformation could explain 11,7% of dependent variable which is innovation performance.

Column (2) shows the regression with control variables. By adding size of firms, total asset, and firm's age as control variables, the digital transformation is still positive significantly effecting innovation performance with coefficient 2.900, indicating that every increase of 1 unit digital transformation, it will increase the innovation performance by 2.900. The value of R^2 is 0.172, indicating the

independent variable could explain the dependent variable at 17.2%.

Meanwhile, column (3) represents the regression with control variables and fixed effects. By holding control variables and

fixed effects, the coefficient of digital transformation effecting innovation performance is 2.034 significant at 1% level with R^2 is 0.207 representing that digital transformation could explain 20.7% of innovation performance.

Table 3. Baseline Regression

Variables	Inpatient		
	(1)	(2)	(3)
dig_degree	4.190*** (0.0728)	2.900*** (0.0809)	2.034*** (0.0971)
lnemployment		-0.176*** (0.0219)	-0.00604 (0.0246)
Intotalasset		0.603*** (0.0220)	0.530*** (0.0241)
lnage		0.339*** (0.0301)	0.223*** (0.0314)
Constant	0.624*** (0.0171)	-6.229*** (0.167)	-6.034*** (0.178)
R-squared	0.117	0.172	0.207
Control Variable	No	Yes	Yes
Year FE	No	No	Yes
Industry FE	No	No	Yes

Robust standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Firms investing in digital transformation can expect tangible innovation growth. For example, if a company increases its digital adoption by one standardized unit—such as investing in AI-driven R&D, automation, or cloud-based innovation platforms—it can anticipate a corresponding rise in innovation performance by 2.034 to 2.900 units, depending on external factors.

Across all models, digital degree consistently shows a strong positive effect on innovation performance, though its magnitude decreases with the inclusion of additional controls and fixed effects. This result is in line with

previous research conducted by (L. Chen et al., 2018; Zhang et al., 2024). The significance of lnemployment and lnage in the fully controlled model indicates that employment and firm age are also important factors influencing inpatient. The improvements in R-squared values across the models suggest that adding controls and fixed effects better captures the variance in innovation performance. Overall, the analysis underscores the robust impact of digital transformation on innovation performance while highlighting the importance of considering firm size, age, and

contextual factors such as year and industry effects.

1.4 Mechanism Test

To further understand the impact of digital transformation on innovation performance, this research includes a mechanism test examining the role of government subsidy. On the one hand, government subsidies can provide financial support that mitigates the substantial costs associated with digital transformation initiatives. By alleviating the financial constraints, subsidies are anticipated to motivate firms to allocate more resources towards digital technologies, thereby bolstering their innovation potential.

On the other hand, government subsidies may lead firms to engage in adaptive innovation behavior in order to obtain subsidies, which may lower the quality of their innovation. In addition, subsidies may also lead to excessive reliance on government funds by enterprises, weakening their drive for independent innovation. To test this mechanism, the study introduces government subsidy as an interaction term in the regression models.

To further examine the effect of digital transformation on innovation performance, this study conducted mechanism test with following models:

$$\ln govsub_{it} = \gamma + \gamma_1 dig_degree_{it} + \gamma_2 \ln employment_{it} + \gamma_3 \ln totalasset_{it} + \gamma_4 \ln age_{it} + Year_t + Ind_i + \varepsilon_{it} \quad (4)$$

$$\ln patent_{it} = \alpha + \beta_1 dig_degree_{it} + \beta_2 \ln govsub_{it} + \beta_3 \ln employment_{it} + \beta_4 \ln totalasset_{it} + \beta_5 \ln age_{it} + Year_t + Ind_i + \varepsilon_{it} \quad (5)$$

The mechanism test results, as presented in Table 4, provide valuable insights into the role of government subsidies in the relationship between digital transformation and innovation performance.

Table 4 model (1) examines the impact of digital transformation (*dig_degree*) on government subsidies (*lngovsub*). The

coefficient for *dig_degree* on *lngovsub* is 1.041, indicating that digital transformation significantly increases government subsidies. This suggests that firms undergoing digital transformation are more likely to receive government subsidies, possibly because digital transformation aligns with government priorities for innovation and modernization.

