Digital Transformation and Innovation Investments

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Abstract. Digital transformation is a key factor in realizing innovative development and driving economic growth, driving companies to improve competitiveness, efficiency, and sustained growth. Innovation investment is an important source of funding for corporate innovation. Does digital transformation affect the tilt of corporate economic resources toward innovation investment projects? To answer the above question, this paper empirically examines the impact and mechanism of digital transformation on corporate innovation investment using a panel regression model with A-share listed companies in Shanghai and Shenzhen, China, from 2012 to 2022 as the initial research object. The study shows that the digital transformation of enterprises will increase the level of innovation investment, and this effect is realized by increasing the level of human capital, reducing surplus management, and lowering the level of cash holdings. The results of this research will provide strong support for enterprises to improve the motivation of innovation investment and innovation quality, help realize the goal of high-quality development of China's economy, and provide an important theoretical basis for relevant policy formulation and decision-making.

Keywords: Digital transformation; Investment in innovation; Human capital; Surplus management.

1. Introduction

In the digital era, digital technologies represented by big data, cloud computing, blockchain, artificial intelligence, and so on have become increasingly mature, promoting the accelerated development of the digital economy. The 19th CPC National Congress report puts forward the construction of digital China, the Fourth Plenary Session of the 19th Central Committee even recognized data as the seventh factor of production after labor, capital, land, knowledge, technology and management, and the "14th Five-Year Plan" for the development of the digital economy in 2022 explicitly pointed out that the digital economy is the main economic form following the agricultural economy and industrial economy. To cope with the new challenges of the new situation, grasp the new opportunities of digital development, expand the new space for economic development, and promote the healthy development of China's digital economy, we will continue to promote the development of China's digital economy in the future. General Secretary Xi Jinping emphasized in the report of the 20th Party Congress that it is necessary to strengthen the deep integration of enterprise-led industry, academia, and research, strengthen goal orientation, improve the transformation and industrialization of scientific and technological achievements, and promote the deep integration of the innovation industry chain and the capital chain and the talent chain, which points out the direction for a better play of the role of enterprises as the main force of innovation in the new era. "Achieving a high level of scientific and technological self-reliance and self-improvement, and entering the forefront of innovative countries" is one of the main goals of Chinese modernization. Thus, digital transformation and enterprise innovation have become an important capital market topic of common concern in both academic and practical circles.

Currently, the literature tends to interpret digital transformation as an extended concept rather than a single technology or process, such as the changes brought about by digital technology[1]. Regarding the economic consequences of digital transformation, most of them focus on corporate innovation[2], total factor productivity [3], business credit[4], and ESG performance [5]. Although domestic and international research on such studies has achieved some worthwhile results, there are relative shortcomings. As one of the "troika" driving economic growth, investment is crucial to developing China's economy. However, no study in the existing literature has accurately linked "enterprise digital transformation and investment in innovation", and the direction and possible mechanism of the

influence between the two can only be speculated in other related materials. To fill the gap in this research area, this paper intends to study the impact of digital transformation on innovation investment.

The possible contributions of this paper are mainly as follows:

(1) Enriches the research on the economic consequences of digital transformation. Incorporating enterprise digital transformation and enterprise innovation investment into the same analytical framework expands the research idea of enterprise innovation in the era of the digital economy, studies the facilitating effect of digital transformation on enhancing innovation investment, and provides new perspectives for enterprises to enhance their innovation investment.

(2) Expanded the related research on innovation investment. This paper sorted out the two mechanisms of human capital and surplus management. It empirically examined them on this basis, enriching the theoretical and empirical research on the micro effects of digital transformation. To a certain extent, it explores the causal relationship between enterprise digital transformation and enterprise innovation investment, deepens the understanding of digital transformation, and expands the realization of ways for enterprises to improve the level of innovation investment through digital transformation, which has certain practical significance.

(3) It has a certain policy reference value. It enriches the relevant theories of digital reform in the digital era, which in turn provides a reference for the government to formulate policies more precisely, which provides important policy insights for further promoting the digital transformation of enterprises and guiding the high-quality development of the economy.

