

The Impact of Digital Transformation on Enterprise Innovation

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Abstract. Against the backdrop of the booming development of the digital economy, digital transformation has become an inevitable trend for enterprises' development. As a core component of an enterprise's core competitiveness, innovation plays a pivotal role in its sustainable development. However, relevant research on digital transformation and enterprise innovation remains scarce at present. Therefore, this study adopts an empirical research method to explore the impact of digital transformation on enterprise innovation based on the theories of information asymmetry and dynamic capabilities. In addition, variables such as internal control and financing constraints are incorporated into the research scope to examine their mediating roles between the two. The study concludes that digital transformation exerts a positive promotional effect on enterprise innovation. Meanwhile, internal control and financing constraints act as intermediary variables in this influence path. The findings of this study provide certain reference for enterprises to carry out digital transformation, and also offer theoretical support for the formulation of government policies.

Keywords: digital transformation; Innovation; internal controls; Financing constraints.

1. Introduction

The innovation-driven development strategy plays a crucial role in the quality improvement and upgrading of China's economy. The enhancement of enterprises' innovation capability is not only an inevitable requirement for the improvement of comprehensive national strength, but also an urgent need for current economic development[1][2]. With the rapid iteration of emerging technologies such as artificial intelligence (AI) and 5G, innovation remains the core driving force for economic growth and social progress. Against the backdrop of "Big Data, Artificial Intelligence, Mobile Internet, and Cloud Computing", the driving advantage of digital transformation has become increasingly prominent, and it has become an inevitable choice for traditional enterprises in the era of the digital economy[3]. The digital economy is a new economic form evolved on the basis of the Internet, while digital transformation is an important path to realize industrial upgrading supported by emerging technologies[4]. The vigorous development of the digital economy has created favorable conditions for enterprises' digital transformation[5]. Especially after the outbreak of the COVID-19 pandemic, the objective reality of restricted personnel mobility and group gatherings has further accelerated the application and popularization of digital technologies. Digital technologies can effectively solve problems such as geographical barriers and poor information flow, spawn more intelligent solutions, and have now gradually become a key factor determining the success or failure of enterprises. At present, the digital transformation of Chinese enterprises is still in its initial stage[6], and how to realize transformation and development with the help of digital technologies has become an urgent survival and development problem for various enterprises.

Rapidly improving innovation capability relying on the digital economy is the core grasp for enterprises to achieve high-quality development. Existing studies have confirmed that increasing investment in digital resources and technologies can promote the innovation of manufacturing enterprises[7]; with the continuous acceleration of the digitalization process, the penetration effect of technology on enterprise innovation has become increasingly in-depth, and modern information technologies and digital platforms have become important supports for enterprise innovation[8]. In the context of the digital economy, it has become an inevitable trend for enterprises to promote digital transformation. Only by conforming to the wave of market digital transformation can enterprises achieve continuous innovation and development. Therefore, how to further advance digital

transformation and enhance technological innovation capability has become an important issue in the process of implementing China's manufacturing power strategy.

As a core indicator to measure the value increment of enterprises after adopting new technologies, innovation performance can not only help enterprises clearly recognize their own independent innovation capability, but also provide a basis for them to clarify the key links affecting the innovation level, thereby ensuring the high-quality and sustainable development of enterprises. Due to the important significance of innovation performance for enterprises to create value rapidly, relevant research has become a hot topic in the business community and academic circles in recent years. However, existing research on the impact of digital transformation on enterprises' innovation capability is still relatively scarce, with divergent research conclusions. The impact effect between the two has not yet formed a consensus, and the internal mechanism of action needs to be further explored. Based on this, this study focuses on the mechanism of action of digital transformation of Chinese enterprises on technological innovation, constructs an index of digital transformation in the manufacturing industry, and quantitatively evaluates its impact effect through empirical research, aiming to provide a reference basis for the practice of enterprises' digital transformation and the formulation of relevant government policies.

