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The Impact of Digital Transformation on the Innovation Capacity of Chinese-Listed Firms: The Role of Government Subsidies

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ABSTRACT

As digital transformation progresses, listed Chinese firms are undergoing significant changes in their practices. These changes are crucial for establishing and maintaining a competitive advantage. This research investigates the process by which digital transformation affects firms' capacity to innovate, specifically focusing on the influence of government subsidies. The data was obtained from 1,063 publicly traded in China from 2018 to 2022 with a total of 4,027 data points. A fixed-effects model, stepwise regression analysis, and bootstrapping techniques were employed to construct the models. To address the conventional quantitative constraints and provide a nuanced comprehension of digital transformation's influence, this study uses textual analysis. Research has shown that digital transformation has a substantial positive impact on the ability of companies to innovate. Additionally, government subsidies are proven to have a role in facilitating this process. This paper offers a fresh viewpoint on comprehending the mechanism of government subsidies for digital transformation and corporate innovation capability. It also provides evidence supporting the idea that government subsidies may enhance innovation incentives more effectively.

Keywords: Capability; Chinese-Listed Firms; Innovation; Text Analysis; Transformation

INTRODUCTION

As digital transformation advances, organizations are undergoing significant shifts in their manufacturing practices. In the current highly competitive market, firms must adopt digital transformation to gain a competitive advantage (Liang & Li, 2022). The digital economy's penetration rate in the secondary industry has reached 24%, highlighting the vital role of digital transformation in fostering economic development (Wang et al., 2022). Intensifying business competition, driven by continuous technological advancements, creates opportunities for innovation and the production of more unique and contemporary products. These technological developments impact various business activities, shaping and transforming aspects of daily life, as technology becomes an integral part of existence (Andiana et al., 2024; Zulfahmi et al., 2022).

The significance of innovation capacity, as a crucial measure of the competitiveness of a nation or a company, should not be underestimated (Fan et al., 2023). In very volatile business landscapes, a company's capacity to independently generate innovative ideas becomes the fundamental basis for its continued existence and growth (Li & Pang, 2023). Assessing the innovation capability of firms is a challenging and multifaceted undertaking. It involves examining their innovation activities from various angles and dimensions, with a particular emphasis on the quality of innovation, particularly in terms of firms' patent research and development efforts (Park et al., 2023).

The industrial policy of China has an important effect on the progress of the economy. One possible mechanism via which industrial policy plays a role is the change of the industrial structure (Chen & Xie, 2019). Government research and development (R&D) subsidies are a significant policy instrument used to encourage innovation. These subsidies have garnered considerable attention because of their ability to promote innovation inside enterprises and facilitate the transformation and upgrading of industrial structures (Hang & Chengliang, 2020). When developing subsidy policies, governments must ensure that subsidies have precise and innovative incentives to produce effective and relevant policy outcomes (Dianfan & Jiaxi, 2022).

This study aims to analyze the impact of digital transformation on the innovation capacity of Chinese-listed firms and explore the mediating role of government subsidies. The existing studies on the complex relationship between digital transformation, innovation capacity, and government subsidies have vital limitations. Some studies such as Liu et al. (2023), Xia & Jia (2023), and Xu (2023) are limited to pharmaceutical firms only and may not reflect current trends as they used data up to 2019-2020. While Wang et al. (2022) and Xie & Wang (2023) may not fully measure the relationship between innovation performance and government subsidies due to limited data. Then, Brüggemann & Proeger (2017), Gao (2023), and Gustafsson et al. (2020) challenge the primary assumption of government subsidies on firms' innovation outcomes and R&D investments in the early stage of the firms. Recognizing these limitations and the complexities of quantitatively assessing corporate digital transformation, this study uses textual analysis as an innovative measurement method that transcends conventional quantitative constraints and provides a nuanced comprehension of digital transformation's influence. Employing updated data and multifaceted analyses, the study endeavors to offer significant contributions to the ongoing discourse surrounding the implications of digital transformation for the innovation capacity of manufacturing firms.