Table 4. Mechanism Test

VARIABLES	Ingovsub (1)	Inpatent (2)
dig_degree	1.041*** (0.0892)	2.042*** (0.0970)
Ingovsub		-0.00728*** (0.00251)
lnemployment	0.204*** (0.0397)	-0.00455 (0.0246)
Intotalasset	1.024*** (0.0376)	0.537*** (0.0245)
lnage	1.314*** (0.0777)	0.232*** (0.0318)
Constant	-3.061*** (0.305)	-6.057*** (0.180)
R-squared	0.320	0.207
Control Variable	Yes	Yes
Year FE	Yes	Yes
Industry FE	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4 model (2) explores the direct effect of digital transformation on innovation performance (lnpatent). The relation of digital transformation on innovation performance is consistently positively significant at 1% with a coefficient of 2.042. This positive and significant relationship highlights that digital transformation indeed fosters innovation, aligning with existing literature that underscores the importance of digital technologies in enhancing a firm's innovative output. The inclusion of the government subsidy variable (Ingovsub) in Model (2) reveals a negative and significant coefficient of -0.00728 at the 1% level. This suggests that higher government subsidies are associated with lower innovation performance when controlling for digital

transformation. It could imply that firms that rely heavily on government subsidies may not be as innovative, possibly due to reduced urgency or incentives to innovate independently. The goals of government subsidies may not consistently match the particular requirements of manufacturing firms. When subsidies are allocated to projects that do not directly support the firms' innovation objectives, their effectiveness in enhancing innovation performance can be diminished.

1.1 Rrobustness Test

Several robustness tests were conducted to ensure the reliability of the results. First, we replaced the innovation performance variable with an alternative measure—R&D

expenditure—using its logarithmic form for analysis, as shown in Table 5 (a) Alternative Y.

Table 5. Robustness Test

VARIABLES	(a) Alternative Y	(b) Subsample - Government Subsidy		(c) Subsample – Size	
	RD	Inpatient		Inpatient	
		(Non-Subsidy)	(Subsidy)	(Small)	(Big)
dig_degree	0.509*** (0.0514)	0.390 (2.075)	1.743*** (0.104)	1.792*** (0.134)	1.287*** (0.155)
Ingovsub	0.424*** (0.0039)			-0.024*** (0.00287)	-0.0755*** (0.00713)
Inemployment	0.1994*** (0.0187)	-0.135 (0.1987)	0.654*** (0.0676)	0.385*** (0.082)	0.866*** (0.114)
Intotalasset	0.427*** (0.0183)	-0.0339 (0.1024)	0.0944* (0.0528)	0.127*** (0.0562)	0.295*** (0.0942)
Inage	-0.2015*** (0.028)	-0.0392 (0.062)	-1.632*** (0.217)	-0.494*** (0.128)	-0.719*** (0.278)
Constant	-4.7515*** (0.126)	1.3643 (1.264)	-0.000285 (0.615)	-1.615*** (0.512)	-5.739*** (1.095)
R-squared	0.707	0.633	0.615	0.560	0.644
Control Variable	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Additionally, we performed two types of subsampling. The first subsample was categorized based on government subsidies as shown in Table 5 model (a) Subsample-Government subsidy, where companies receiving subsidies were marked as Subsidy, and those without were marked Non-Subsidy. The second subsample was categorized based on company size as shown in Table 5 model (b) Subsample-Size, following the classification standard of the National Bureau of Statistics of China (<https://www.stats.gov.cn/english/>), which defines enterprises with more than 1,000 employees as large. Accordingly, in our study, companies with 1,000 or more

employees were marked as Big, while those with fewer than 1,000 were marked Small in the table. The results of the robustness test, presented in Table 5, indicate that the regression outcomes remain consistent with the previous findings, confirming the robustness of our analysis.

