

An Investigation into the Effects of Digital Transformation on the Innovative Performance of Manufacturing Enterprises

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Abstract

Digital transformation and innovation are inevitable requirements for enterprises to gain competitive advantages and achieve long-term high-quality development. This article selects Chinese A-share listed manufacturing companies from 2014 to 2022 as samples to explore how digital transformation affects corporate innovation performance and the mediating role of corporate resilience. Research has revealed that digital transformation exerts a considerable beneficial impact on the innovative capabilities of manufacturing enterprises, and enterprise resilience plays a significant mediating role in this process. At the same time, the digital transformation of large and growing enterprises has imposed a more notable effect on their innovation performance compared to other enterprises. Therefore, manufacturing enterprises should fully leverage their resilience as an intermediary based on their own considerations, accelerate the digital transformation, and effectively enhance their innovation performance.

Keywords

Digital Transformation, Enterprise Innovation Performance, Enterprise Resilience, Intermediary Effect, Manufacturing Enterprises

1. Introduction

With the continuous upgrading of national economy and policies, digital transformation has become one of the core strategies of national development and modernization. The Notice of The State Council on the Issuance of Digital China Construction and Development Strategy released in 2018 for the first time elevated digitalization and intelligence to a national level strategic height. At the end

of 2024, the Ministry of Industry and Information Technology (MIIT) and two other government bodies jointly issued the Implementation Guide for Digital Transformation of Manufacturing Enterprises, providing guidance to help enterprises enhance their strategic planning capabilities, strengthen benchmarking and decision-making abilities, clarify differentiated transformation pathways, and improve their transformation support systems. In 2025, the National Data Work Conference proposed to further implement the digital transformation initiative, vigorously advance the “East Data, West Computing” project, and promote the integration and innovative application of data resources. Meanwhile, the State Administration for Market Regulation (SAMR) approved and released China’s first national standard for digital transformation, establishing a reference framework in this field. As the only way for China’s high-quality economic development, digital transformation not only helps enterprises improve their innovation and competitiveness, but also effectively promotes social economic development, improvement of people’s livelihood and enhancement of national security capabilities.

The enterprise resilience of manufacturing enterprises is defined as the ability of enterprises to predict potential threats in the face of external shocks and effectively respond to them, and learn from them to promote their growth, which plays a crucial role in resolving shocks and promoting enterprise development and growth. Similar to enterprise innovation, digital transformation is characterized by long cycles and strong uncertainties, so enterprises need to have strong enterprise resilience. Current research primarily focuses on the impact of enterprise digital transformation on enterprise resilience, high-quality development, or overall performance, with limited attention to micro-level effects such as innovation performance. However, in the context of the digital wave, enterprise innovation cannot be overlooked. Therefore, this paper improves the measurement index of enterprise resilience. From the perspective of enterprise resilience, it constructs an intermediary model to study the impact mechanism of digital transformation of manufacturing enterprises on innovation performance. At the same time, through in-depth research through heterogeneity analysis, it provides a scientific basis for enterprises’ organizational adjustment and strategic choice, and enriches the research in related fields.

2. Literature Review

2.1. Connotation and Measurement of Digital Transformation

Digital transformation refers to the process of an organization adopting digital technology and intelligent means to transform and upgrade the existing business model, process and operation frame, aiming to improve the production efficiency of the enterprise, expand the scale of revenue and reduce costs, so as to adapt to and lead the digital era. Based on the existing micro-level researches, the measurement of digital transformation can be roughly divided into two categories. One is to measure in the form of questionnaires, which are prepared with the assistance

of experts and sent to the employees of the enterprise to fill in (Xiao et al., 2024a). One is to conduct research through text analysis. Chen et al. (2021) and Yuan et al. (2021) determined keywords related to enterprise digital transformation by consulting a team of digital transformation experts, and calculated the degree of digital transformation in the corresponding year through a certain measurement formula. Zareie et al. (2024) combined the dictionaries developed in recent years to form a relatively comprehensive list of digital-related vocabulary, and used Python for text analysis to calculate the frequency of related words to measure the score of enterprise digital transformation.

2.2. Connotation and Measurement of Enterprise Innovation Performance

Innovation performance, as one of the core variables to judge whether an enterprise is successful in innovation, is the key to the long-term sustainable development of an enterprise. Innovation performance refers to the efficiency of innovation activities, the results obtained and its impact on the operation of enterprises.

According to research by some scholars (Zhao et al., 2022; Li et al., 2023; Zang et al., 2022), enterprise innovation performance is often measured through a single dimension, such as the number of patents granted, the number of patent citations, or the number of patent applications. Meanwhile, other scholars measure innovation performance across multiple dimensions. Zhang (2024) divides enterprise innovation performance into two dimensions—breakthrough innovation and incremental innovation—based on the ambidextrous innovation perspective for a comprehensive assessment. Wen et al. (2023) select data on inventions, utility models, and design patents, assigning different weights to each to form a new patent application index, which is then used to measure enterprise innovation performance.

