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Research on the Impact of Digital Transformation on Innovation in Specialized, Sophisticated, Refined, and Novel Enterprises

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Abstract: This paper takes A-share listed companies in Shanghai and Shenzhen from 2013 to 2023 as the research object, and deeply analyzes the impact mechanism between digital transformation and innovation in specialized, sophisticated, refined, and novel enterprises. The research conclusions show that digital transformation has a positive promoting effect on both innovation input and innovation performance of these enterprises. Mechanism test results indicate that digital transformation drives the input and output of innovation in specialized, sophisticated, refined, and novel enterprises mainly by acquiring external resources and improving governance capabilities[1]. The conclusions of this study help to gain a deeper understanding of the digital innovation-driven effect of specialized, sophisticated, refined, and novel enterprises and more comprehensively evaluate the implementation effect of digital transformation.

Keywords: Digital transformation; Specialized, sophisticated, refined, and novel enterprises; Innovation input; Innovation performance

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1. Introduction

In recent years, specialized, sophisticated, refined, and novel enterprises, as an important force in China's high-quality economic development, have received extensive attention. Characterized by professionalism, sophistication, distinctiveness, and innovation, they possess prominent innovation capabilities and competitive advantages, occupy a leading position in niche markets, and play a significant role in promoting industrial upgrading and technological innovation. By 2022, over 40,000 specialized, sophisticated, refined, and novel small and medium-sized enterprises have been cultivated, among which 4,762 are "little giant" enterprises. These enterprises have played an important role in filling domestic technological gaps and improving the industrial chain level[2].

Digital transformation brings new opportunities and challenges to the innovation of specialized, sophisticated, refined, and novel enterprises. It can activate the innovation vitality of small and medium-sized enterprises and enhance the competitiveness of China's industrial and innovation chains. The application of digital technologies can significantly improve enterprises' innovation efficiency and reduce innovation costs. Relying on digital transformation, small and

medium-sized enterprises can integrate existing resources, promote innovation through diversified technological channels, achieve differentiation and cost leadership via the Internet, improve innovation efficiency, reduce innovation risks, and facilitate knowledge sharing and collaborative innovation among enterprises, thereby enhancing the efficiency of the entire innovation ecosystem. Based on this, this paper takes China's A-share listed companies in Shanghai and Shenzhen from 2013 to 2023 as the research object to explore the impact mechanism of digital transformation on the innovation input and output of specialized, sophisticated, refined, and novel enterprises[3]. The main contributions of this paper are as follows: It links digital technology with long-term corporate behaviors, conducts analysis from two aspects—external innovation resource connections and internal governance capability improvement—based on agency theory, resource-based theory, and innovation theory, constructs a theoretical analysis model of digital transformation and enterprise innovation, and provides a new value utility testing approach and paradigm for evaluating the implementation effect of digital transformation through empirical tests.

2. Theoretical analysis and research hypotheses

From the perspective of external resource acquisition, digital transformation empowers enterprises through digital technologies, promoting the gradual conversion of massive data into information assets and digital resources. This process can not only expand the reserve scale of enterprises' innovation resources but also enhance their ability to explore and utilize these resources, ultimately injecting impetus into the improvement of innovation sustainability. Based on the signal transmission theory, "specialized, sophisticated, distinctive, and novel" small and medium-sized enterprises can convey positive signals to the capital market through digital transformation, such as responding to national policy orientations and attaching importance to data asset construction. This helps enhance their market reputation, attract investors' attention, and obtain high-quality capital support. At the same time, the national strategic support and policy dividends brought by digital transformation can effectively alleviate the financing difficulties of such enterprises, improve credit availability, and thereby promote them to increase investment in innovation[4]. From the framework of principal-agent theory, the strong data collection and analysis capabilities of digital transformation can strengthen the complementary effect between heterogeneous information, break down communication barriers between enterprises, and promote the formation of a collaborative innovation pattern and the accumulation of innovation resources. In addition, this capability also helps financial institutions obtain enterprise information in a low-cost and efficient manner, grasp their operating conditions and credit levels in real-time, thereby reducing information asymmetry between banks and enterprises, lowering financing thresholds, and reducing financing costs. With the dual guarantees of obtaining external innovation funds and accumulating innovation resources, the sustainable innovation development of specialized, sophisticated, distinctive, and novel enterprises have a more solid foundation.