2.0 Conclusion

This research provides a thorough analysis of the impact of digital transformation on the innovation performance of manufacturing firms in China, utilizing panel data from 3,678 firms over the period from 2016 to 2023. Through a comprehensive analysis utilizing various regression models and

mechanism tests, the findings underscore that digital transformation plays a pivotal role in fostering innovation. The consistent positive effect of digital transformation on innovation performance across all models reaffirms its critical role in enhancing a firm's innovative capabilities.

Firstly, the empirical results unequivocally demonstrate a strong positive correlation between digital transformation and innovation performance. Specifically, the regression results indicate that a one-unit increase in digital transformation leads to a 2.900 increase in innovation performance, with the effect remaining robust even after controlling for firm characteristics and fixed effects with coefficient = 2.034, $p < 0.01$. The model explains 20.7% of the variation in innovation performance ($R^2 = 0.207$), reinforcing the strong relationship between digital transformation and innovation. Firms that adopt and integrate advanced digital technologies show marked improvements in their innovative output. These technologies enable firms to optimize their operational processes, reduce costs, enhance product development, and respond more swiftly to market changes, thereby driving higher levels of innovation.

Secondly, the analysis takes into account several control variables, including firm size, total assets, and firm age. The positive effect of digital transformation on innovation performance remains robust even when these variables are controlled. This indicates that larger firms, which typically possess more substantial resources, are better equipped to leverage digital technologies for innovation. It also suggests that the benefits of digital

transformation are not confined to specific firm characteristics but are broadly applicable across the manufacturing sector.

Thirdly, the role of government subsidies is examined within the context of digital transformation. Overall, the mechanism test results indicate that while digital transformation significantly boosts innovation performance, the role of government subsidies is complex. The results show that government subsidies negatively influence digital transformation efforts, their impact on innovation performance is statistically significant when all control variables and fixed effects are considered. Firms engaging in digital transformation might rely less on subsidies, and excessive reliance on such subsidies could potentially dampen innovation efforts. Therefore, it requires further details of the allocation of government subsidy. The data provided from the database is merely the amount of government subsidy. Future research should delve deeper into the allocation mechanisms and strategic use of government subsidies to maximize their impact on innovation. This includes ensuring that subsidies are effectively allocated to projects directly supporting firms' innovation objectives. The results advocate for further detailed studies on the specific allocation of government subsidies to better understand their impact on innovation performance. These findings also underscore the importance of a balanced approach in policy-making, where support for digital transformation should be coupled with measures that encourage firms to innovate independently.

In conclusion, this research underscores the transformative potential of digital technologies in enhancing the innovative capacities of manufacturing firms in China. It highlights the importance of strategic investment in digital transformation to achieve competitive advantage and sustain innovation in a rapidly evolving technological landscape. Policymakers are encouraged to refine subsidy programs to better align with the innovation objectives of firms, ensuring that public resources are effectively utilized to foster technological advancement and economic growth. Future studies should continue to explore the intricate dynamics between digital transformation, government support, and innovation performance to provide more granular insights and guide effective policy and strategic decisions.

For policymakers, the findings suggest a need for more targeted and efficient allocation of subsidies. Ensuring that subsidies align with the specific innovation needs of firms could enhance their effectiveness. Additionally, reducing the regulatory burden associated with obtaining subsidies might help firms focus more on innovation activities rather than navigating administrative processes. Policymakers should also consider fostering an environment that supports the development of internal capabilities within firms, such as management quality and technological expertise, to maximize the impact of subsidies on innovation.

For future researchers, this study opens several avenues for further investigation. One area is the detailed examination of how government subsidies are allocated and their

specific impact on different types of innovation activities. Understanding the strategic allocation of subsidies could shed light on their effectiveness and enhance firms' innovation outcomes. Furthermore, comparative studies across different sectors and regions would provide deeper insights into the broader applicability of the findings and help identify sector-specific or region-specific strategies for leveraging digital transformation to enhance innovation performance. Future research could also explore sectoral differences in digital adoption, as various industries may experience unique challenges and opportunities in their digital transformation journeys. Additionally, cross-country comparisons would offer valuable insights into how different national contexts—such as regulatory environments, economic development, and cultural factors—affect the relationship between digital transformation and innovation performance.