LITERATURE REVIEW

Digital Transformation and Innovation Capacity

The theory of technical innovation seeks to elucidate the causes and processes behind the occurrence of technological advancements, their catalysts, their effects on the economy and society, and the mechanisms by which these advancements disseminate and progress (Wei et al., 2023). Simultaneously, the advancement of technical innovation theory also underscores the influence of external elements, such as knowledge management, market change, and social environment, on the process of innovation (Fedulov & Pobedin, 2021). Digital information is an intricate process that involves the integration of digital technology into all aspects of a business, resulting in substantial changes to its operations. This approach compels organizations to reassess their innovation efforts by incorporating digital technology into their operations and business model innovation (Xu, 2023; Zhai et al., 2022). The focus is on how businesses may use digital technology to strengthen their ability to innovate in the digital economy age (Selimović, 2021).

Xu (2023) has presented compelling evidence linking digital transformation to enhanced innovation capabilities in enterprises. Drawing on data from the 2011-2020 Digital Finance Index and insights from Shanghai and Shenzhen A-share listed companies analyzed using a panel fixed utility model, Xu's research indicates that digital transformation plays a crucial role in improving innovation abilities by alleviating financing constraints within firms. Moreover, subsequent studies highlight that digital transformation has a notably stronger positive impact on innovation capabilities in private enterprises. Similarly, Guan (2023) has concluded that digital transformation contributes to enhancing innovation within China's A-share listed companies. By facilitating easier data analysis, reducing financing constraints, and strengthening internal controls, digital transformation creates a conducive environment for sustainable development and organizational innovation. These findings underscore the transformative potential of digital technologies in fostering innovation and sustainable growth across different sectors of the economy.

The synergy between digital and technical skills is essential for organizations aiming to drive digital innovation effectively. Wang and Li (2023) conducted empirical research using static and dynamic panel regressions, along with examining social capital's moderating role, to explore how digital and technological capabilities jointly influence digital innovation within enterprises. Their findings highlight that the combined strength of digital capability and technology absorptive capability significantly enhances a company's ability to innovate digitally. Gupta et al. (2024) explored digital innovation and transformation through dynamic capability and institutional theories. They proposed a four-layered approach to drive these processes within organizations: digital champions as change agents, a digital council for monitoring, a digital core team for technological enablement, and reverse mentoring to foster innovative cultural change and dynamic capabilities. These studies underscore the importance of fostering the coordinated development of digital and technological capabilities within organizations. Such efforts not only bolster their capacity for digital innovation but also hold substantial implications for advancing high-quality development in sectors like manufacturing.

Furthermore, digital transformation supports this integration by providing new technical platforms and tools while increasing investments in research and development. These advancements further enhance companies' innovation capabilities, aligning with broader trends observed in recent study (Gupta et al., 2024). Digital transformation indirectly enhances the innovation performance of businesses by altering their network structure,

which includes the expansion of structural holes and the enhancement of network centrality (Shabbir et al., 2023).

Digital technology may impact a company's ability to innovate by enabling business model innovation, which in turn influences the company's inventive capacities (Nureen et al., 2023). To summarize, the following theories are put forward.

H1: Digital transformation improves the innovative capacity of firms.

Role of Government Subsidies

Policy intervention theory is a significant field within economics that examines how governments employ various methods to affect the behavior of individuals or groups to attain certain social and economic objectives. These methods include several approaches such as communications, promoting change, advocating for change, imposing penalties for non-compliance, and enhancing the appeal of change (Balch, 1980). Government subsidies are a kind of policy intervention when the government provides direct financial assistance to certain sectors, companies, or people. Subsidies may take the form of direct monetary aid or be provided via mechanisms such as tax exemptions and loan guarantees (Osagiede & Ekhosuehi, 2015).

Government subsidies encourage companies to participate in technology innovation and digital transformation by offering financial assistance that lowers their research and development expenses and uncertainties (Andargoli et al., 2023). Government subsidies in the firm's innovation process serve as a means of signaling, indicating important information about the industry's strategic direction and policy preferences (Wu, 2017). Furthermore, government subsidies have the potential to stimulate corporate innovation by enhancing enterprises' financial condition and mitigating financial limitations (Li et al., 2021).