In terms of internal governance capabilities, the application of digital technologies plays a positive role in improving the governance level of specialized, sophisticated, distinctive, and novel enterprises, thereby providing support for their innovation and development. At the organizational structure level, the characteristics of diversified data sharing promote the evolution of enterprise organizational forms towards decentralization, accelerate data circulation efficiency, significantly improve organizational operation efficiency, effectively reduce the degree of information asymmetry, and alleviate principal-agent problems. Through high-frequency and real-time information perception and interaction, managers can make innovation decisions that are in line with the goal of maximizing enterprise performance. At the strategic level, digital transformation promotes enterprise managers to change their ways of thinking, establish a data-centric strategic orientation, and then make adaptive adjustments to enterprise strategies, improving the efficiency and quality of innovation decisions[5]. Based on the construction of a "fault-tolerant mechanism", digital transformation creates a more transparent information environment for enterprise management, production, and operation through the mining and analysis of massive information by digital technologies. This environment not only helps shareholders objectively evaluate the innovation capabilities of management but also reduces management's concerns about innovation failures or short-term

performance fluctuations, thereby enhancing the willingness of both parties to participate in enterprise innovation activities and promoting enterprises to continuously increase investment in innovation[6]. Based on the above analysis, this paper puts forward the following hypotheses:

H1: Digital transformation can promote innovation input of specialized, sophisticated, distinctive, and novel enterprises.

H2: Digital transformation can improve innovation performance of specialized, sophisticated, distinctive, and novel enterprises.

3. Research design

3.1. Data sources and sample selection

This paper takes A-share listed companies in Shanghai and Shenzhen from 2013 to 2023 as the research objects, and analyzes the innovation effects brought by the digital transformation of specialized, sophisticated, distinctive and novel enterprises through empirical tests. Based on the list of specialized, sophisticated, distinctive and novel enterprises published by the Ministry of Industry and Information Technology and the list of specialized, sophisticated, distinctive and novel listed companies on the Qichacha website, the sample data were screened as follows: (1) Excluding ST, *ST financial companies; (2) Excluding samples with serious missing data and outliers. Finally, 737 enterprises and a total of 3593 samples were obtained. Relevant data are from corporate annual reports, incoPat patent database, CSMAR database and the website of the National Bureau of Statistics [7-8].

3.2. Variable definition

3.2.1. Digital transformation

Drawing on the research of Wu Fei, Zhao Chenyu and Zhen Hongxian, this paper uses Python and text analysis methods to mine the annual reports of listed companies, extract keywords related to digital transformation, and construct a digital transformation dictionary. The frequency of keywords in the report is counted, and the sum of the word frequencies plus 1 is taken as the logarithm to measure the level of enterprise digital transformation.

3.2.2. Innovation performance

Since the time of patent application is consistent with the time of innovation output, it is more scientific and reasonable to measure the innovation performance of specialized, sophisticated, distinctive and novel enterprises by the number of patent applications of enterprises in the current year, specifically calculated by the natural logarithm of the number of patent applications of enterprises in the current year plus 1.

3.2.3. Innovation input

Drawing on the research of Wang Liming et al., R&D funds and the number of R&D personnel are all manifestations of R&D input. Therefore, the proportion of enterprise R&D funds in main business income and the proportion of enterprise R&D personnel in the total number of employees are used to comprehensively measure the degree of innovation input.

3.2.4. Control variables

In order to prevent estimation bias caused by omitted variables, referring to existing studies, some variables that may affect the innovation input and output of specialized, sophisticated, distinctive and novel enterprises are selected as control variables, including company age (Age), return on assets (Roa), equity balance (Top1), asset-liability ratio (Lev), nature of equity (Soe), growth rate of total operating income (Growth), board size (Board), duality of chairman and general manager (DU), operating efficiency (Laz), etc. [9].

To verify the impact of digital transformation on the innovation input and output of specialized, sophisticated,

distinctive and novel enterprises, the following regression models are constructed:

$$Patent_{i,t}=\alpha_0+\alpha_1 DT_{i,t}+\alpha_2 Top1_{i,t}+\alpha_3 Age_{i,t}+\alpha_4 Roa_{i,t}+\alpha_5 Growth_{i,t}+\alpha_6 Lev_{i,t}+\alpha_7 Soe_{i,t}+\alpha_8 Board_{i,t}+\alpha_9 DU_{i,t}+\alpha_{10} Laz_{i,t}+\Sigma year+\Sigma Ind+\varepsilon \quad (1)$$

$$RD_{i,t}=\alpha_0+\alpha_1 DT_{i,t}+\alpha_2 Top1_{i,t}+\alpha_3 Age_{i,t}+\alpha_4 Roa_{i,t}+\alpha_5 Growth_{i,t}+\alpha_6 Lev_{i,t}+\alpha_7 Soe_{i,t}+\alpha_8 Board_{i,t}+\alpha_9 DU_{i,t}+\alpha_{10} Laz_{i,t}+\Sigma year+\Sigma Ind+\varepsilon \quad (2)$$

4. Empirical results and analysis

4.1. Descriptive statistics

In **Table 1**, the standard deviation of innovation performance is 1.172, with a mean value of 4.177, a maximum value of 6.594, and a minimum value of 0.693. For innovation input, the standard deviation is 0.197, the mean is 0.290, the maximum is 1.035, and the minimum is 0.0273. These figures indicate that there are significant differences in innovation input and output levels among specialized, sophisticated, distinctive, and novel enterprises. The mean value of digital transformation is 1.792, with a minimum of 0, a maximum of 5.561, and a standard deviation of 1.536, suggesting a large gap in the degree of digital transformation among specialized, sophisticated, distinctive, and novel enterprises [10-11].