Beyond these areas, emerging technologies like artificial intelligence (AI), blockchain, and IoT present new opportunities for research on digital transformation. As AI-driven technologies continue to evolve, examining their specific impact on innovation and competitive advantage will be crucial for understanding how firms can best leverage these tools. Future studies could also explore the role of digital transformation in promoting sustainability by integrating green technologies and practices, which have become increasingly important in global business strategies. Moreover, addressing global digitalization challenges, such as data privacy, cybersecurity, and digital equity,

will be vital for understanding how firms can navigate the complex and evolving digital landscape.

Authorship contribution statement

Fatma Satyani: Writing the original draft, data curation, formal analysis, project administration. **Shuxin:** Review and editing, supervision, data curation, methodology, formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

- Bresciani, S., Huarng, K.-H., Malhotra, A., & Ferraris, A. (2021). Digital transformation as a springboard Digital innovation and transformation: An institutional perspective or product, process and business model innovation. *Journal of Business Research*, 128(204–210).
<https://www.sciencedirect.com/science/article/pii/S0148296321000734>
- Cefis, E., Leoncini, R., Marengo, L., & Montresor, S. (2023). Firms and innovation in the new industrial paradigm of the digital transformation. *Industry and Innovation*, 30(1), 1–16.
<https://www.tandfonline.com/doi/full/10.1080/13662716.2022.2161875>
- Chen, L., Tu, R., Huang, B., Zhou, H., & Wu, Y. (2018). Digital transformation's impact on innovation in private enterprises: Evidence from China. *Journal of Innovation and Knowledge*, 3(1), 44–55.
- Chen, P., & Kim, S. K. (2023). The impact of digital transformation on innovation performance – The mediating role of innovation factors. *Heliyon*, 9(7).
<https://doi.org/10.1016/j.heliyon.2023.e17500>
- Geroski, P. A. (1996). Market Structure, Corporate Performance, and Innovative Activity. *The Economic Journal*, 106(434).
<https://doi.org/https://doi.org/10.2307/234946>
- Goldfarb, A., & Tucker, C. (2019). Digital Economics. *Journal of Economic Literature*, 57(1), 3–43.
<https://doi.org/10.1257/jel.20171452>
- Gong, C., & Ribiere, V. (2021). Developing a unified definition of digital transformation. *Technovation*, 102(July 2020).
<https://doi.org/10.1016/j.technovation.2020.102217>
- Guo, L., & Xu, L. (2021). The effects of digital transformation on firm performance: evidence from China's manufacturing sector. *Sustainability (Switzerland)*, 13(22), 1–18.
<https://doi.org/10.3390/su132212844>
- Hinings, B., Gegenhuber, T., & Greenwood, R. (2018). Digital innovation and transformation: An institutional perspective. *Information and Organization*, 28(1), 52–61.
<https://www.sciencedirect.com/science/article/pii/S1471772718300265>
- Hung, B. Q., Nham, N. T. H., & Ha, L. T. (2023). The importance of digitalization in powering environmental innovation performance of European countries. *Journal of Innovation & Knowledge*, 8(1).
<https://www.sciencedirect.com/science/article/pii/S2444569X22001196>
- Jiang, Y., & Wang, X. (2024). Digital Transformation, Innovation Capability and Speed of Internationalization. *Finance Research Letters*, 105448.
<https://doi.org/10.1016/j.frl.2024.105448>
- Li, M., Cao, G., Li, H., Hao, Z., & Zhang, L. (2023). How government subsidies affect technology innovation in the context of Industry 4.0: evidence from Chinese new-energy enterprises. *Kybernetes*.
<https://doi.org/10.1108/K-08-2022-1098>
- Li, X., & Wu, C. (2024). Influence mechanism of government subsidy on the green transformation of coal company in China. *International Journal of Mining Science and Technology*, 34(7), 1033–1040.
<https://doi.org/10.1016/j.ijmst.2024.07.013>
- Lo, C. P., & Lee, Y. (2024). Digitalization, AI Intensity, and International Trade. *Annals of Economics and Finance*,