2. Theoretical Analysis

Compared with ordinary capital investment, enterprise innovation investment has certain heterogeneous characteristics, with typical high-risk, long-cycle, and unpredictable features, and is generally regarded as a risky project with a high degree of uncertainty[6]. First, the degree of digital transformation usually has consistency with the firm's innovation strategy, which promotes a jump in the firm's R&D investment. Tao Meng [7] points out that digital transformation positively affects firms' business model adaptation, and business model changes lead to changes in firms' innovation strategies and promote innovation investment. Secondly, digital transformation can improve firms' innovation capability, which is the ability to generate or apply innovative activities, improve or develop products or services, introduce new products or services to the market, and improve or create production or management processes[8], and at the same time, digital technology enhances firms' technological innovation capability, which helps firms to plan the best way for technological innovation to evolve, and increases the likelihood of technological innovation success [9], so firms have the motivation and ability to support their resources towards R&D and innovation activities. Finally, the digital transformation of enterprises can improve the input-output efficiency, and the improvement of the input-output ratio enhances the profitability of enterprises, and the benefits brought to enterprises will further reverse the effect on the investment in digitalization projects, prompting enterprises to further expand the innovation investment projects[10]. Based on this, this paper discusses the impact of digital transformation on corporate innovation investment from the perspective of human capital and surplus management.

(1) Digital transformation can increase investment in innovation by facilitating human capital restructuring and upgrading the level of human capital. Capital is an important factor in the economic development of a country, and the development of the digital economy depends on technological progress and human capital. Human capital is the capital embodied in workers and characterized by creativity and innovation, such as the physical condition of workers and the knowledge they possess[11]. The era of the digital economy puts forward higher requirements for human capital, and the digital transformation of enterprises not only lies in promoting business transformation but also cannot be separated from a high-quality talent strategic layout. In the process of enterprise digital transformation, the complexity of production increases, to skillfully use advanced digital technology,

enterprises will recruit highly educated, high-quality talents, such a clear skill bias on the knowledge reserves and professionalism of workers[12], which contributes to the optimization of the structure of human capital and improves the level of human capital in enterprises. The introduction of high-quality talents will also bring rich management experience and advanced business concepts, providing human capital support for the implementation and promotion of innovative investment projects[6]. In addition, the enhancement of the competitive advantage of human capital and the improvement of human capital reserves stimulate the demand for enterprises to increase innovation investment[13].

(2) Digital transformation can increase investment in innovation by reducing surplus management. Surplus information is the main indicator to show the operating results and financial status of a company, and its quality directly affects the decision-making effect of external stakeholders, which involves corporate strategy formulation and future development direction[14]. By observing R&D-based surplus management in a group of representative firms, researchers have found that R&D investment leaves managers with a wide scope for adjustment and concluded that managers' underinvestment in R&D activities is common[15]. Due to the high-risk and long-cycle nature of corporate innovation activities, managers become defensive about innovation activities, their willingness to innovate decreases, and they will choose to encroach on funds that should have been invested in innovation projects using surplus management[16]. In the era of the digital economy, with the gradual deepening of the degree of digital transformation of enterprises and the close integration of enterprise operations and digital technology, digital technology reveals a crucial role in internal governance and influences surplus management behavior. First, digital technology reduces the degree of information asymmetry and eliminates the barriers to information flow between different departments, thus promoting transparent interaction within the company, and reducing the ability to manage surplus. Second, firms can effectively optimize resource allocation and improve productivity and operational efficiency through digital technology, making managers less motivated to manipulate surplus management[17]. Finally, digital transformation helps firms enhance coordination capabilities and improve monitoring efficiency, thus improving the quality of internal control and suppressing the incentives for surplus management. Following this logic, this paper argues that digital transformation can increase investment in innovation by reducing surplus management.

Based on the above analysis, the following research hypotheses are proposed:

H1: Digital transformation can be a positive catalyst for investment in innovation.

H2: Digital transformation improves investment in innovation through two mechanisms: increasing human capital, and reducing surplus management.