2. Literature Review

2.1. Research on Digital Transformation

Affected by the differences in informatization levels and digital economy development among countries, foreign research on digital transformation (DT) began earlier than that in China. The concept of DT was first proposed in 1995, when Negroponte defined it as a digital reform carried out by enterprises in terms of means of production and relations of production. The digital economic environment provides support for DT. Mergel (2019) argued that DT accelerates resource sharing through digital information technology to reduce enterprise operating costs and enhance core competitiveness [10]. Jia Jingkun, Zhu Ying et al. (2022) put forward the viewpoint that DT promotes enterprise development through digital technologies. At present, there is no consensus on the definition of DT in existing research.

From a micro perspective, research on the outcomes of DT covers the following aspects. Du Chuanzhong and Zhang Yuan (2021) found that DT can play a positive role in enterprise productivity through economies of scale, economies of scope, technological innovation, and management efficiency [12]. Qi Huaijin et al. (2020) discovered that DT can reduce information asymmetry, thereby improving corporate governance [13]. Kleis et al. (2012) found that under a certain level of innovation, investment in information technology has a positive promoting effect on enterprise innovation. Current research on the impact of DT on enterprises mainly focuses on its influence on business models and enterprise value enhancement, and innovation is an important dimension of enterprise value.

With the development of the digital economy, research on DT evaluation indicators has gradually increased in recent years, but there is still no unified standard. Qi Huaijin (2020) used the proportion of digital economy-related items in intangible assets to measure the level of corporate digital economy. In 2021, the CSMAR Database launched the Listed Companies' Digitalization Database, which measures the degree of DT by capturing relevant texts on DT in listed companies' annual reports and calculating the frequency of keywords such as artificial intelligence technology and big data technology in the reports.

2.2. Research on Enterprise Innovation

The innovation theory was first proposed by Schumpeter (1912), who believed that innovation is the integration of new combinations of products, process technologies, materials and energy, markets, and organizational structures, and pointed out that innovation is a dynamic process. Innovation includes multi-dimensional content and is a complex and comprehensive production and operation

activity. It can bring more economic benefits and value to the company through innovation in products, technology, organization, systems, and business models.

Innovation is the main manifestation of an enterprise's core competitiveness. Among external influencing factors, Huang Can (2020) found through research that religion has a certain impact on enterprise innovation. Government behavior and the intensity of intellectual property protection also have an impact on it. Li Wenjing and Zheng Manni (2016) showed that the impact of government policies on innovation outcomes is more quantitative, and listed companies will carry out relevant innovation activities to obtain government support funds [16]. Existing research mainly explores the internal factors affecting enterprise innovation from the perspectives of internal control and financing constraints. Wang Yanan et al. (2019) found that internal control can promote enterprise innovation by narrowing information gaps and reducing agency conflicts [17]. Zhong Kai et al. (2015) believed that reducing corporate financing constraints and ensuring innovation investment have a positive impact on the company.

Enterprise innovation involves high risks and many influencing factors, so high-quality internal control is crucial for enterprise innovation. Innovation includes the entire dynamic process of innovation resource input, achievement R&D, and achievement marketization. In terms of innovation input, scholars such as Kang Zhiyong (2018) chose the proportion of R&D personnel in the total number of employees and the proportion of R&D expenses in operating income to measure the degree of innovation input [14]. However, due to the risks of innovation activities, this perspective may be one-sided. Tang Song et al. (2020) used the number of patent inventions to evaluate enterprise innovation output, believing that the number of patent inventions is a direct reflection of innovation results [15]. Regarding innovation efficiency, some scholars currently measure it from two dimensions: the number of patent applications and the number of granted patents.

2.3. Research on Internal Control

This study holds that internal control refers to an internal governance system established by all employees of an enterprise to achieve the reliability of financial reports, efficient operation of the enterprise, and realization of enterprise goals. It is also a process of continuously discovering and improving corporate governance loopholes.