Li et al. (2023) investigated the impact of government subsidies on technology innovation in new-energy enterprises during the industry 4.0 era, analyzing data from 225 listed new-energy firms spanning from 2010 to 2020. Employing panel fixed effect regression models, they concluded that intermittently increasing subsidies for new-energy enterprises and guiding their digital transformation are crucial strategies. Similarly, Liu et al. (2023) examined the role of government subsidies in enhancing innovation and sustainable development among listed biopharmaceutical firms in China. Using static and dynamic panel mediation effect models with data from 2013 to 2019, they found that R&D subsidies significantly contribute to boosting innovation outputs within these firms. Both studies underscore the pivotal role of government subsidies in fostering innovation across different sectors in China. It highlights the importance of targeted subsidy policies in promoting technological advancement and economic growth in strategic sectors of the Chinese economy.

Nevertheless, there have been long-standing debates regarding the role of government subsidies in supporting innovative activities. Several studies have identified various constraints and adverse consequences associated with government support in promoting innovation. One concern is that government subsidies might potentially hinder the creative activities of non-subsidized enterprises. Ding et al. (2022) applied dynamic evolutionary game theory to analyze how government subsidy strategies influence firms' innovation strategies based on cost-benefit considerations. Their study shows that firms' choice of innovation strategy hinges on maximizing individual interests, where the marginal benefits directly impact game outcomes. Government subsidies positively impact the innovation strategy choices of subsidized firms but negatively affect non-subsidized competitors, leading to a crowding-out effect.

The study on dairy cattle husbandry in Russia highlights that subsidies are often misdirected, failing to promote innovation due to inadequate emphasis on introducing new technologies and supporting efficient enterprises (Grudkina et al., 2021). This suggests that the current state support system for agriculture in Russia mainly aims to mitigate negative factors rather than fostering innovation in dairy cattle husbandry. Furthermore, Gustafsson et al. (2020) indicate that firms with low productivity are more likely to seek and receive governmental grants, suggesting that subsidies may not always effectively support innovation. Highly productive firms tend to avoid seeking grants, potentially leading to a misallocation of resources. If subsidies primarily benefit low-productivity firms, they may not fully achieve their goal of stimulating innovation and growth. This implies that the effectiveness of subsidies in fostering innovation can be compromised when they disproportionately support less productive firms. Similarly, Gao (2023) observes that in the early stages of the Chinese wind industry, government subsidies did not significantly impact firms' innovation outcomes or R&D investments, despite having a positive intent. This discrepancy suggests that subsidies may not have been effectively utilized to support innovation. Factors such as the non-R&D use of subsidies, market demand uncertainty, and insufficient amounts and duration of subsidies could have contributed to this outcome. Therefore, ineffective utilization of subsidies can undermine their ability to achieve the intended goal of promoting innovation in emerging industries like renewable energy.

These findings underscore the need for a more targeted and effective approach to subsidy allocation. To enhance the impact of subsidies on innovation, it is crucial to focus on supporting firms that are actively pursuing new technologies and demonstrating high productivity. Additionally, subsidies should be structured to address the specific needs of emerging industries and ensure they are used effectively for R&D and innovation. Because if subsidies are not used effectively, they may fail to fulfill the intended goal of supporting innovation (Brüggemann & Proeger, 2017; Gustafsson et al., 2020; Gao, 2023). Policymakers should consider these factors to improve the efficacy of subsidies and better achieve their goals of fostering innovation and growth.

As empirical findings on this topic remain largely inconclusive, this study contributes to the ongoing debate, thus, the following hypothesis is offered based on this foundation.

H2: Government subsidies mediate the relationship between digital transformation and innovation capacity.

