Digital Transformation and Innovation Performance: the Mediating Roles of Open Innovation and Absorptive Capacity

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Abstract. Digital transformation promotes the cross-organizational flow of knowledge to provide a new impetus and a new engine for corporate innovation. This study uses dynamic capability theory to demonstrate the intrinsic linkages between digital transformation, open innovation, absorptive capacity and innovation performance. The study utilizes data from Chinese A-share listed manufacturing enterprises from 2016 to 2022. The results show that there is a significant positive correlation between digital transformation and enterprise innovation performance, and the results are still valid after robustness test. The findings of the mediating mechanism indicate that digital transformation can facilitate open innovation activities and enhance the absorptive capacity of enterprises, which leads to improved innovation performance. Starting from the knowledge flow perspective, this paper provides essential theoretical and empirical support for clarifying the mechanism of digital transformation in manufacturing and its impact on innovation performance. The study has significant implications for the long-term development of China's manufacturing industry in the digital economy environment.

Keywords: digital transformation; open innovation; absorptive capacity; innovation performance;

1 INTRODUCTION

In light of the current rapid expansion of the global digital economy, China's digital economy has entered a new stage of growth. According to the Digital China Development Report (2022), China's digital economy expected to total 50.2 trillion yuan by 2022, accounting for 41.5% of the GDP [1]. The digital economy, with digital technology as its core driver, has greatly contributed to the advancement of productivity [2]. To adapt to the new economic environment, many enterprises have started actively pursuing digital transformation to enhance their competitiveness and foster innovation.

The openness, availability, and integration of digital technologies, are reshaping the innovation model of enterprises, making knowledge flow between the external environment and the internal innovation activities of the company[3]. In the process of digital transformation, the widespread application of digital technology has strengthened

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the connection for open innovation between subjects of innovation. Enterprises utilize open innovation for knowledge interoperability, which enhances their innovation capabilities [4]. At the same time, the knowledge absorption capacity of enterprises plays an important role in absorbing innovative resources[5], quickly identifying external knowledge and evaluating its effectiveness. However, few scholars have paid attention to the mechanism of open innovation and absorptive capacity's influence on innovation performance in the process of digital transformation, and there is a lack of relevant empirical tests.

Based on dynamic capability theory, this paper aims to explore the impact of digital transformation on the innovation performance and its internal mechanisms from the knowledge perspective. Manufacturing is critical to future high-quality economic development. Therefore, this study utilizes data from China's listed manufacturing businesses from 2016 to 2022. The paper makes some significant contributions: firstly, it enriches the existing research on the digital transformation of the manufacturing industry and suggests ways for China to become a manufacturing powerhouse and achieve high-quality development. Second, it broadens the scope of research the performance of enterprise innovation. It looks into how open innovation, specifically from the open innovation perspective, and absorptive capacity relate to the relationship between innovation performance and digital transformation.

2 THEORETICAL REVIEW AND RESEARCH HYPOTHESES

2.1 Digital Transformation and Innovation Performance

Digital transformation involves the strategic actions taken by enterprises to achieve digitalization across all aspects of production, management, and sales by adopting digital technologies such as artificial intelligence, blockchain, cloud computing, and big data [6]. The dynamic capability theory emphasizes that enterprises enhance their competitive advantage by continuously learning, adapting, and innovating in the face of constantly changing external environments. Digital transformation, through extensive data collection and in-depth analysis, it can help break down information barriers within and outside the enterprise, improving the information gap caused by the "digital divide" [7]. Additionally, it can promote cross-departmental and cross-geographical cooperation, thereby strengthening innovation collaboration. It reduces delays in decision-making and physical objects and improves the efficiency of innovation. It enables enterprises and external partners to engage in distributed, virtualized, and large-scale knowledge collision and interaction, thereby promoting innovation in interaction methods and strategic cooperation between enterprises [8]. Based on the above analysis, we propose hypothesis 1:

Digital transformation has a significant positive impact on innovation performance.