Regarding the impact on enterprise innovation, the internal control promotion theory believes that internal control plays an important role in enterprise innovation. Cui Zhijuan (2011) proposed that when a company is willing to disclose internal control information, it indicates that the company has a high level of internal control and a high level of innovation investment [18]. Based on the perspective of inefficient investment, Fang Hongxing and Jin Yuna (2013) concluded that the more sound the internal control, the less invalid investment [19]. In addition, innovation activities require a large amount of capital investment, have a long time span, and are high-risk, so many managers avoid carrying out innovation activities. Sound internal control can reasonably regulate the behavior of enterprise managers. Eberhart (2008) also proposed that perfect internal control can effectively reduce agency costs and information asymmetry in enterprise innovation. Through empirical testing, Zhang Juan and Huang Zhizhong (2016) found that perfect internal control helps enterprise innovation projects adjust in a timely manner according to changes in the external environment and stimulate enterprise innovation vitality [20]. Wu Houtang (2016) believed that relatively perfect internal control can help enterprises expand financing channels, reduce the obstacles of financing constraints to innovation input, and ensure the normal conduct of innovation activities [21]. Wang Yunchen et al. (2015) found through research that a high level of internal control can reasonably allocate enterprise resources and reduce enterprise innovation risks [22].

In contrast, the "internal control paradox" holds that innovation itself is a process of continuous experimentation with uncertainty, and formulating relevant assessment standards will rigidify the enterprise's business thinking. Ni Juan (2020) supplemented the internal control paradox by pointing out that the essence of internal control is the system, and the restrictiveness of the system and the flexibility of innovation will generate contradictions [23].

2.4. Research on Financing Constraints

Fazzari et al. believed that financing constraints arise because the opportunity cost of a firm's internal capital is less than the cost of external financing, and the greater the difference between the two costs, the more likely the enterprise is to face financing constraints. Through sorting out existing literature, this paper finds that scholars at home and abroad generally believe that financing constraints are unfavorable to enterprise innovation. Regarding the influencing factors of financing constraints, existing research mainly focuses on macro and micro aspects.

At the macro level, regarding government subsidies alleviating financing constraints, Xie Weimin et al. (2009) believed that government subsidies can finance companies, thereby directly alleviating the problem of capital shortage [25]. In addition, Guo Yue (2018) showed in her research that government subsidies help enterprises send positive signals to the market to increase external investment [26]. Regarding industrial policies, the state can alleviate enterprise financing constraints by changing the macro environment faced by enterprises (Zhang Xinmin, Zhang Tingting, 2018), but it may also induce enterprises to carry out targeted innovation activities to enjoy policy preferences, which is not conducive to the development of innovation activities [27]. Regarding tax policies, tax reductions in tax policies can directly reduce corporate cash outflows and prevent enterprises from affecting innovation due to insufficient funds.

At the micro level, existing research believes that financing structure, listing status, and executive characteristics affect financing. Hu Hengqiang and Fan Conglai (2020) showed in their research that internal financing and equity financing can effectively promote enterprise innovation [28]. However, there is no consensus in existing literature on whether debt financing can effectively alleviate financing constraints. On the one hand, the listing status of enterprises can broaden financing channels, but on the other hand, it will also exacerbate agency problems and thus affect enterprise innovation. Regarding executives, Yu Yihua, Zhao Qifeng et al. (2018) believed that as decision-makers of enterprise innovation, executives' social resources can effectively alleviate financing pressure and play an important role in enterprise innovation [29].

2.5. Review of Research Trends

From previous research, it can be seen that enterprise innovation in the digital environment is a hot topic at present. However, there are few domestic and foreign studies on the relationship between DT and enterprise innovation. Most of the existing empirical papers conduct relevant research on innovation as part of enterprise performance. There are also few studies on the mechanism by which DT affects enterprise innovation. In addition, there is no unified standard for the measurement of DT and enterprise innovation.

Therefore, this study reviews the relevant literature on the relationship between DT and enterprise innovation, and selects Chinese listed companies as samples. Through empirical research, it explores the impact of DT on enterprise innovation. On this basis, combined with theories such as information asymmetry and dynamic capabilities, it introduces internal control and financing constraint variables to explore their impact mechanisms on DT and enterprise innovation.

3. Proposal of Research Hypotheses

3.1. Digital Transformation and Enterprise Innovation Capability

Ji Xiangxi (2021) argues that enterprise characteristics, corporate governance, and digitalization level are the main factors affecting enterprise innovation [33]. In the current context of the digital economy, digital transformation has become an inevitable choice for enterprise development. He Fan's (2019) research shows that enterprise digital transformation can effectively improve the level of innovation [34]. Combining existing research results, the driving effect of digital transformation on enterprise innovation can be analyzed from the following three aspects.