2.3. Connotation and Measurement of Enterprise Resilience

Most definitions of enterprise resilience describe it from three perspectives: capability, process, and outcome. From the capability perspective, enterprise resilience is defined as the combination of the enterprise's ability to bounce back from external shocks, to adapt, to learn actively and to improve in order to overtake (Sajko et al., 2021; Duchek, 2020; Sahebjamnia et al., 2018). From the process perspective, enterprise resilience refers to the active process through which enterprises respond to and manage disruptions (Ma et al., 2018). From the outcome perspective, enterprise resilience is characterized as the successful result of an enterprise's ability to effectively cope with shocks or unexpected crises (DesJardine et al., 2019).

The measurement of enterprise resilience in existing researches primarily adopts two approaches: direct and indirect measurement. Direct measurement involves assessing resilience through scale-based methods. Indirect measurement generally consists of three approaches. The first is based on an enterprise's response to ex-

ternal shocks, such as the extent and duration of stock price declines (Hu et al., 2022); Secondly, it is using market-related indicators, such as stock price performance to measure resilience (Albuquerque et al., 2020); the last is assessing resilience through financial indicators, such as changes in net profit (Ortiz-de-Mandojana et al., 2016). Wang & Cui (2023) and Chen et al. (2024), considering the complexity and dynamic nature of enterprise resilience, constructed a comprehensive evaluation index system that includes multiple primary and secondary indicators, employing the entropy method for measurement. Meanwhile, Liu Li et al. (2025) focused on enterprise resilience from a long-term perspective, measuring it using a two-dimensional framework of growth and volatility.

3. Research Hypothesis

3.1. Digital Transformation and Enterprise Innovation Performance

In the case of the rapid development of globalization and intelligent technology, digital transformation through its penetration, creativity, etc., helps enterprises to better meet the needs of the market and consumers, enhance the competitiveness of enterprises, and promote the innovative development of enterprises.

First, digital transformation can effectively enhance enterprise innovation performance through multiple pathways: optimizing resource allocation, breaking through existing innovation boundaries, strengthening organizational learning and absorptive capacity, precisely adjusting innovation strategies, and improving adaptability to the innovation environment (Zhang, Yuan, & Quan, 2024). Building on this foundation, enterprises can effectively mobilize soft innovation resources, precisely control and monitor innovation processes, enhance R&D capabilities, and leverage digital technologies to optimize innovation mechanisms, thereby reducing innovation costs (Ma et al., 2024). Meanwhile, digital transformation helps reduce operational costs while increasing innovation funding. By utilizing big data and other digital technologies, it accelerates resource allocation optimization and improves innovation resource utilization efficiency. Furthermore, it alleviates innovation financing pressures through expanded funding channels, collectively contributing to improved innovation performance (Song & Song, 2023). Notably, while digital transformation may temporarily reduce innovation performance in the short term, enterprises can implement modular management approaches in the long run to effectively reduce production factor consumption while enhancing decision-making and management efficiency (Zhang, Yi, & Li, 2024). Moreover, by employing digital technologies to mitigate risks, break down information barriers, and establish shared business networks with other enterprises, the enterprise can significantly improve innovation efficiency, thereby generating greater innovation performance outputs (Xiao et al., 2024b). Therefore, we propose the following hypothesis:

H1: Digital transformation can effectively enhance enterprise innovation performance.

3.2. Digital Transformation, Enterprise Resilience and Enterprise Innovation Performance

As the driving force of enterprise innovation and development, digital transformation can help enterprises coordinate internal and external resources in uncertain situations, effectively enhance their dynamic adaptability to gain competitive advantages, and consequently improve their resilience. In subsequent innovation processes, enterprises will face fewer risks and greater support, facilitating increased innovation performance.

The impact of digital transformation on enterprise resilience mainly includes the following aspects. First, during digital transformation, enterprises, on the one hand, explore new opportunities and resources through exploratory innovation to actively respond to crises and achieve recovery and growth, thereby enhancing their adaptability. On the other hand, through exploitative innovation, they integrate existing resources and capabilities, reduce the harm of disruptive innovation by learning while maintaining existing models, contributing to stable enterprise development (Jiang et al., 2022). Second, digital transformation will enhance the human-machine synergistic effect of enterprises and optimize the human capital structure. Through the learning of digital technology, knowledge and experience sharing among employees can be realized and the quality of human capital can be improved. Moreover, the digital transformation of enterprises can help alleviate the impact of financing constraints, reduce financing thresholds and costs, and resolve financing problems (Chen & Wang, 2023). Third, enterprise digital transformation can effectively improve urban-level employment environments and digital infrastructure construction, while enhancing enterprises' innovation capabilities and internal control abilities (Luo et al., 2024). Meanwhile, the use of digital technologies encourages all enterprise departments, partner enterprises, and society to participate in open innovation, enhancing R&D precision, reducing innovation risks, and improving enterprises' risk perception and resilience (Yin et al., 2025).

During digital transformation, enterprises face constantly evolving innovation environments. Strong resilience helps enterprises absorb new knowledge and information, reconfigure resources, promptly respond to unknown risks and challenges, facilitating sustainable and high-quality development and providing guarantees for innovation (Zhang et al., 2023). Secondly, enterprises with high organizational resilience respond more flexibly to risks and challenges, reducing decision-making errors and resource waste when facing external shocks, enabling them to mitigate risks, continuously focus on core businesses, strengthen technological innovation, and create economic benefits (Zhang, Wang, & Shi, 2024). Finally, resilience as an enterprise attribute is also a capability possessed by enterprises. Rooted in enterprises, resilience can be summarized as redundant resources, organic structures, agile cultures, and external reciprocity. Redundancy manifests as heterogeneity, promoting idea collisions and creativity within enterprises; organic structures manifest as resource flow and sharing, providing space for employee autonomous development and incentivizing innovation activities; agile

cultures manifest as support and encouragement, enabling employees to exercise initiative and motivating innovation; external reciprocity manifests as resources and support, where establishing mutual benefit and trust helps enterprises achieve win-win outcomes with stakeholders, reducing innovation risks and improving innovation efficiency (Tian & Ding, 2023). Therefore, we propose the following hypotheses:

H2: Digital transformation can improve enterprise resilience.