2.2 The Mediating Role of Open Innovation

Open innovation refers to the purposeful utilization and management of knowledge inflows and outflows [9] by firms to engage in innovation activities with external partners, customers, suppliers, academia, etc. In the digital era, enterprises utilize digital technology with the characteristics of openness, availability, generativity, convergence, and self-growth while undergoing digital transformation. It provides new support for enterprises to carry out open innovation activities across organizational boundaries [10]. Digital transformation also offers a wider range of platforms and tools for collaborative research and development (R&D). These include open innovation platforms and digital collaboration tools that enterprises utilize to integrate resources and enhance the efficiency of their services. In addition, digital transformation has changed the way which innovation occurs. With the support of digital technology, innovation sharing can be promoted, increasing the possibility of integrating different innovation elements and technologies among enterprises. This greatly enhances the ability of open innovation, facilitates the establishment of innovation networks between enterprises and external parties, and provides great convenience for conducting collaborative research and development [11]. Based on the above analysis, we propose hypothesis 2:

Digital transformation has a significant positive impact on open innovation.

Digital transformation helps reduce the information asymmetry of enterprises, thereby reducing the risks and costs associated with open innovation [12]. This can reduce the risk of innovation for enterprises and enhance their innovation performance. Under digital transformation, enterprises can establish a flat organizational structure and streamline their business processes using digital technology. This enables better resource integration and distribution. Furthermore, enterprises find it easier to innovate during the upgrading process due to the quick development and deployment of digital technologies. The improvement in operational efficiency allows enterprises to achieve greater output performance, even with the same resources. Based on the above analysis, we propose hypothesis 3:

Open innovation mediates the relationship between digital transformation and innovation performance.

2.3 The Mediating Role of Absorptive Capacity

Absorptive capacity, as a crucial component of dynamic capabilities, is an important innovative capability for organizations [13] . "Absorptive capacity" describes the capability to recognize, absorb, transform, and utilize valuable knowledge and technology both within and outside the organization[14]. Enterprises are supported in enhancing their absorption capacity by putting digital transformation into practice. Firstly, the adoption of cutting-edge digital technologies like big data and cloud computing, provides rapid access to a large amount of user data in a cost-effective and multi-dimensional manner. This improves resource allocation efficiency and enhances the ability of enterprises to absorb and integrate internal and external resources [15], [16]. Secondly, digital transformation can also help enterprises accurately acquire relevant resources and capabilities in dynamic environments, enabling accurate matching of resources and

capabilities. This, in turn, improves the efficiency of information processing and provides a material guarantee for enterprises to absorb and transform relevant information and knowledge. Therefore, we propose hypothesis 4:

Digital transformation has a significant positive impact on absorptive capacity.

Absorptive capacity, by integrating and generating new innovation resources and transforming them into part of the enterprise's future absorptive capacity [17] , can also accelerate the speed, frequency, and level of enterprise innovation, forming a virtuous cycle. This process also contributes to perfecting the enterprise's own innovation model. Enterprises with strong acquisition and absorptive capabilities may be better able to recognize external trends and internalize this information, which will enable them to update their knowledge stocks on a regular basis [18] . This gives them a first-mover advantage in new product development. They may also react promptly to market and consumer demands by fusing all facets of technology and customer information, which improves their innovation performance. Thus, we propose hypothesis 5:

Absorptive capacity mediates the relationship between digital transformation and innovation performance.

According to the above theoretical derivation and hypotheses, this paper develops the following research framework, as shown in Figure 1.

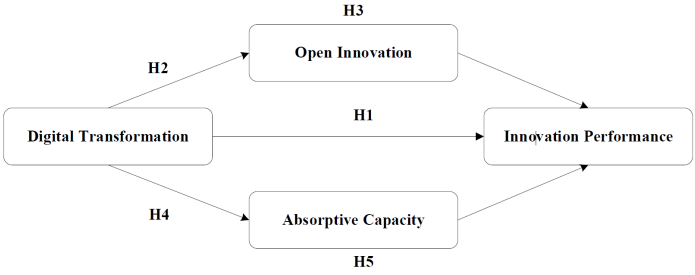

Fig. 1. Theoretical model

3 RESEARCH DESIGN

3.1 Sample Selection and Data Sources

The core of China's economy and the main driver of innovation is the manufacturing sector. This paper focuses on the period from 2016 to 2022 and examines the manufacturing companies listed on China's A-share market in Shanghai and Shenzhen as the research subject. The variable data mainly come from the CSMAR and CNRDS databases. During the data collation process, samples from ST companies and *ST companies with significant missing variable observations were excluded. As a result, 2623 observations were obtained. The main continuous variables in this research are shortened by 1% above and below to lessen the influence of extreme values. Finally, Stata 17.0 is the program used in this paper for statistical analysis and data processing.