First, digital transformation affects enterprise innovation through the information effect. Fang Gang and Chang Ruihan (2021) point out that digital transformation helps enterprises mobilize knowledge resources. With the help of digital technologies, enterprises can timely obtain and transmit various types of information in the production and operation process, providing support for decision-makers at all levels to formulate more scientific and effective decisions [35]. Technologies such as big data can help enterprises accurately capture external environmental information, improve data analysis capabilities, thereby clarifying innovation directions and developing products and services more in line with market demand. At the same time, digital transformation improves the transparency of enterprise information through the application of digital technologies, helping stakeholders fully understand the business status of enterprises, enhancing their investment willingness, and thus injecting capital impetus into enterprise innovation.

Second, digital transformation affects innovation efficiency by acting on enterprise productivity. On the one hand, digital transformation realizes information sharing among various departments, which is conducive to stimulating the innovation motivation of all employees; on the other hand, digital transformation provides more advanced technical support for enterprise innovation activities, promoting the efficient and intelligent development of the innovation process, and thus promoting enterprise innovation. In addition, digital technologies can help enterprises rationally allocate limited resources and improve the efficiency of various production and operation links; at the same time, digital transformation will also promote enterprises to form an adaptive flat organizational structure, creating favorable conditions for the in-depth application of digital technologies in innovation.

Third, digital transformation helps enterprises improve their risk management and control capabilities. Enterprises implementing digital transformation send positive signals to the outside world and are more likely to obtain financial support from investors. At the same time, digital technologies can realize the transparency of enterprise information and processes, creating a good environment for improving the level of enterprise risk-taking. The higher the level of enterprise risk-taking, the more willing enterprises are to invest funds in high-return but high-risk innovation activities. In addition, enterprises can accurately predict the degree of consumer demand for products through digital technologies, reducing the risk of failure in the marketization stage of innovation results.

Based on the above analysis, this study proposes the following hypothesis.

H1: Digital transformation can promote enterprise innovation.

3.2. The Mechanism of Action of Internal Control

Digital transformation exerts an impact on enterprise internal control in multiple dimensions. Digital technologies help promote the reform of enterprise organizational structure, reduce the degree of information asymmetry, and thus alleviate principal-agent problems; by realizing information sharing in all links of production and operation, strengthen communication and collaboration among departments, and optimize the level of corporate governance; the information management system spawned by digital transformation can improve the security and transparency of information data, and strengthen the supervision of internal personnel of the enterprise; in addition, digital transformation enables enterprises to obtain information more comprehensively and timely, helping enterprises accurately predict and identify risks in the business process, and formulate efficient and intelligent risk response strategies through data analysis.

Innovation activities are characterized by high investment and high uncertainty. Affected by factors such as performance appraisal, many managers have short-sighted behaviors towards innovation activities. Internal control, however, can help enterprises establish a reasonable organizational structure and reduce the occurrence of principal-agent problems through scientific system arrangements. The good working atmosphere created by high-quality internal control is more likely to stimulate the innovation vitality of various organizational departments; at the same time, good internal control helps enterprises efficiently allocate resources, ensure the stability of innovation investment, and lay a solid foundation for enterprise innovation. In addition, innovation activities are

accompanied by extremely high risks. As the core risk management mechanism of enterprises, internal control can help enterprises timely detect and respond to various adverse factors in the innovation process, reducing risks to a controllable range; at the same time, good internal control can also help enterprises broaden financing channels and alleviate financing constraints. To sum up, internal control has a promoting effect on enterprise innovation.

Based on the above analysis, this study proposes the following hypothesis.

H2: Internal control is a channel through which digital transformation acts on enterprise innovation.

3.3. The Mechanism of Action of Financing Constraints

Existing literature generally agrees with the view that "financing constraints are unfavorable to enterprise innovation". Enterprise innovation itself is a high-risk and high-investment activity that has high demand for funds, so it is extremely vulnerable to the constraints of financing constraints. Digital transformation can alleviate enterprises' financing constraints in multiple aspects, thereby promoting enterprise innovation.