H3: Digital transformation can promote the improvement of enterprise innovation performance by enhancing enterprise resilience.

To sum up, the research model of this paper is shown in the figure below (Figure 1):

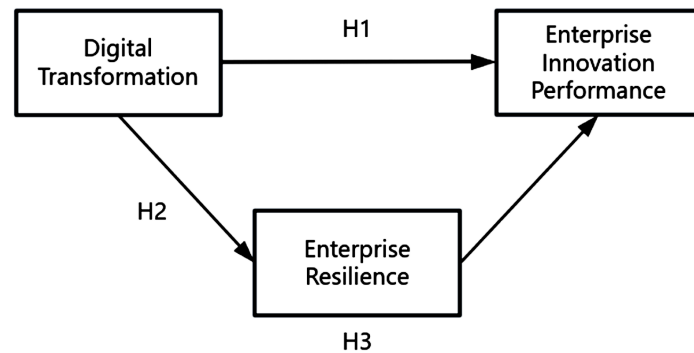


Figure 1. Research model.

4. Research Design

4.1. Sample Selection and Data Source

Considering data availability and research value, this study selects data from China's A-share listed manufacturing enterprises from 2014 to 2022 as the initial sample. The digital transformation data were extracted from enterprise annual reports, while patent counts and other enterprise data were obtained from the China Stock Market & Accounting Research Database (CSMAR). To ensure more reliable regression results, the samples are treated as follows: Exclude ST/*ST enterprises and observations with severe missing key variables; Only samples with continuous seven-year records are retained; and the continuous variables are shrunken by 1 percent on both sides. The final sample consists of 9108 observations from 1012 enterprises.

4.2. Variable Measurement

1) Explained variable: enterprise innovation performance

The explained variable is enterprise innovation performance (Innovation). In order to ensure the comprehensiveness of the data, this paper combined the total number of patent applications of listed companies and subsidiaries in the patent sub-database of listed enterprises and subsidiaries from 2014 to 2017, and the total number of patent applications of listed enterprises from 2018 to 2022 in the re-

search and development innovation sub-database of listed enterprises. Constitute a data table of the total number of patent applications of listed manufacturing enterprises from 2014 to 2022. Drawing on existing approaches (Yu & Ma, 2024; Jiang et al., 2023; Bai et al., 2019) and accounting for both the right-skewed distribution of data and the possibility of zero patent applications, we apply a log transformation after adding one to the patent application counts.

2) Explanatory variable: digital transformation

The explanatory variable is digital transformation (Digital). Prior researches on measuring enterprise digital transformation have suffered from limitations such as single-dimensional indicators and strong subjectivity. To develop more scientific and reasonable variables, this paper draws on the methods of Chen et al. (2021), Yuan et al (2021), and Wu et al (2021), combined with a digital transformation dictionary and using Python tools for text analysis. Firstly, by searching the officially released national policy documents, 29 keywords related to enterprise digital transformation, including digitalization, intelligence and digital technology, were screened to form an enterprise digital transformation dictionary. To ensure rigorous word frequency counting, we employed Python's "Jieba" segmentation tool to process enterprise annual reports through word segmentation, matching, and keyword frequency extraction. We then calculated the total occurrence frequency of digital transformation-related terms. Finally, accounting for potential right-skewed distribution, we applied a log transformation after adding one to the word frequency counts, using this as the indicator of enterprise digital transformation intensity.

3) Intermediary variable: enterprise resilience

The intermediary variable is enterprise resilience (Resilience). By referring to the existing studies on enterprise resilience (Zhang & Dong, 2024; Zhang & Hu, 2023; Chen et al., 2023), this paper finds that most of the existing studies measure enterprise resilience from a single or a few indicators. In order to make the measurement of enterprise resilience more representative, this paper draws on the studies of Wang & Cui (2023), Wang & Huang (2023), and Li & Kong (2023), and comprehensively selects 4 first-level indicators of defense ability, resistance ability, recovery ability, and growth ability, as well as 12 second-level indicators to measure enterprise resilience (Table 1). In this paper, the entropy weight method is used to measure enterprise resilience comprehensively, in order to reduce the influence of subjective factors and enhance the rigor and credibility of data.

Table 1. Enterprise resilience evaluation index system.