RESEARCH METHOD

Data and Samples

Given the particularity of the regulations in the Chinese stock exchange market, a set of criteria for selecting the sample was developed. Firms identified by the Chinese stock market as "ST" (Special Treatment) were excluded. Accordingly, these firms may engage in excessive surplus management to manipulate profits and comply with listing rules (Chen & Wu, 2020). Firms that lack accounting and financial information were also excluded. The study also applied a filtering process to continuous variables where values below the 1st percentile and above the 99th percentile were omitted. Additionally, this research addresses the issue of possible sample data aggregation features and mitigates the impact of heteroskedasticity and autocorrelation concerns by adjusting the standard errors of regression coefficients for clustering at the company level. Thus, a total of 4,027 imbalanced panel datasets consisting of 1,063 A-share manufacturing businesses registered on the stock market from 2018 to 2022 were used.

The data were sourced from the CSMAR database and annual reports of publicly traded companies to gather secondary information. The information is developed based on globally recognized standards and within the framework of China. Additionally, citation studies of data generated for specific projects can offer valuable insights to encourage data sharing and facilitate scientific discoveries (Callaghan, 2014). Annual reports of publicly traded corporations serve as a regularly reported corporate form that offers crucial financial and operational information for various stakeholders (Alduais, 2022).

Table 1 presents the full understanding of the concentration trend, level of variability, and range of data distribution for each variable in the sample.

Table 1. Data Description and Descriptive Statistics

Variable	Obs	Mean	Std	Min	Max
Innovation Capacity	4,027	149.203	407.973	1	3202
Digital Transformation	4,027	41.366	10.966	23.694	67.781
Government Subsidy	4,027	17.315	1.449	13.614	21.077
Intangible Assets	4,027	19.331	1.462	15.659	23.210
Tobin's Q	4,027	1.931	1.405	0.701	22.321

Table 2 displays the Variance Inflation Factor (VIF) values obtained from the multicollinearity test conducted on the variables. Based on the basic premise of VIF, a VIF value beyond 10 indicates the potential presence of multicollinearity issues (Sugiyono in Pradnyawati et al., 2023). The variables in this research had VIF values ranging from 1.05 to 2.01, indicating the absence of multicollinearity among them.

Table 2. VIF Detection Values for Multicollinearity Tests

Variable	VIF	1/VIF
Dx	1.15	0.867
Government Subsidy	2.01	0.499
Intangible Assets	1.88	0.531
Tobin's Q	1.05	0.953
Mean VIF	1.52	

Variable Measurement

Measuring the extent of corporate digital transformation using quantitative methodologies remains a topic of significant interest in both academic research and commercial applications (Wu et al., 2023). Crucial information regarding digital transformation can be efficiently extracted from extensive text data using sophisticated text mining and natural language processing methods (Hitham et al., 2023).

In this study, the variable “Digital Transformation (Dx)” is assessed using data obtained from text-mining terms related to various advanced technologies, such as artificial intelligence, face recognition, driverless technology, robotics, computer-aided design, machine vision, autonomous driving, cloud computing, edge computing, graph computing, the internet of things, cloud storage, cloud technology, big data, data mining, virtual reality, augmented reality, network security, information security, data security, O2O, B2B, B2C, intelligent manufacturing, digital marketing, and digital management.

This research employs a quantitative approach to assess the dependent variable "Innovation Capacity (InCap)" which is measured by the number of citations to patents in a given year and R&D costs represent the initial financial commitment made by companies towards their innovation initiatives. The number of patents obtained is a

subsequent result of these efforts, while patent citations serve as a significant measure of the quality of R&D associated with the patents (Ponta et al., 2021).

Furthermore, this research utilizes government subsidies (GovSub) as a mediating variable and adopts an objective evaluation of government subsidies by collecting the quantity of government subsidy details in the annual reports of publicly traded firms (Wang et al., 2023).

Among the chosen control variables are intangible assets and Tobin's Q. Intangible assets have a crucial role in the expansion potential and long-term success of companies, particularly those that heavily invest in research and development (Hayati & Masdupi, 2022). Tobin's Q is a metric that allows investors to evaluate the desirability of investing in a company (Atinc et al., 2012).