First, digital transformation can effectively alleviate the problem of information asymmetry and increase enterprises' external financing opportunities. In the current market environment, the problem of information asymmetry between internal and external enterprises is prominent, leading to the underutilization of resources and thus pushing up financing costs. Digital technologies can help enterprises efficiently obtain, process and transmit effective information, facilitating stakeholders to fully understand the development status of enterprises and thus make reasonable investment decisions. Second, in the digital context, digital technologies help enterprises improve resource allocation efficiency and management efficiency, and enhance corporate reputation; enterprises implementing digital transformation can improve the quality of annual report information disclosure, raise the level of enterprise value evaluation, and are more likely to obtain financial support from investors. Third, under the policy orientation of the country advocating enterprise digital development, Xiao Hongjun, Yang Zhen (2021) and others believe that digital transformation is conducive to promoting enterprises to fulfill their social responsibilities. Enterprises that actively respond to policy calls are more likely to obtain government subsidy support, thereby helping the development of innovation activities [36]; at the same time, government subsidies can send positive signals to the outside world, helping enterprises obtain more external investment opportunities. In addition, digital transformation can directly improve enterprise production efficiency, increase enterprise income, and ease capital pressure.

Based on the above analysis, this study proposes the following hypothesis.

H3: Financing constraints are a channel through which digital transformation acts on enterprise innovation.

4. Research Design

4.1. Sample Selection and Data Sources

The sample of this study is selected from the data of listed companies during 2013-2020. The samples are processed as follows: (1) Excluding samples from the financial industry. (2) Excluding samples of ST and PT companies. (3) Winsorizing variables at the 1% level.

The data of this study are mainly obtained from the CSMAR Database. The number of enterprise patent applications and authorizations is sourced from CNRDS. STATA 17 software is used for regression analysis.

4.2. Variable Definition

4.2.1 Dependent Variable

Existing research holds that patents are the most direct reflection of enterprise innovation achievements, and their data sources are more reliable. In this study, the natural logarithm of the

number of patent applications of listed companies in the current year plus 1 is taken to measure the innovation capability of enterprises.

4.2.2 Independent Variable

There is no unified standard for measuring digital transformation in existing research. This study selects the digital transformation index from the CSMAR Database to measure the degree of enterprise digital transformation.

4.2.3 Mediating Variable

(1) Internal Control. In China, most studies use the "five elements of internal control" and "internal control index" as evaluation indicators. Among these indicators, the internal control index of Dibo Company reflects more internal control content and is widely used by many scholars. This paper also adopts this index to measure enterprise internal control.

(2) Financing Constraints. There are two main methods to measure financing constraints: single-variable indicators and multi-variable indicators. This paper uses the commonly used KZ index to measure the financing level of enterprises.

4.2.4 Control Variables

Based on existing literature, this study controls for factors such as firm size, asset-liability ratio, return on assets, firm age, and cash flow.

Model Construction

To verify how digital transformation promotes enterprise innovation, we establish the following model:

$$\text{Patent1} = \beta_0 + \beta_1 \text{DT}_{it} + \beta_2 \text{Control}_{it} + \sum \text{Year} + \sum \text{Industry} + \varepsilon \quad (1)$$

To explore the mechanism of action of financing constraints and internal control between the two, the following models are constructed:

$$\text{M} = \beta_0 + \beta_1 \text{DT}_{it} + \beta_2 \text{Control}_{it} + \sum \text{Year} + \sum \text{Industry} + \varepsilon \quad (2)$$

$$\text{Patent1} = \alpha_0 + \alpha_1 \text{DT}_{it} + \alpha_2 \text{M} + \alpha_3 \text{Control}_{it} + \sum \text{Year} + \sum \text{Industry} + \varepsilon \quad (3)$$

Where M is the mediating variable, representing internal control and financing constraints. Other variables are consistent with those mentioned above.

5. Empirical Tests and Result Analysis

5.1. Descriptive Statistics

Descriptive statistics show that the mean value of enterprise digital transformation is 1.436, and the median is 1.099. This indicates that the current level of enterprise digitalization is unbalanced, and there are significant differences in digital transformation among different companies. The maximum value of enterprise innovation level is 7.184, and the minimum value is 0, which also shows that there are obvious differences in the innovation degree of different types of companies. In addition, as can be seen from the table1, the distribution of financing constraints and internal control among the sample enterprises is also unbalanced.