Table 1. Descriptive Statistical Results of Main Variables

Variable	Sample Size	Mean	Standard Deviation	Minimum	Median	Maximum
Patent	3,593	4.177	1.172	0.693	4.277	6.594
RD	3,593	0.290	0.197	0.0273	0.230	1.035
DT	3,593	1.792	1.536	0	1.609	5.561
Age	3,593	2.910	0.277	2.197	2.944	3.497
Top1	3,593	30.86	13.03	8.330	29.13	67.08
Soe	3,593	0.110	0.313	0	0	1
Board	3,593	9.247	2.168	5	9	15
Growth	3,593	0.169	0.315	-0.483	0.125	1.498
DU	3,593	0.541	0.498	0	1	1
Laz	3,593	1.666	1.015	0.374	1.446	6.604
Lev	3,593	0.303	0.165	0.0424	0.276	0.736
Roa	3,593	0.0480	0.0603	-0.190	0.0501	0.210

4.2. Benchmark regression results

Table 2 presents the benchmark regression results of this paper. To verify the impact of digital transformation on the innovation input and output of specialized, sophisticated, distinctive, and novel enterprises, this paper adopts a progressive regression method. The explained variable in Columns (1) and (3) is innovation performance. Column (1) includes control variables and controls for year and industry fixed effects, with the coefficient of innovation performance being 0.0299, significant at the 10% level. Column (3) only includes the core explanatory variable without adding control variables or year and industry fixed effects, and the coefficient of innovation performance is 0.0414, significant at the 1% level. The explained variable in Columns (2) and (4) is innovation input. Column (2) includes control variables and controls for year and industry fixed effects, and the regression result of innovation input (RD) is 0.0194, significant at the 1% level. Column (4) only includes the core explanatory variable without adding control variables or year and industry fixed effects, and the regression result of innovation input (RD) is 0.0427, significant at the 1% level. From the regression results in Columns (1)

and (2), it can be concluded that enterprise digital transformation has a positive promoting effect on the innovation input and innovation performance of specialized, sophisticated, distinctive, and novel enterprises[12-13] . Based on this, Hypotheses H1 and H2 of this paper are verified.

Table 2. Enterprise Digital Transformation and Innovation of Specialized, Sophisticated, Distinctive, and Novel Enterprises

	(1)	(2)	(3)	(4)
	Patent	**RD**	**Patent**	**RD**
DT	0.0299*	0.0194***	0.0414***	0.0427***
	(1.82)	(5.56)	(2.72)	(10.27)
Control Variables	Controlled	Controlled	No	No
Industry	Yes	Yes	No	No
Year	Yes	Yes	No	No
N	3593	3593	3593	3593
Adjusted R2	0.2584	0.2744	0.0043	0.1034

Note: ***,**,* indicate significance at the 1%, 5%, and 10% levels, respectively; the values in parentheses are t-values adjusted for robustness.

4.3. Robustness tests

4.3.1. Replacement of the explained variable

Specialized, sophisticated, distinctive, and novel enterprises pay more attention to the innovativeness of patents to maintain their "leading" market position. To test the robustness of the research conclusions, this study refers to the method of Zhou Donghua et al., replacing the explained variable "innovation performance" with the number of invention patent applications. The number of invention patent applications is added by 1 and then calculated by taking the logarithm. The study finds that the research conclusions remain robust after replacing the explained variable.

4.3.2. Replacement of the econometric model

Considering that there are many zero values in the number of enterprise patent applications, the explained variable "innovation performance" belongs to censored data with a left limit point of 0, which may have the characteristic of left-censoring. Based on this, this study draws on the method of Lennox et al. and uses the Tobit model for regression analysis. The study finds that the results are basically consistent with the benchmark regression results, which proves the robustness of the research results [14].

5. Conclusions and implications

Against the background of the deep integration of the real economy and the digital economy, exploring the path of digital technology empowering enterprise innovation is an urgent issue for specialized, sophisticated, distinctive, and novel enterprises. Based on this, this paper uses the data of A-share listed companies in Shanghai and Shenzhen from 2013 to 2023 to empirically test the impact of digital transformation on the innovation input and performance of specialized, sophisticated, distinctive, and novel enterprises, and draws the following conclusions: Digital transformation significantly promotes the innovation input and innovation performance of specialized, sophisticated, distinctive, and novel enterprises. This conclusion plays a demonstration role for specialized, sophisticated, distinctive, and novel enterprises in realizing digital transformation and is conducive to enhancing their innovation vitality [15]. In addition, the Chinese government should adopt policies to actively promote specialized, sophisticated, distinctive, and novel enterprises to accelerate

the process of digital transformation, thereby stimulating their enthusiasm for improving the quality and quantity of innovation.

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