The CSMAR database has published the "Database of Digital Transformation Research of Listed Companies in China". The database was created using pertinent information found in the annual reports, fundraising announcements, qualification certificates, and other announcements made by listed firms. This study employs text analysis to remove the MD&A (Management Discussion and Analysis) content and analyze the frequency of specific keywords. Additionally, it calculates the enterprise digital transformation index by weighing six indicators: strategic leadership, technology drive, organizational empowerment, environmental support, digital achievements, and digital application.

Estimation Models

Fixed effects models (FEM) mitigate the influence of omitted variable bias by accounting for individual characteristics that remain constant over time. This reduces the impact of dynamic misspecification, enhances estimation efficiency, employs adaptive instrumental variable methods, and incorporates bias correction and testing (deHaan, 2021). This work developed a multivariate regression model while accounting for individual fixed factors. To assess the impact of Dx on the innovative capacity of manufacturing firms (H1), the following model was constructed:

$$InCap_{i,t} = \alpha_0 + \alpha_1 Dx_{i,t} + \sum \varphi_i Controls_{i,t} + u_i + \varepsilon_{i,t} \quad (1)$$

The Baron and Kenny (1986) method of causal stepwise regression analysis is often used to find primary predictors and identify mediators. To examine the mediating role of government subsidies in the relationship between Dx and innovation capacity (H2), the following model was constructed:

$$GovSub_{i,t} = \beta_0 + \beta_1 Dx_{i,t} + \sum \varphi_i Controls_{i,t} + u_i + \varepsilon_{i,t} \quad (2)$$
$$InCap_{i,t} = \lambda_0 + \lambda_1 Dx_{i,t} + \lambda_2 GovSub_{i,t} + \sum \varphi_i Controls_{i,t} + u_i + \varepsilon_{i,t} \quad (3)$$

In Models 1-3, InCap denotes the number of references to the patents of firm *i* in year *t*. Dx denotes the digital transformation index of firm *i* in year *t*. GovSub denotes the amount of government subsidies of firm *i* in year *t*. α_0, β_0, λ_0 stands for the intercept term α_1, β_1, λ_1 denotes the regression coefficient of the explanatory variables, λ_2 denotes the regression coefficient of the mediating variable, φ denotes the regression coefficient of the control variable, u_i denotes fixed effects at the individual firm level, $\varepsilon_{i,t}$ and denotes the residual term.

Additionally, the research employed the bootstrapping method to aid in parameter estimation within statistical models and to facilitate statistical hypothesis testing. This technique involved generating multiple resampled datasets from the original sample,

without imposing explicit assumptions about the underlying data distribution (Alfons et al., 2022).

All analyses, including modeling and hypothesis testing, were conducted using Stata 17.0 software. These methodological procedures played a crucial role in maintaining data integrity, improving the robustness of the statistical findings, and thereby strengthening the scientific validity and credibility of the study.

RESULTS

The Effects of Digital Transformation on Innovation Capacity

The study hypothesized that digital transformation improves the innovation capacity of firms. Table 3 provides a comprehensive overview of the outcomes obtained from the FEM.

Table 3. Fixed Effects Regression Results on the Effect of Digital Transformation on Innovation Capacity

	(Model 0)	(Model 1)
	InCap	InCap
Dx	5.448***	5.257**
	(3.36)	(3.26)
Intangible Assets		33.940**
		(3.29)
Tobin's Q		9.493***
		(3.82)
cons	-26.970	-686.253**
	(-0.42)	(-3.22)
N	4027	4027
R^2	0.270	0.274
F	38.891	28.399

Note: ***, **, and * denote statistical significance at the .01%, 1%, and 5% levels of significance, respectively. The t-statistics (in parentheses) are based on standard errors adjusted for clustering at the firm level.

Table 3 presents the results of two regression models examining the impact of digital transformation on innovation capacity, with intangible assets and Tobin's Q included as control variables in the second model. In both models, digital transformation shows a significant positive effect on innovation capacity, with coefficients of 5.448 ($p < .01$) and 5.257 ($p < .05$), respectively. These indicate a robust positive relationship between digital transformation and innovation capacity.