Table 1. Descriptive Analysis

Variable	Observations	Mean	Median	Minimum	Maximum
DT	21651	1.434	1.099	0	6.252
Patent1	21651	2.708	2.890	0	7.184
ICQ	21651	630.4	659.5	0	941.3
KZ	21651	0.860	1.120	-11.35	11.71
Size	21651	22.28	22.10	19.52	26.40
Lev	21651	0.428	0.419	0.0460	0.925
ROA	21651	0.0370	0.0360	-0.398	0.244
FirmAge	21651	2.925	2.944	1.792	3.555
Cashflow	21651	0.0480	0.0470	-0.196	0.257

5.2. Regression Analysis Results

5.2.1 Test of the Relationship between Digital Transformation and Enterprise Innovation

As shown in the table2, Column (1) presents the regression result without including control variables, which reveals a significant positive correlation between digital transformation and enterprise innovation. Column (2) reports the regression analysis of the model after adding control variables. The obtained regression coefficient is positive and significant at the 1% level. Thus, Hypothesis H1 is supported.

Table 2. Main Regression Test

Variables	(1) Patent1	(2) Patent1
DT	0.259*** (0.009)	0.136*** (0.008)
Size		0.633*** (0.009)
Lev		-0.186*** (0.056)
ROA		1.113*** (0.147)
FirmAge		-0.205*** (0.031)
Cashflow		0.255* (0.142)
_cons	2.611*** (0.102)	-10.312*** (0.212)
Year	Yes	Yes
Industry	Yes	Yes
N	21651	21651
r ² _a	0.325	0.489

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

5.2.2 Test of the Mechanism of Action of Financing Constraints and Internal Control

Table 3 presents the test results of the mechanisms of internal control and financing constraints. The results in Column (2) indicate that digitalization can improve the level of internal control, with a regression coefficient of 3.425, which is significant at the 1% level. Sound internal control can alleviate agency problems, stimulate organizational innovation motivation, and thereby promote enterprise innovation. It can be seen that digital transformation acts on internal control to drive enterprise innovation. Thus, Hypothesis H2 is supported.

Column (3) shows that digital transformation can effectively alleviate enterprise financing constraints. Its regression coefficient is negative and significant at the 1% level. Enterprise digital transformation can reduce information asymmetry and broaden financing channels. In addition, it can help enterprises better allocate resources and improve management efficiency. To sum up, Hypothesis H3 is verified, that is, digital transformation promotes enterprise innovation by alleviating financing constraints.

Table 3. Mechanism Test

Variables	(1) Patent1	(2) ICQ	(3) KZ
DT	0.136*** (0.008)	3.425*** (0.815)	-0.019** (0.008)
Size	0.633*** (0.009)	18.301*** (0.859)	-0.295*** (0.009)
Lev	-0.186*** (0.056)	-49.374*** (5.562)	6.365*** (0.058)
ROA	1.113*** (0.147)	757.967*** (14.565)	-6.902*** (0.151)
FirmAge	-0.205*** (0.031)	-20.327*** (3.072)	0.296*** (0.032)
Cashflow	0.255* (0.142)	-27.092* (14.017)	-15.186*** (0.146)
_cons	-10.312*** (0.212)	303.578*** (21.027)	4.399*** (0.219)
Year	Yes	Yes	Yes
Industry	Yes	Yes	Yes
N	21651	21651	21651
r ² _a	0.489	0.192	0.709

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

5.3. Robustness Test

5.3.1 Variable Substitution Method

In this regression, a new variable for measuring enterprise innovation is selected. The natural logarithm of the total number of granted invention patents, utility model patents, and design patents plus 1 is used to measure innovation. The regression results show that digital transformation and enterprise innovation still have a significant positive correlation at the 1% level.