3.2 Variable Description

Dependent Variable: Innovation Performance. The paper adopts the number of invention patents filed by listed enterprises in the year as a measure of innovation performance[19]. Considering the right-skewed distributional pattern of patent data and accounting for heteroskedasticity, the number of patent applications is logarithmically transformed by adding 1 to the count. This transformed count is then used as a measure of firms' innovation performance.

Independent Variable: Digital Transformation. This study measures the degree of digital transformation by adding 1 for logarithmic processing to word frequency data related to digital transformation [20] in the CMRDS database.

Mediating Variables. Open Innovation: we refer to the study conducted by Jiang [21] , which uses the logarithm of the number of authorized patents of joint innovation plus 1 as a proxy variable for open innovation.

Absorptive Capacity: The absorptive capacity is measured by calculating the ratio of the sample enterprise's annual R&D expenditures of the sample enterprise to its operating revenues[14].

Control Variables. In order to mitigate potential endogenous interference resulting from the omission of variables, this paper follows the practices of Wen[22] and Bai[23] and selects the following variables as control variables: (1) Firm Size (SIZE); (2) Profitability of Assets (ROA); (3) Asset-liability Ratio (LEV); (4) Total Asset Turnover (TAT); (5) Age of Firm (AGE); (6) Equity Concentration (TOP10); (7) Nature of Ownership (SOE).

3.3 Model Construction

This paper constructs Model 1 to Model 6 to test hypotheses:

$$IP_{i,t+1} = \alpha_0 + \alpha_1 DT_{it} + \varepsilon_{it} \tag{1}$$

$$IP_{i,t+1} = \beta_0 + \beta_1 DT_{it} + \beta_2 SIZE_{it} + \beta_3 ROA_{it} + \beta_4 LEV_{it} + \beta_5 TAT_{it} + \beta_6 TOP10_{it} + \beta_7 AGE_{it} + \beta_8 SOE_{it} + \sum Indus + \sum Year + \varepsilon_{it} \tag{2}$$

$$OI_{it} = \gamma_0 + \gamma_1 DT_{it} + \gamma_2 SIZE_{it} + \gamma_3 ROA_{it} + \gamma_4 LEV_{it} + \gamma_5 TAT_{it} + \gamma_6 TOP10_{it} + \gamma_7 AGE_{it} + \gamma_8 SOE_{it} + \sum Indus + + \sum Year + \varepsilon_{it} \tag{3}$$

$$IP_{i,t+1} = \delta_0 + \delta_1 DT_{it} + \delta_2 OI_{it} + \delta_3 SIZE_{it} + \delta_4 ROA_{it} + \delta_5 LEV_{it} + \delta_6 TAT_{it} + \delta_7 TOP10_{it} + \delta_8 AGE_{it} + \delta_9 SOE_{it} + \sum Indus + \sum Year + \varepsilon_{it} \tag{4}$$

$$AC_{it} = \zeta_0 + \zeta_1 DT_{it} + \zeta_2 SIZE_{it} + \zeta_3 ROA_{it} + \zeta_4 LEV_{it} + \zeta_5 TAT_{it} + \zeta_6 TOP10_{it} + \zeta_7 AGE_{it} + \zeta_8 SOE_{it} + \sum Indus + \sum Year + \varepsilon_{it} \tag{5}$$

$$IP_{i,t+1} = \eta_0 + \eta_1 DT_{it} + \eta_2 OI_{it} + \eta_3 SIZE_{it} + \eta_4 ROA_{it} + \eta_5 LEV_{it} + \eta_6 TAT_{it} + \eta_7 TOP10_{it} + \eta_8 AGE_{it} + \eta_9 SOE_{it} + \sum Indus + \sum Year + \varepsilon_{it} \quad (6)$$

i stands for listed companies, t stands for statistical year, IP stands for the explanatory variable innovation performance; DT stands for the explanatory variable digital transformation; OI and AC stand for the mediator variables open innovation and absorptive capacity, respectively; SIZE, ROA, LEV, TAT, TOP10, AGE, and SOE are the control variables. In order to control for the potential effects of industry and time factors, this paper controls for the dummy variables of time (Year) and industry (Industry) in the benchmark model; ε is a random perturbation term; and α, β, γ, δ, ζ, and η are regression coefficients of the corresponding variables, respectively.