In Model 1, the control variables intangible assets and Tobin's Q are included. It is shown that intangible assets have a significant positive effect on innovation capacity ($p < .05$). Tobin's Q also shows a significant positive effect on innovation capacity ($p < .01$). These results highlight the importance of considering intangible assets and market valuation when analyzing the determinants of innovation capacity.

The R-squared values for the models are 0.270 and 0.274, indicating that approximately 27% and 27.4% of the variance in innovation capacity is explained by the independent variables in the models. The F-statistics for the models are 38.891 and 28.399, respectively, demonstrating that the overall models are statistically significant.

In summary, the results indicate that digital transformation significantly enhances innovation capacity. The inclusion of intangible assets and Tobin's Q as control variables further refines this relationship, highlighting the importance of these factors in driving innovation. Additionally, the findings suggest that the use of digital technology by publicly traded industrial companies in China has a substantial impact on enhancing their capacity to innovate, thus providing strong support for H1.

Mediating Effect of Government Subsidy in the Relationship Between Digital Transformation and Innovation Capacity

The study also explored the mediating role of government subsidy in the relationship between digital transformation and innovation capacity firms with intangible assets and Tobin's Q included as control variables. Table 4 shows the results of the stepwise regression analysis.

Table 4. Regression Results for the Mediating Effect of Government Subsidy in Digital Transformation and Innovation Capacity Relationship

	(Model 2)	(Model 3)
	GovSub	InCap
Dx	0.012*	5.257**
	(2.42)	(3.26)
GovSub		-0.143
		(-0.02)
Intangible Assets	0.304***	33.974**
	(5.93)	(3.28)
Tobin's Q	0.020	9.489***
	(0.84)	(3.85)
cons	11.019***	-684.445**
	(11.66)	(-2.92)
N	4027	4027
R^2	0.049	0.274
F	25.664	24.842

Note: ***, **, and * denote statistical significance at the .01%, 1%, and 5% levels of significance, respectively. The t-statistics (in parentheses) are based on standard errors adjusted for clustering at the firm level.

In Model 2, digital transformation emerges as a significant driver of innovation capacity, showing a positive effect with a coefficient of 5.257 ($p < .01$). This finding underscores that increased adoption of digital technologies enhances the ability of publicly traded industrial firms in China to innovate, aligning with the hypothesis (H1) that digital transformation boosts innovation capabilities. However, government subsidies do not exhibit a direct significant effect on InCap (-0.143, not significant), suggesting that while government subsidies may influence innovation indirectly through other mechanisms, they do not directly contribute to enhancing innovation capacity in this specific context when controlling for other variables. Meanwhile, intangible assets significantly enhance innovation capacity ($p < .01$ level), highlighting their critical role in fostering innovation within firms. Similarly, Tobin's Q shows a strong positive effect on innovation capacity ($p < .001$ level), indicating that higher market valuation relative to assets correlates with greater innovation capacity.

The overall model fit for Model 2 is robust, with an R-squared value of 0.274, indicating that approximately 27.4% of the variance in InCap is explained by the independent variables. The F-statistic of 24.842 confirms that the model is statistically significant, providing confidence in the relationships observed.

The inclusion of intangible assets and Tobin's Q in the models further highlights their importance, as both variables show significant positive effects on innovation capacity. However, the core finding here is that while government subsidies increase with digital transformation, they do not play a mediating role in enhancing innovation capacity. The direct pathway from digital transformation to innovation capacity is more robust, suggesting that firms can directly leverage their digital transformation efforts to boost their innovation outcomes, irrespective of the level of government subsidies received.

Robustness Test

To enhance the dependability of prior research outcomes and mitigate the impact of measurement inaccuracies and other variables, this study adhered to the methodology outlined by Zhai et al. (2022). It is important to mention that the Bootstrap test yields dependable estimates and conclusions, even in cases when the raw data deviates from the assumption of normal distribution. The results of the Bootstrap test are shown in Table 5. The observed coefficient for the indirect effect demonstrates a statistically significant positive impact.