Table 4. Robustness Test1

Variables	(1)	(2)
	Patent Award	Patent Award
DT	0.109*** (0.008)	0.121*** (0.008)
Size	0.402*** (0.010)	0.586*** (0.008)
Lev	-0.284*** (0.066)	-0.140*** (0.053)
ROA	0.930*** (0.179)	0.423*** (0.138)
FirmAge	-0.840*** (0.037)	-0.213*** (0.029)
Cashflow	0.054 (0.171)	0.374*** (0.133)
_cons	-4.167*** (0.224)	-9.541*** (0.199)
Year	Yes	Yes
Industry	Yes	Yes
N	21651	21651
r ² _a	0.116	0.494

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

5.3.2 Replacement of Regression Model

In the previous section, a fixed effects model was used for regression. To avoid result differences caused by model selection, this study adopts the OLS linear regression model and random effects model to conduct an empirical study on the relationship between digital transformation and enterprise innovation. As shown in Table5 below, the regression coefficients of digital transformation are all significantly positive at the 1% level. The above conclusion is confirmed again.

Table 5. Robustness Test2

Variables	OLS	fe	re
	Patent1	Patent1	Patent1
DT	0.136*** (0.008)	0.136*** (0.008)	0.136*** (0.008)
Size	0.633*** (0.009)	0.633*** (0.009)	0.633*** (0.009)
Lev	-0.186*** (0.056)	-0.186*** (0.056)	-0.186*** (0.056)
ROA	1.113*** (0.147)	1.113*** (0.147)	1.113*** (0.147)
FirmAge	-0.205*** (0.031)	-0.205*** (0.031)	-0.205*** (0.031)
Cashflow	0.255* (0.142)	0.255* (0.142)	0.255* (0.142)
_cons	-10.588*** (0.210)	-10.312*** (0.212)	-10.588*** (0.210)
Year	Yes	Yes	Yes
Industry	Yes	Yes	Yes
N	21651	21651	21651
r ² _a	0.509	0.489	

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

5.4. Heterogeneity Test

5.4.1 Grouping by Nature of Property Rights

Yuan Jianguo et al. (2016) argued that non-state-owned enterprises face greater competitive pressure and thus pay more attention to innovative development. In contrast, state-owned enterprises have a certain degree of institutional dependence and operational inertia, which is not conducive to enterprise innovation. Therefore, this section divides the sample into two groups according to the nature of property rights for discussion. As shown in the table below, whether for state-owned enterprises or non-state-owned enterprises, digital transformation has a very significant positive correlation with enterprise innovation. In addition, after conducting the inter-group coefficient difference test, it is found that digital transformation of state-owned enterprises has a stronger promoting effect on corporate innovation. Under the background of digital transformation, the emergence of new technologies puts forward higher requirements for talent training. It may be because state-owned enterprises have more digital talent resources and a larger number of high-quality talents than non-state-owned enterprises, so the impact of digitalization on enterprise innovation in state-owned enterprises is higher than that in non-state-owned enterprises.

Table 6. Property Rights Grouping Results

Variables	(1) Stata-owned Enterprise	(2) Non-stata-owned Enterprise
DT	0.147*** (0.015)	0.137*** (0.010)
Size	0.673*** (0.014)	0.574*** (0.012)
Lev	-0.479*** (0.098)	-0.070 (0.070)
ROA	0.980*** (0.321)	1.150*** (0.165)
FirmAge	-0.176*** (0.061)	-0.205*** (0.037)
Cashflow	-0.080 (0.243)	0.473*** (0.173)
_cons	-10.511*** (0.376)	-9.307*** (0.283)
Year	Yes	Yes
Industry	Yes	Yes
N	7678.000	13871.000
r ² _a	0.604	0.421

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

5.4.2 Regional Grouping

There are significant developmental differences between the eastern, central, and western regions of China, and the western region faces severe imbalances in digital infrastructure and digital development. Therefore, this study explores the impact on enterprises by dividing the sample into different regions. As shown in Table7, the impact of digital transformation on enterprise innovation is positive in all three regions (eastern, central, and western) and significant at the 1% level. In addition, the impact of digital transformation on enterprise innovation in the western region is higher than that in the central and eastern regions. The western region has great development potential. To alleviate the imbalance in digital economic development, the government and the market should work together to strengthen the construction of digital infrastructure in the western region, actively explore solutions, and promote enterprise innovation. This may be because the original digital construction

of enterprises in the western region is relatively weak, so advancing digital transformation has a more obvious promoting effect on innovation.