Primary index	Secondary index	Calculation method	Index property
Defense Capability	Debt-to-market ratio	Total liabilities/Total owner's equity	-
	Redundant assets	Current assets/Current liabilities	+
	Per capita operating income of enterprises	Revenue/Total number of employees	+

Continued

	Net asset value per share	Shareholders' equity/Total number of shares	+
Resistance	Stock decline	(Low price for the year – High price for the year)/High price for the year	+
	Employee mobility	(End/Beginning of period) – 1	+
	Return on equity	Net profit/Average balance of shareholders' earnings	+
Recovery Ability	Turnover of total assets	Operating income/Ending total assets	+
	Net profit	Income tax expense on gross profits	+
	Year-on-year growth rate of total assets	(End of period – Beginning of period)/Beginning of period	+
Growth Ability	Year-on-year growth rate of operating income	(End of period – Beginning of period)/Beginning of period	+
	Year-on-year growth rate of net profit	(End of period – Beginning of period)/Beginning of period	+

First, Defense Capability. A key feature of enterprise resilience is its defensive capability, that is, its ability to mitigate losses caused by risk. Based on the existing research results at home and abroad, this paper takes three secondary indicators, debt-to-market ratio, redundant assets and per capita business income, as measurement indicators. [Gittell et al. \(2006\)](#) found that cash holding level and debt-to-market ratio of enterprises are important indicators to measure the degree of financial crisis tolerance of enterprises, and a lower debt-to-market ratio means that enterprises use less debt financing, that is, enterprises have lower financial risk and strong solvency. [George \(2005\)](#) believes that redundant resources are a kind of potential available resources, which can be transferred or reconfigured by enterprise to achieve its purpose. Undeposited redundant resources can directly reflect the financial flexibility and strategic flexibility of enterprises, which is an important part of enterprise resilience. According to the research of [Yang & Yin \(2018\)](#), operating income is an important part of the cash inflow of enterprises, and a higher cash ratio can help enterprises better cope with various crises. The per capita operating income of enterprises is directly related to the operational efficiency of enterprises, thus affecting the defense their capability. High per capita operating income is an important basis for resisting external risks, which means that enterprises have high resilience.

Second, Resistance. The resistance ability of enterprises refers to the ability of enterprises to maintain continuous operation, resist risks, recover quickly and develop sustainably when facing various internal and external risks. Based on the

research of domestic and foreign scholars (DesJardine et al., 2019; Ortiz-de-Mandojana et al., 2016; Hu et al., 2020), this paper summarizes three secondary indicators: net asset value per share, stock decline and employee mobility. Net asset value per share reflects the current value of the assets owed by each stock, and is a key indicator to evaluate the economic strength of an enterprise. The higher the net asset value per share, the stronger the economic strength and solvency of the enterprise, so there are more resources to withstand risks and crises. Measuring the decline in stock price by the degree of stock price decline in the year reflects the decline speed and space of stock price in a specific period of time. If external shocks or risks lead to a large decline in stock price, the weaker the resistance of the enterprise. Employee mobility refers to the transfer, resignation and transfer of employees between enterprises. A high employee turnover rate means that the human resources of the enterprise are unstable, which may have a negative impact on the enterprise and further affect the enterprise's resistance ability.

Third, Recovery Ability. Resilience helps companies recover and rebuild during and after a crisis. Recovery Ability is an intuitive manifestation of enterprise resilience (Dalziell & McManus, 2004). By referring to the research of Shi & Li (2022) and combining with other literatures, this paper summarizes three secondary indicators, namely return on equity, total asset turnover and net profit. The level of return on equity, total asset turnover and net profit can reflect the speed and intensity of profitability recovery of enterprises. And a high level of return on equity, total asset turnover and net profit will help enterprises to recover quickly after crises and risks.

Fourth, Growth Ability. An enterprise's ability to grow is also an important part of measuring its resilience. Based on the research of existing scholars (Guo et al., 2019; Zhou & Lin, 2015), this paper selects three secondary indicators, namely the growth rate of total assets, the year-on-year growth rate of operating income and the year-on-year growth rate of net profit. The growth rate of enterprise assets scale in a certain period can be reflected by the year-on-year growth rate of total assets, which is an important reflection of enterprise growth ability. A high year-over-year growth rate of total assets usually means that the company is expanding rapidly, with frequent investment activities and expanding asset models. The year-on-year growth rate of operating income can better evaluate the operating status and development potential of enterprises. The high year-on-year growth rate of operating income indicates that the market demand for an enterprise's products or services is strong and its growth capacity is strong. The year-on-year growth rate of net profit measures the operating efficiency of enterprises. A high year-on-year growth rate of net profit indicates that the profitability of enterprises is enhanced and the operating efficiency is improved, which provides a solid financial foundation for the growth of enterprises.

4) Control variables

In order to ensure the robustness of the research results, other factors that may interfere with the innovation performance of enterprises are controlled based on

relevant studies (Song & Song, 2023; Zhang & Li, 2023; Zhang & Long, 2022). Specific control variables include: Board Size (BS), which is measured by the logarithm of the total number of board members; Independent Director Ratio (Indep), measured by the number of independent directors as a percentage of the total number of directors on the board; Asset-liability ratio (Lev), measured as the ratio of total assets to total liabilities; Fixed Asset Density (Fixed), measured as the ratio of net fixed assets to total assets; Concentration of Shares (Share), measured by the proportion of the largest shareholder (Table 2).

Table 2. Variable selection and definition.