Table 5. Results of Bootstrap

	Observed Coefficient	Bootstrap std. err.	z	P>|z|	Normal-based [95% conf. interval]
Indirect Effects	1.823	0.234	7.80	.000	(1.365 2.281)
Direct Effects	8.092	0.708	11.42	.000	(6.703 9.480)

The bootstrap analysis reveals both indirect and direct effects of digital transformation on innovation capacity, with government subsidy acting as the mediator. The indirect effect of digital transformation on innovation capacity through government subsidies suggests that digital transformation positively impacts innovation capacity indirectly by increasing government subsidies ($p < .001$). In terms of the direct effects of digital transformation on innovation capacity, excluding the mediating role of government subsidies, the data demonstrates a strong direct relationship between digital transformation and innovation capacity, independent of government subsidies ($p < .001$).

In summary, the analysis shows that digital transformation enhances innovation capacity through both direct and indirect pathways, with government subsidies serving as a mediator. However, the direct effect of digital transformation on innovation capacity is significantly larger than the indirect effect via government subsidies. This underscores that while government subsidies do contribute to the process, the primary driver of innovation capacity is the direct impact of digital transformation itself. Combining insights from the bootstrap analysis and regression models highlights that firms should prioritize digital transformation initiatives to boost innovation capacity while recognizing that government subsidies provide additional, but relatively minor, support.

DISCUSSION

The study's main objective is to examine the impact of digital transformation on the innovation capacity of Chinese-listed firms and the role of government subsidies in the nexus. Using data from 1,063 publicly traded in China from 2018 to 2022, the study validates the significant positive influence of digital transformation on companies' ability to innovate (H1), supported by empirical analysis within the context of publicly traded Chinese manufacturing enterprises. This finding resonates with contemporary academic perspectives emphasizing the transformative impact of new technologies and enhanced operational models within organizations, collectively known as digital transformation (Guan, 2023; Gupta et al., 2024; Xu, 2023). Similar to Guan (2023) and Xu (2023), the findings highlight the transformative potential of digital technologies in driving innovation and promoting sustainable growth across various sectors of the economy, especially with the inclusion of intangible assets and Tobin's Q, marking a pivotal shift in how businesses in the digital economy innovate and compete. However, it should be noted that digital transformation alone is insufficient (Jin & Qin, 2024). The integration of innovation capabilities like synergizing digital and technical skills is crucial for optimizing performance and outcomes (Gupta et al. 2024; Wang & Li, 2023). Collectively, the findings of the study and these studies highlight the importance of strategic alignment, investment in digital skills, and supportive regulatory frameworks to fully realize the benefits of digital transformation.

Moreover, the study reveals that digital transformation directly enhances innovation capacity significantly more than through the mediation of government subsidies. While government subsidies do have a positive mediating effect, aligning with the studies of Andargoli et al. (2023) and Li et al. (2021), their impact is relatively minor compared to the direct benefits of digital transformation. The core finding here is that while government subsidies increase with digital transformation, they do not play a mediating role in enhancing innovation capacity. The direct pathway from digital transformation to innovation capacity is more robust, suggesting that firms can directly leverage their digital transformation efforts to boost their innovation outcomes, irrespective of the level of government subsidies received. More interestingly, the study found a negative correlation coefficient between government subsidies and innovation capacity which suggests a nuanced dynamic, emphasizing the need for accurate and effective subsidy allocation. Same with the findings of Ding et al. (2022, Grudkina et al. (2021), and Gustafsson et al. (2020), this underscores the importance for firms to focus on digital transformation initiatives to drive innovation capacity while recognizing that government subsidies can provide additional, albeit smaller, support. Overall, this suggests that firms should prioritize digital transformation initiatives to enhance innovation outcomes, as the direct influence of these efforts is more substantial. Because the misallocation of subsidies could undermine innovation, underscoring the need for careful policy design to ensure that subsidies effectively support innovation efforts without adverse effects (Brüggemann & Proeger, 2017; Ding et al., 2022; Gao, 2023; Gustafsson et al., 2020).