4 EMPIRICAL ANALYSIS

4.1 Descriptive Statistics and Correlation Analysis

The results of the covariance test, correlation analysis, and descriptive statistics performed on the variables are shown in Table 1. The findings indicate that innovation performance and digital transformation have a strong and positive link (β = 0.217, p<0.01), which aligns with Hypothesis 1 and provides supporting for the study's main premise Additionally, the key variables, including digital transformation, innovation performance, and open innovation, are all significantly correlated with each other at the 1% level. Moreover, all variables have Variance Inflation Factors (VIF) less than 5, which suggests that there are no significant problems with multicollinearity. These results provide a solid foundation for further hypothesis testing.

Table 1. Results of descriptive statistics and correlation analyses

	MEAN	SD	1	2	3	4	5	6	7	8	9	10	11	VIF
IP	2.49	1.55	1.00											
DT	1.85	1.37	0.22***	1.00										1.17
OI	2.66	1.45	0.38***	0.20***	1.00									1.27
AC	5.10	3.74	0.01	0.30***	-0.01	1.00								1.40
SIZE	22.83	1.24	0.46***	0.03*	0.41***	-0.26***	1.00							1.90
ROA	0.05	0.06	0.10***	-0.09***	-0.02	-0.15***	0.070***	1.00						1.40
LEV	0.44	0.18	0.25***	0.07***	0.19***	-0.24***	0.53***	-0.340***	1.00					1.88
TAT	0.64	0.35	0.15***	-0.09***	0.01	-0.40***	0.22***	0.23***	0.18***	1.00				1.28
TOP10	55.82	14.12	0.08***	-0.10***	0.05**	-0.11***	0.20***	0.22***	-0.03*	0.12***	1.00			1.11
AGE	-	-	0.07***	-0.01	0.12***	-0.140***	0.20***	-0.03*	0.17***	0.10***	-0.02	1.00		1.10
SOE	-	-	0.18***	-0.07***	0.10***	-0.15***	0.32***	-0.09***	0.29***	0.12***	0.07***	0.24***	1.00	1.20

4.2 Benchmark Regression and Robustness Test

The benchmark regression results are presented in Table 2. The regression findings of innovation performance and digital transformation are shown in columns 1-2. At the 1% level of significance, the regression coefficients of the two models are 0.245 and 0.256. It suggests that innovation performance and digital transformation have a strong positive association. Thus, hypothesis 1 was verified. This research investigates whether digital transformation provides organizations with a sustained competitive advantage, taking into account the time lag impact. Column 3 represents the results of innovation performance lagged for two periods, while column 4 represents the results of innovation performance lagged for three periods. The robustness of the findings in this research is demonstrated by the main impacts being determined to be significant at the 1% level.

Considering that mutual causation and sample self-selection may have an impact on both the independent and dependent variables. For additional testing, the Heckman two-step approach is employed in this paper. The regression results are presented in column 5 of Table 1. Heckman's two-step regression analysis reveals that the regression coefficient for enterprise digital transformation (DT) is 0.293. Even after taking sample selection bias into account, this coefficient has passed the significance test at the 1% level, suggesting that digital transformation can considerably improve enterprise performance.

Table 2. Results of the benchmark regressions

	IP (1)	**IP (2)**	**IP(t+2) (3)**	**IP(t+3) (4)**	**IP (5)**
DT	.245***(.022)	.256***(.019)	.25***(.025)	.231***(.033)	.293***(.030)
IMR					2.596***(.422)
SIZE		.526***(.027)	.583***(.035)	.619***(.044)	.585***(.032)
ROA		2.397***(.475)	.897(.621)	-.427(.809)	2.487***(.559)
LEV		.252(.195)	.1(.256)	.03(.333)	.158(.233)
TAT		.212***(.079)	.191*(.106)	-.035(.138)	.374***(.098)
TOP10		-.003(.002)	-.005*(.003)	-.005*(.003)	-.004**(.002)
AGE		.001(.005)	0(.007)	-.001(.009)	.003(.006)
SOE		.182***(.058)	.145*(.074)	.041(.096)	.071(.069)
Indus	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES
Cons	2.036***(.05)	-10.053***(.552)	-11.093***(.711)	-11.54***(.912)	-12.781***(.685)
Obs	2623	2623	1528	916	1980
R^2	.047	.292	.304	.298	.296