Variable class	Variable symbol	Variable name	Variable definition	Resources
Explanatory variable	Intelligent	Intelligent transformation	Ln(Intelligent Transformation Word Frequency + 1)	Enterprise Annual Reports
Explained variable	Innovation	Innovation performance	Ln(Number of patent applications + 1)	China Stock Market & Accounting Research Database (CSMAR)
Intermediate variable	Resilience	Enterprise resilience	Enterprise resilience comprehensive evaluation index	China Stock Market & Accounting Research Database (CSMAR)
Control variable	BS	Board Size	Ln(Total number of Directors)	China Stock Market & Accounting Research Database (CSMAR)
	Indep	Independent Director Ratio	Number of independent directors/Total number of board members	
	Lev	Asset-liability ratio	Total assets/total liabilities	
	Fixed	Fixed Asset Density	Net fixed assets/total assets	
	Share	Concentration of Shares	The proportion of the largest shareholder	

4.3. Model Construction

According to the assumptions proposed in this paper, in order to verify the impact of digital transformation on enterprise innovation performance and explore the mediating role of enterprise resilience, this paper designs the following econometric regression model:

$$\text{Innovation}_{i,t} = \alpha_0 + \alpha_1 \text{Digital}_{i,t} + \sum_j \alpha_j \text{Controls}_{i,t}^j + \delta_t + \mu_i + \varepsilon_{i,t} \quad (1)$$

In order to test the mediating effect of enterprise toughness, based on the research of Wen & Ye (2014) on the mediating effect, The following mediation effect model is constructed:

$$\text{Resilience}_{i,t} = \beta_0 + \beta_1 \text{Digital}_{i,t} + \sum_j \beta_j \text{Controls}_{i,t}^j + \delta_t + \mu_t + \varepsilon_{i,t} \quad (2)$$

$$\text{Innovation}_{i,t} = \lambda_0 + \lambda_1 \text{Digital}_{i,t} + \lambda_2 \text{Resilience}_{i,t} + \sum_j \lambda_j \text{Controls}_{i,t}^j + \delta_t + \mu_t + \varepsilon_{i,t} \quad (3)$$

Among them, i is the individual enterprise, t is the year, j is the number of main control variables, Controls^j is the j th control variable, δ_t , μ_t , $\varepsilon_{i,t}$ represents the industry fixed effect, annual fixed effect and random error term respectively.

5. Empirical Results and Analysis

5.1. Descriptive Statistics

Table 3 shows the descriptive statistical results of all variables in this paper. The minimum value of enterprise digital transformation is 0, the maximum value is 7.209, the mean value is 2.475, and the standard deviation is 1.184, indicating that the sample enterprises have great differences in digital transformation. The minimum value of innovation performance is 0.693, the maximum value is 9.705, the mean value is 3.927, and the standard deviation is 1.376, indicating that there is a large difference in innovation performance among the sample firms. The minimum value of enterprise toughness is 0.014, the maximum value is 0.688, and the mean value is 0.307, indicating that there are differences in enterprise resilience among the sample enterprises. In addition, there is no significant difference between the control variables and the existing studies.

Table 3. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Digital	9108	2.475	1.184	0	7.209
Resilience	9108	0.307	0.155	0.014	0.688
Innovation	9108	3.927	1.376	0.693	9.705
Fixed	9108	0.226	0.129	0	0.766
Lev	9108	0.413	0.177	0.014	1.037
BS	9108	8.543	1.585	0	18
Indep	9108	37.505	5.656	0	80
Share	9108	32.194	14.113	1.84	89.99

5.2. Correlation Analysis

Table 4 is the correlation table of the variables in this paper. The results show that the two-by-two relationships between enterprise digital transformation, enterprise innovation performance and enterprise resilience of intermediary variability are all significant at the level of 1%, and they are all positively correlated. At the same

time, the Variogram Inflation Factor (VIF) was calculated for all explanatory variables. The results are shown in **Table 5**. The average VIF value of all explanatory variables is 1.14, and the highest value is 1.35, all of which are far below the threshold of 10, so there is no multicollinearity problem.

Table 4. Results of correlation analysis.

Variable	Innovation	Digital	Resilience	Fixed	Lec	BS	Indep	Share
Innovation	1.000							
Digital	0.344***	1.000						
Resilience	0.099***	0.182***	1.000					
Fixed	-0.123***	-0.256***	-0.141***	1.000				
Lev	0.310***	0.066***	0.004	0.138***	1.000			
BS	0.122***	-0.050***	0.012	0.102***	0.125***	1.000		
Indep	0.034***	0.014	0.004	-0.011	0.004	-0.482***	1.000	
Share	0.053***	-0.070***	-0.068***	0.050***	0.044***	0.005	0.053***	1.000

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 5. Measurement results of variance inflation factor.

Variable	VIF	1/VIF
BS	1.35	0.742885
Indep	1.32	0.759735
Fixed	1.12	0.894774
Digital	1.11	0.898620
Lev	1.05	0.950698
Resilience	1.05	0.953288
Share	1.01	0.985782
Mean VIF	1.14	

5.3. Analysis of Empirical Results

Table 6 shows the results of the basic regression analysis in this paper. Model (1) in **Table 6** is the test result of the impact of digital transformation on enterprise innovation performance. It can be seen from the table that the regression coefficient of digital transformation on enterprise innovation performance is 0.239, which is significant at the 1% level. Based on this, hypothesis 1 is verified, that is, digital transformation can effectively enhance enterprise innovation performance.