Table 7. Regional Grouping Regression Results

Variables	Eastern part Patent1	Central part Patent1	Western part Patent1
DT	0.133*** (0.009)	0.133*** (0.022)	0.177*** (0.025)
Size	0.639*** (0.010)	0.570*** (0.024)	0.652*** (0.024)
Lev	-0.102 (0.067)	-0.236 (0.144)	-0.252* (0.151)
ROA	1.067*** (0.170)	1.489*** (0.385)	1.028** (0.430)
FirmAge	-0.151*** (0.036)	-0.305*** (0.084)	-0.352*** (0.096)
Cashflow	0.483*** (0.166)	0.008 (0.359)	-0.512 (0.404)
_cons	-10.576*** (0.247)	-8.080*** (0.649)	-11.183*** (0.632)
Year	Yes	Yes	Yes
Industry	Yes	Yes	Yes
N	15283	3446	2920
r2	0.496	0.526	0.519
r2_a	0.493	0.516	0.506

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

6. Summary

With the continuous development of the digital economy, the digital transformation of enterprises has become an inevitability. Innovation is an important component of an enterprise's core competitiveness and is of great significance to the sustainable and high-quality development of enterprises. Therefore, this study takes the data of listed companies from 2013 to 2020 as samples to analyze the impact of digital transformation on enterprise innovation and the underlying mechanism. Adopting an empirical research method, this study explores the role of digital transformation in enterprise innovation under the frameworks of information asymmetry theory and dynamic capability theory. In addition, internal control and financing constraints are incorporated into the research scope to analyze their roles between digital transformation and enterprise innovation. The main research conclusions are as follows.

First, digital transformation can promote enterprise innovation. Firstly, with the use of digital technologies, enterprises can timely obtain and transmit various internal and external information, which helps decision-makers at all levels make more correct and effective decisions. It also helps stakeholders fully understand the enterprise, enhancing their willingness to invest, thereby driving corporate innovation. Secondly, digital transformation provides more advanced technical conditions for enterprise innovation activities, making them more efficient and intelligent. The productivity of enterprises is improved, thereby promoting innovation efficiency. Finally, digital transformation helps enterprises improve their risk management and control capabilities and reduce innovation risks. Companies undergoing digital transformation are more likely to send positive signals to the outside world, and investors are willing to provide funds for enterprise innovation. At the same time, enterprises can reasonably predict the degree of consumer demand for products through digital

technologies, reducing the possibility of innovation failure. This study conducted a robustness test on the conclusion by replacing the measurement method of variables, and finally obtained the same conclusion.

Second, internal control is a channel through which digital transformation acts on enterprise innovation. Digital transformation helps reduce the degree of information asymmetry, strengthen communication among various departments of the enterprise, and thereby optimize corporate governance. It enables enterprises to obtain more comprehensive and timely information, thereby accurately predicting and identifying operational risks and enhancing internal control. Internal control has a promoting effect on innovation. Sound internal control helps enterprises establish appropriate organizational structures and reduce the occurrence of principal-agent problems. At the same time, it helps enterprises broaden financing channels and reduce the impact of financing constraints on enterprise innovation. In addition, sound internal control assists enterprises in effectively allocating resources, ensuring innovation investment, and laying the foundation for enterprise innovation.

Third, financing constraints are a channel through which digital transformation acts on enterprise innovation. Digital transformation alleviates enterprises' financing pressure in multiple aspects to promote enterprise innovation. Firstly, digital transformation can reduce information asymmetry and increase external financing opportunities. Secondly, digital technologies help enterprises improve resource allocation efficiency and other aspects, enhancing corporate reputation. Enterprises undergoing digital transformation can improve the quality of annual report information disclosure, raise the level of enterprise value evaluation, and are more likely to obtain financial support from investors. Finally, under the national policy calling for enterprise digital development, digital transformation is conducive to promoting enterprises to fulfill their social responsibilities. Enterprises that actively respond are more likely to obtain increased government subsidies, thereby facilitating the development of innovation activities.

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