*** p<.01, ** p<.05, * p<.1

4.3 Mediating Effects Tests

This study uses the stepwise regression approach for regression analysis in order to investigate the mediating roles of open innovation and absorptive ability in digital

transformation on innovation performance. Table 3 shows the regression results. Column 1 in Table 3 reveals that the regression coefficient between open innovation and digital transformation is 0.192, indicating statistical significance at the 1% level. It implies that open innovation is significantly and favorably impacted by digital transformation, which supports H2. Column 2 examines open innovation's mediating function. The regression coefficient of open innovation sand innovation performance is 0.221, which is also significant at the 1% level. It indicates that open innovation can play a partially moderating function between digital transformation and innovation performance, playing a partial mediating role. Thus, Hypothesis 3 is supported. Column 3 and column 4 assess the absorptive capacity's mediating function. The correlation between digital transformation and absorptive capacity in column 3 is 0.732, indicating significance at the 1% level. This supports Hypothesis 4 by showing that digital transformation significantly improves absorptive capacity. The absorptive capacity and innovation performance regression coefficient in column (4) is 0.064, which is likewise significant at the 1% level. This implies that the relationship between digital transformation and innovation performance can be positively mediated by absorptive capacity.

Table 3. Results of the mediating effect test

	OI (1)	IP (2)	AC (3)	IP (4)
DT	.192***(.019)	.214***(.019)	.732***(.046)	.209***(.02)
OI		.221***(.019)		
AC				.064***(.008)
SIZE	.536***(.027)	.408***(.028)	-.248***(.065)	.542***(.027)
ROA	-.867*(.468)	2.588***(.464)	-7.203***(1.143)	2.859***(.473)
LEV	-.583***(.192)	.381**(.191)	-4.199***(.47)	.521***(.196)
TAT	-.213***(.078)	.259***(.078)	-3.015***(.191)	.405***(.082)
TOP10	-.001(.002)	-.003(.002)	-.003(.005)	-.003(.002)
AGE	.013**(.005)	-.002(.005)	-.057***(.013)	.005(.005)
SOE	-.072(.057)	.198***(.057)	-.057(.14)	.186***(.057)
id	YES	YES	YES	YES
year	YES	YES	YES	YES
cons	-9.662***(.544)	-7.918***(.57)	14.595***(1.329)	-10.989***(.557)
Obs	2623	2623	2623	2623
R^2	.218	.325	.295	.309

*** p<.01, ** p<.05, * p<.1

Table 4. The results of the mediating effect test of Bootstrap

	Coef.	Std.	Z	P>Z	[95%CI]
DT-OI-IP Indirect effect	0.041	0.006	7.230	0.000	[0.030,0.052]
DT-O-IP Direct effect	0.205	0.019	10.790	0.000	[0.168,0.242]
DT-AC-IP Indirect effect	0.044	0.007	6.070	0.000	[0.030,0.058]
DT-AC-IP Direct effect	0.202	0.021	9.630	0.000	[0.161,0.243]

Stepwise regression was the main technique used in the aforementioned study to investigate the mediating impact. However, this method is known for its lower precision in testing. Therefore, this paper draws on the research conducted by Wang [24] and utilizes the Bootstrap method to further examine the significance of the mediating role of open innovation and absorptive capacity in digital transformation on innovation capacity. The findings of this analysis are presented in Table 4. In the process of testing the mediating effect of open innovation, the 95% confidence interval of the indirect effect is (0.030, 0.052), and the direct effect is (0.168, 0.242). Neither of these intervals contains 0, which confirms the significance of the mediating effect of open innovation. Similarly, in the process of testing the mediating effect of absorptive capacity, the 95% confidence interval of the indirect effect is (0.030, 0.058), and the direct effect is (0.161, 0.243). None of these intervals contains 0, the importance of the absorptive capacity mediating impact is confirmed.

5 CONCLUSION AND IMPLICATIONS

The paper draws the following conclusions: Firstly, digital transformation can greatly enhance firms' innovation performance and will have a substantial positive impact in the next 2-3 years. Second, through these two channels—open innovation and improved firm absorptive capacity—digital transformation can favorably impact innovation performance.

Drawing from the aforementioned conclusions, this research proposes the subsequent management insights: First, digital transformation is an important opportunity that enterprises must face in the digital era. Enterprises need to continuously promote the construction of their own digital transformation, and in this way to strengthen data openness and sharing, effectively integrate resources, and create conditions for their own innovation capabilities. In addition, enterprises need to encourage the sharing of knowledge throughout departments and monitor the growth of open innovation initiatives. Finally, the role of absorptive capacity should be emphasized to promote the coordination of the enterprise's own absorptive capacity to digest, absorb and transform knowledge resources. It is crucial in encouraging manufacturing companies to innovate and, eventually, improving their performance in this area.

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