In this paper, when examining the intermediary effect of enterprise resilience, we refer to the “three-step method of intermediary effect test”. In Model (2) in **Table 6**, the coefficient of digital transformation is 0.0672, which is significant at the 1% level, indicating that enterprise digital transformation has a positive and

significant impact on enterprise resilience, and hypothesis 2 is validated. Model (3) is the test result of the impact of enterprise innovation performance on digital transformation and enterprise resilience. The regression coefficient of digital transformation is 0.208, and that of enterprise resilience is 0.466, which is significant at the 1% level. Compared with Model (1), when enterprise resilience is added to Model (3), the regression coefficient of digital transformation decreases slightly but is still significantly positive at the level of 1%. Hypothesis 3 verification is established. The regression results show that enterprise resilience plays a positive mediating role in the relationship between digital transformation and enterprise innovation performance.

Table 6. Results of basic regression.

Variable	Model (1)	Model (2)	Model (3)
	Innovation	Resilience	Innovation
Digital	0.239*** (21.22)	0.0672*** (28.46)	0.208*** (17.66)
Fixed	-0.982*** (-7.30)	-0.638*** (-22.65)	-0.684*** (-4.96)
Lev	0.442*** (4.97)	-0.194*** (-10.40)	0.532*** (5.97)
BS	0.0442*** (4.14)	0.00736** (3.28)	0.0408*** (3.83)
Indep	0.00314 (1.25)	0.00107* (2.02)	0.00265 (1.06)
Share	-0.00547*** (-3.90)	-0.00238*** (-8.09)	-0.00436** (-3.11)
Resilience			0.466*** (8.82)
_cons	3.054*** (16.97)	0.338*** (8.97)	2.896*** (16.09)
Industry and year	controlled	controlled	controlled
N	9108	9108	9108
R ²	0.0818	0.1848	0.0906
Bootstrap mediation effect test			
Intermediate effect size	0.391283***		
95% confidence interval	[0.3337728, 0.4487931]		
Sampling frequency	1000		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, In parentheses are t values adjusted for Robust standard error.

In order to ensure the stability of the intermediate mechanism, Bootstrap test is carried out on the basis of three-step test. The results of Bootstrap test show that the 95% confidence interval does not include 0, and the mediation effect is positive and significant at the 1% level. At the same time, the intermediate effect accounted for 58.69% of the total effect. Hypothesis 3 is tested again.

5.4. Robustness Test

1) Replace the explained variable

To ensure the robustness of the test results, this paper does natural logarithm processing after adding 1 to the number of patent grants and takes this as the substitute variable of enterprise innovation performance. The regression results are shown in **Table 7**. As shown in the table, although the significance of enterprise resilience has changed to some extent in Model (3), the result is still significant, so the conclusion is still valid.

Table 7. Alternate variable regression results.

Variable	Model (1)	Model (2)	Model (3)
	Innovation_1	Resilience	Innovation_1
Digital	0.151*** (12.31)	0.0672*** (28.46)	0.142*** (11.03)
Fixed	-0.745*** (-5.08)	-0.638*** (-22.65)	-0.658*** (-4.35)
Lev	0.261** (2.69)	-0.194*** (-10.40)	0.287** (2.95)
BS	0.0442*** (3.79)	0.00736** (3.28)	0.0432*** (3.71)
Indep	0.000741 (0.27)	0.00107* (2.02)	0.000595 (0.22)
Share	-0.0000650 (-0.04)	-0.00238*** (-8.09)	0.000260 (0.17)
Resilience			0.137* (2.36)
_cons	2.839*** (14.47)	0.338*** (8.97)	2.793*** (14.16)
Industry and year	controlled	controlled	controlled
N	9108	9108	9108
R ²	0.0291	0.1848	0.0298

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, In parentheses are t values adjusted for Robust standard error.

2) Change the sample selection scope

Considering the impact of external shocks on enterprise innovation performance and enterprise resilience during the study period, this paper excluded the sample data in 2015 and 2020 in order to avoid the impact of the stock market crash in 2015 and the COVID-19 epidemic in 2020. After the robustness test, the results did not change and the conclusion still holds (Table 8).

Table 8. Regression results of changing sample selection range.

Variable	Model (1)	Model (2)	Model (3)
	Innovation	Resilience	Innovation
Digital	0.198*** (15.25)	0.0678*** (24.59)	0.176*** (12.95)
Fixed	-0.882*** (-5.67)	-0.622*** (-18.82)	-0.679*** (-4.26)
Lev	0.414*** (4.04)	-0.205*** (-9.41)	0.481*** (4.67)
BS	0.0462*** (3.80)	0.00762** (2.94)	0.0437*** (3.60)
Indep	0.00516 (1.79)	0.00153* (2.50)	0.00466 (1.62)
Share	-0.00517** (-3.21)	-0.00212*** (-6.17)	-0.00448** (-2.78)
Resilience			0.325*** (5.40)
_cons	3.026*** (14.70)	0.317*** (7.25)	2.922*** (14.17)
Industry and year	controlled	controlled	controlled
N	7084	7084	7084
R ²	0.0620	0.1789	0.0665

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, In parentheses are t values adjusted for Robust standard error.