- 25(1), 251–273.
- Merín-Rodríguez, J., Dasí, À., & Alegre, J. (2024). Digital transformation and firm performance in innovative SMEs: The mediating role of business model innovation. *Technovation*, 134(May). <https://doi.org/10.1016/j.technovation.2024.103027>
- Nambisan, S. (2017). Digital Entrepreneurship: Toward a Digital Technology Perspective of Entrepreneurship. *Entrepreneurship: Theory and Practice*. <https://doi.org/10.1111/etap.12254>
- Nambisan, S., Wright, M., & Feldman, M. (2019). The digital transformation of innovation and entrepreneurship: Progress, challenges and key themes. *Research Policy*, 48(8), 103773. <https://doi.org/10.1016/j.respol.2019.03.018>
- Rosenbusch, N., Brinckmann, J., & Bausch, A. (2011). Is innovation always beneficial? A meta-analysis of the relationship between innovation and performance in SMEs. *Journal of Business Venturing*, 26(4), 441–457. <https://doi.org/10.1016/j.jbusvent.2009.12.002>
- Schumpeter, J. A. (1934). The Theory of Economic Development: An Inquiry Into Profits, Credit, Interest, and the Business Cycle. In *Social Science Electronic Publishing* (Vol. 25, Issue 1, p. 255).
- Shinkle, G. A., & Suchard, J.-A. (2018). Innovation in newly public firms: The influence of government grants, venture capital, and private equity. *Australian Journal of Management*, 44(2). <https://doi.org/10.1177/0312896218802611>
- Teece, D. J. (2010). Handbook of the Economics of Innovation, Vol. 1. In *Handbook of the Economics of Innovation* (Issue December, pp. 1–11). <https://www.sciencedirect.com/topics/economics-econometrics-and-finance/dynamic-capabilities>
- Urbinati, A., Chiaroni, D., Chiesa, V., & Frattini, F. (2020). The role of digital technologies in open innovation processes: an exploratory multiple case study analysis. *R and D Management*, 50(1), 136–160. <https://doi.org/10.1111/radm.12313>
- Vial, G. (2019). Understanding digital transformation: A review and a research agenda. In *Journal of Strategic Information Systems* (Vol. 28, Issue 2, pp. 118–144). <https://doi.org/10.1016/j.jsis.2019.01.003>
- Wan, X., & Ding, H. (2024). Can government subsidies for the digital economy promote corporate innovation? *European Journal of Innovation Management*. <https://doi.org/10.1108/EJIM-04-2024-0375>
- Wang, B., Khan, I., Ge, C., & Naz, H. (2024). Digital transformation of enterprises promotes green technology innovation – The regulated mediation model. *Technological Forecasting and Social Change*, 209. <https://doi.org/10.1016/j.techfore.2024.123812>
- Wang, Z., & Yang, F. (2024). Digital transformation and corporate innovation with herd effects. *Finance Research Letters*, 62(December 2023). <https://doi.org/10.1016/j.frl.2024.105240>
- Wu, W., Zhao, K., & Li, L. (2021). Can government subsidy strategies and strategy combinations effectively stimulate enterprise innovation? Theory and evidence. *Economia Politica*, 38(2), 423–446. <https://doi.org/10.1007/s40888-021-00230-y>

- Yang, Y., Zhang, C., Liu, B., Huang, Y., & Tai, Y. (2024). Mystery of special government subsidies: How does digital transformation promote enterprise innovation and development? *Economic Analysis and Policy*, 83, 1–16. <https://doi.org/10.1016/j.eap.2024.06.003>
- Zhang, H., Wang, X., & Akhtar, M. W. (2024). Digital transformation, supplier concentration, and CEO financial experience: Unveiling the dynamics of innovation performance in Chinese firms. *Journal of Cleaner Production*, 442(58). <https://doi.org/10.1016/j.jclepro.2024.140825>
- Zhou, H. (2021). Fixed costs and the division of labor. *Annals of Economics and Finance*, 22(1), 63–81.