CONCLUSION

This study examined the impact of digital transformation on the innovation capacity of Chinese-listed firms while exploring the roles of government subsidy in this dynamic. To achieve this, the study developed an empirical framework for evaluating these relationships, addressing gaps in previous research. Using imbalanced panel data with a total of 4,027 data points from 1,063 A-share manufacturing businesses registered on the stock market from 2018 to 2022, a fixed-effects model was employed to construct the model.

The study concluded that digital transformation significantly enhances the innovative capacity of organizations. It not only changes how organizations operate but also promotes the effective collaboration of internal resources and improves the quality of patent research and development, thereby substantially boosting enterprises' innovative capabilities. This finding aligns with contemporary academic perspectives, which highlight that adopting innovative technologies and advancing operational frameworks—collectively known as digital transformation—opens new growth opportunities (Guan, 2023; Gupta et al., 2024; Xu, 2023). However, it is crucial to recognize that digital transformation alone is insufficient (Jin & Qin, 2024). To truly optimize performance and achieve desired outcomes, it is necessary to integrate innovation capabilities, such as combining digital and technical skills (Gupta et al., 2024; Wang & Li, 2023). The study, along with these related findings, underscores the importance of strategic alignment, investment in digital skills, and supportive regulatory frameworks to fully leverage the benefits of digital transformation.

Both stepwise regression analysis and bootstrapping techniques show that government subsidies indirectly help link digital transformation with innovation capacity. While these subsidies do not directly affect innovation capacity, their indirect role in supporting other mechanisms that drive innovation is significant and should not be ignored. The study also found a negative correlation between government subsidies and innovation capacity, indicating a more complex relationship. This highlights the need for precise and effective allocation of subsidies to prevent any adverse effects on innovation. Government subsidies play a key role in encouraging technological innovation and digital transformation by reducing research and development costs and uncertainties. However, the significant impact of intangible assets and Tobin’s Q suggests that firms should also focus on managing and leveraging these factors to enhance their innovation capabilities. Consistent with findings from Ding et al. (2022), Grudkina et al. (2021), and Gustafsson et al. (2020), it is clear that firms should prioritize digital transformation efforts to improve innovation capacity. While government subsidies can provide some support, their impact is relatively limited compared to the direct benefits of investing in digital transformation. Therefore, companies should focus on these initiatives to achieve better innovation outcomes. Additionally, subsidy policies must be carefully designed to ensure they support innovation effectively without causing negative side effects, as misallocated subsidies can impede progress (Brüggemann & Proeger, 2017; Ding et al., 2022; Gao, 2023; Gustafsson et al., 2020).

This study contributes to the theoretical understanding of digital transformation's impact on innovation capacity within Chinese-listed firms by developing an empirical framework and addressing research gaps. It reveals that digital transformation enhances organizational innovation by fostering internal resource collaboration and improving patent research and development quality, aligning with contemporary academic perspectives on the opportunities offered by innovative technologies. Furthermore, the study highlights the indirect role of government subsidies in facilitating the relationship between digital transformation and innovation, emphasizing the government's crucial role in incentivizing firms to engage in technology innovation and digital transformation. Practically, these findings offer strategic guidance for firms aiming to leverage digital transformation for enhanced innovation, while also providing insights for policymakers to design effective subsidy programs to promote innovation-driven growth and enhance competitiveness in the market.

LIMITATION

While the study makes valuable contributions, it is constrained by its exclusive focus on listed businesses within China's manufacturing sector, potentially limiting its applicability to other industries or unlisted enterprises. Future research endeavors should address this limitation by expanding the sample to include companies from diverse sectors and varying magnitudes. Moreover, to obtain a more comprehensive understanding, subsequent studies could explore additional multifaceted measures related to digital transformation. By broadening the scope of analysis and incorporating a wider range of industry contexts and measurement variables, future research can enhance the depth and breadth of insights into the dynamics of digital transformation and its impact on innovation capacity.

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DECLARATION OF CONFLICTING INTERESTS

No potential conflict of interest was reported by the authors.

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