5.5. Lag Effect and Heterogeneity Test

1) Consider Hysteresis Effect

Considering the complexity and long-term nature of digital transformation, the uncertainty and complexity in the process of innovation research and development, and the change of market acceptance, the impact of digital transformation on the innovation performance of enterprises may have a lagging effect. There-

fore, this paper considers the digital transformation of manufacturing enterprises as a lagging third-order treatment, and the results are shown in **Table 9**. As can be seen from Model (2), Model (3) and Model (4) in **Table 9**, enterprise digital transformation can still promote the improvement of enterprise innovation performance with a lag of one and two periods, and the regression coefficients are 0.0967 and 0.0663 respectively, both of which are significant at 1% level. The conclusion is still valid.

Table 9. Considers the regression results of hysteresis effect.

Variable	Model (1)	Model (2)	Model (3)	Model (4)
	Innovation	Innovation	Innovation	Innovation
Digital	0.239*** (21.22)	0.132*** (8.84)	0.0896*** (6.14)	0.0404* (2.49)
Fixed	-0.982*** (-7.30)	-0.813*** (-5.56)	-0.580*** (-3.60)	-0.388* (-2.11)
Lev	0.442*** (4.97)	0.327*** (3.37)	0.303** (2.81)	0.277* (2.20)
BS	0.0442*** (4.14)	0.0418*** (3.69)	0.0395** (3.27)	0.0311* (2.34)
Indep	0.00314 (1.25)	0.00182 (0.69)	0.00334 (1.21)	0.00361 (1.21)
Share	-0.00547*** (-3.90)	-0.000355 (-0.22)	0.00130 (0.73)	0.00509* (2.44)
L. Digital		0.0967*** (6.81)		
L2. Digital			0.0663*** (4.96)	
L3. Digital				0.00314 (0.22)
Industry and year	controlled	controlled	controlled	controlled
_cons	3.054*** (16.97)	3.049*** (15.84)	3.154*** (15.28)	3.383*** (14.82)
N	9108	8096	7084	6072
R ²	0.0818	0.0527	0.0226	0.0055

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, In parentheses are t values adjusted for Robust standard error.

2) Heterogeneity of Firm Size

The size of an enterprise will affect its overall development and innovation output by influencing its economic strength and the degree of policy support. Based on this, this paper divides enterprise size into total assets and tries to explore the heterogeneity of enterprise size. In this paper, group regressions are conducted by dividing enterprises into two groups, small and medium-sized enterprises (SMEs) and large enterprises (LSEs), based on the mean value of the size of the enterprises. The results are shown in the first two columns of **Table 10**. As shown in the table, whether it is small and medium-sized enterprises or large enterprises, digital transformation has a positive and significant impact on enterprise innovation performance. Among them, the regression coefficient of small and medium-sized enterprise group is 0.197, and that of large enterprise group is 0.210, both of which are significant at 1% level.

Table 10. Results of heterogeneity analysis.

Variable	SMEs	LSEs	Growth	Maturity
	Innovation	Innovation	Innovation	Innovation
Digital	0.197*** (11.53)	0.210*** (13.34)	0.243*** (14.42)	0.208*** (12.68)
Fixed	-0.755*** (-3.87)	-0.852*** (-4.16)	-0.812*** (-4.39)	-1.028*** (-4.87)
Lev	0.572*** (4.58)	-0.242 (-1.64)	0.905*** (7.70)	-0.335* (-2.20)
BS	0.0359* (2.19)	0.0454** (3.22)	0.031 (1.96)	0.068*** (4.40)
Indep	-0.00038 (-0.10)	0.00634 (1.85)	0.00189 (0.50)	0.00693* (1.98)
Share	-0.00834*** (-3.73)	-0.00328 (-1.59)	-0.00927*** (-4.65)	-0.00248 (1.13)
Industry and year	controlled	controlled	controlled	controlled
_cons	2.784*** (10.55)	3.792*** (14.96)	2.890*** (11.12)	3.148*** (11.71)
N	4554	4554	4895	4213
R ²	0.0680	0.0579	0.1050	0.0641

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, In parentheses are t values adjusted for Robust standard error.

The results show that no matter the size of the enterprise, digital transformation can effectively increase the innovation performance of the enterprise, and the pro-

motion effect of large enterprises is relatively obvious. The reasons may be as follows: 1) Large enterprises usually have stronger economic strength and can give adequate financial support in the process of digital transformation to promote their innovation performance. 2) Large enterprises are more able to attract and retain more high-quality comprehensive talents. On the one hand, their professional skills can effectively promote enterprise innovation; on the other hand, their educational background and experience can make them willing to accept innovation and pay for it. At the same time, it is easier to form an atmosphere of teamwork and knowledge sharing to further improve innovation performance. 3) Due to the large scale of production, large enterprises can obtain more investment, greater policy support and better service, etc., which can help enterprises digital transformation and improve their innovation performance. 4) Large enterprises generally have more clear and long-term strategic goals and plans. In the process of digital transformation, large enterprises can gradually promote the transformation work according to their own needs, and long-term goals and plans can help large enterprises accumulate experience and resources in the transformation process, and ultimately improve their innovation performance.

3) Heterogeneity of Enterprise Lifecycle

According to existing research, enterprises at different stages of development have different strategies and objectives, and the enterprise life cycle will affect the innovation behavior of enterprises to a certain extent. With reference to existing studies, this paper divides enterprises into two stages: growth stage and maturity stage according to age, namely, growth stage with age less than 12 and maturity stage with age greater than or equal to 12, so as to explore the impact of digital transformation on enterprise innovation performance in different development stages. The results are shown in the last two columns of **Table 10**.

As can be seen from the table, whether the enterprise is in growth or maturity, its digital transformation can positively and significantly promote the innovation performance of the enterprise. Specifically, the regression coefficient of enterprises in the growth is 0.243, and that of enterprises in maturity is 0.208, both of which are significant at the level of 1%. The results suggest that digital transformation is effectively in promoting the growth of innovation performance in both growing and mature enterprise, but the promotion effect is more pronounced in growing enterprise. The reasons may be as follows: 1) Compared with mature enterprises, enterprises in the growth stage usually face the pressure of rapid expansion and market share, and their innovation willingness is stronger. Digital transformation can provide technological breakthroughs for growth-stage enterprises, enabling them to adapt to market changes more quickly and meet market demand, thus promoting the improvement of their innovation performance. 2) Compared with mature enterprises, the organizational structure of growing enterprises is relatively flexible, and it is easier to accept and adapt to the needs of innovation, so that enterprises can adjust the strategic direction faster in the process of digital transformation, optimize the allocation of resources, promote innovation output,

and improve innovation performance; 3) Although the business scale of growing enterprises is relatively small, the growth potential is huge. Therefore, in the case of limited resources, enterprises usually concentrate resources on key areas such as digital transformation, and then rely on concentrated investment, which can promote the innovation ability of enterprises and improve the innovation performance; 4) The organizational culture of mature enterprises is more stable than that of growth-stage enterprises, and the way of dealing with innovation is relatively conservative, while the growth-stage enterprises pay more attention to the cultivation of innovative culture, encourage employees' innovative thinking, and provide necessary support, which can better stimulate employees' innovative spirit and creativity, and promote the improvement of innovation performance.

6. Conclusion and Policy Recommendations

6.1. Research Conclusion

Based on the data of China's manufacturing A-share listed enterprises from 2014 to 2022, this paper investigates the relationship between enterprise digital transformation and enterprise innovation performance, and explores the mediating effect of enterprise resilience. The main conclusions are as follows: 1) Digital transformation can effectively improve enterprise innovation performance, and the conclusion is still valid after robustness test and hysteresis effect test; 2) Digital transformation can effectively enhance the resilience of enterprises and promote the improvement of enterprise innovation performance; 3) Digital transformation plays a more significant role in promoting the innovation performance of large enterprises, and digital transformation is more effective in improving the output of innovation performance of enterprises in the growth.

6.2. Policy Recommendations

Based on the above conclusions, the following insights are obtained:

1) The state and government should provide strong support for the digital transformation of manufacturing enterprises. The state should further consolidate the digital infrastructure, and formulate a differentiated transformation path for the industry. The government should provide sufficient funds, policies and technical support to help cultivate interdisciplinary talents. Meanwhile, the overall environment should be optimized to reduce resistance to digital transformation. For enterprises of different sizes and in different life cycles, the state and government should take personalized measures according to the characteristics of different types of enterprises, and focus on helping large enterprises and growing enterprises to explore their correct transformation path, promote the output of enterprise innovation performance, and achieve high-quality development of enterprises.

2) Enterprises should develop appropriate strategies to further advance digital transformation. On the one hand, enterprises need to establish long-term development concepts and break information barriers. They should not affect the dig-

ital transformation process of enterprises due to temporary fluctuations in innovation performance and strengthen the construction of enterprise resilience from the four aspects of defense ability, resistance ability, recovery ability and growth ability. On the other hand, in the process of digital transformation, enterprises should accurately position the goals and paths of transformation, promote it in stages, and avoid blindly following the strategy of transformation. At the same time, enterprises need to fully combine internal and external resources, strengthen cooperation with upstream and downstream enterprises, provide strong support for digital transformation, and ensure the practicality of digital transformation.

3) Enterprises should strengthen their own strength and accurately innovate the performance evaluation mechanism. In order to effectively implement digital transformation, manufacturing enterprises should actively cultivate composite talents and enhance the comprehensive quality and innovation ability of employees. Meanwhile, enterprises need to introduce high-end talents with rich experience and strong professional skills in a timely manner. On the one hand, they can help enterprises establish an effective talent incentive mechanism and help the long-term development of enterprises. On the other hand, they can provide intellectual support for digital transformation, effectively lead enterprises to promote digital transformation and promote the output of innovative performance. In addition, enterprises should establish a multi-dimensional dynamic monitoring mechanism for innovation performance, timely adjust transformation strategies and resource allocation according to the test results, and achieve long-term high-quality sustainable development of enterprises through continuous optimization strategies and adjustment of investment.

6.3. Shortcomings and Prospects

This paper has the following shortcomings: First, the selected research data are all from the China Stock Market & Accounting Research Database (CSMAR). It lacked first-hand data and was limited to manufacturing enterprises, which limits the depth of research. In the future, the research could conduct field investigations and develop industry-specific studies. Secondly, this paper only studies the impact of digital transformation on enterprise innovation performance, as well as the mediating mechanism of enterprise resilience. The research path and mechanism need to be further expanded, and in the future, the research perspective can be broadened to investigate more path mechanisms.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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