3. Research design

3.1 Data sources

This paper takes Chinese A-share listed companies in Shanghai and Shenzhen from 2012 to 2022 as the research sample, and the financial data required for the empirical study is obtained from the Cathay Pacific database and is processed concerning the following criteria: (1) excluding the samples of the financial industry, (2) excluding the samples of all ST or ST* companies, (3) excluding the samples of the companies with abnormal financial data, (4) excluding the samples of companies with missing data, and (5) excluding the samples of the financial industry, with a total of 16,258 companies' annual data obtained. A total number of 16,258 annual data is obtained from the samples. Meanwhile, to mitigate the impact of potential outliers, the continuous variables are shrink-tailed at the two-sided 1% level.

3.2 Empirical models

To examine the impact of digital transformation on firms' investment in innovation, this paper sets up the following benchmark regression model:

$$Innovation_{i,t} = \alpha_0 + \alpha_1 Digi_{i,t} + \alpha_2 \sum Controls_{i,t} + \sum Industry + \sum Year + \varepsilon_{i,t}$$

The explanatory variable *Innovation* represents innovation investment, and the core explanatory variable *Digi* measures the extent of firms' digital transformation. The subscripts i and t represent firms and years, respectively, and the parameter α₁ is used to characterize the effect of Digi on firms' innovation investment. *Controls* are firm-level control variables. *industry* and year are industry and year dummy variables. $\sum Industry$ Industry and Year are industry and year dummy variables.$\sum Year$ denote industry fixed effects and year fixed effects, respectively, and $\varepsilon_{i,t}$ the random error term in the model.

3.3 Definition and measurement of variables

In this paper, we refer to the methodology of Xuefeng Zhou et al. [18] concerning the study of Fei Wu et al. [19] The definitions and descriptions of all variables are shown in Table 1.

Table 1 List of variable definitions

Variable type	variable name	coding	measurement method
explanatory variable	Innovative Investments	Innovation	R&D investment / sales revenue x 100%
explanatory variable	Digital Transformation	Digi	Add 1 to the summed word frequency based on the aggregated crawler data and take the logarithm.
control variable	Corporate Performance	Roa	EBIT/average total assets
	Enterprise Size	Size	Measured using the natural logarithm of the firm's total assets for the year
	Age of Business	Age	Year of the firm sample minus year of listing
	Enterprise Value	Tobinq	Enterprise market value/replacement cost
	Corporate Growth	Growth	Revenue growth rate
	Gearing	Leverage	Total liabilities / total assets
	Current ratio	Liquid	Current assets / total assets
	Shareholding Concentration	Top1	The shareholding ratio of the largest shareholder
	Number of Board of Directors	Board	The number of directors plus one takes the natural logarithm
	Ratio of Sole Director	Indep	Percentage of independent directors
	Two Jobs in One	Dual	Whether the chairman of the board and the general manager are concurrently appointed, yes is 1, no is 0
	Property Right	owner	1 for state-owned enterprises, 0 for non-state-owned

4.   Empirical results and analysis

4.1 Descriptive statistics

Table 2 shows the descriptive statistics of the main variables. As shown in Table 2, the maximum value of innovation investment based on sales revenue is 26.900, the minimum value is 0.030, the average value is 4.892, and the median value is 3.780, reflecting that there are large differences in the level of innovation investment among enterprises. In general, the level of innovation investment of Chinese enterprises is low, and their innovation investment strategy is conservative, they do not have a competitive advantage in the international arena, and the innovation ability of enterprises needs to be improved. The digital transformation indicator, with a maximum value of 4.990, a mean value of 1.602, and a standard deviation of 1.451, shows that there is also a certain gap in the level of enterprise digital transformation, and most of the enterprises are in the state of just starting, and the degree of digital transformation is low. And the correlation analysis of the main variables, the Pearson correlation coefficient of digital transformation and enterprise innovation investment is 0.084 and passed the 1% significance level test, indicating that there is a positive correlation between digital transformation and enterprise innovation investment, which initially supports the research hypothesis

of this paper, pending further regression analysis. The control variables and explanatory variables are generally correlated, which is consistent with the theoretical expectations and can indicate that the selection of control variables in this paper is more reasonable. At the same time, this paper carries out the multicollinearity test for all the explanatory variables, and the results show that the average variance inflation factor of all the explanatory variables is 1.38, and the maximum value is 2.04, which is much smaller than 10, indicating that the explanatory variables in this paper do not have serious multicollinearity problems.

Table 2 Descriptive statistics of the main variables

variable name	sample size	upper quartile	average value	(statistics) standard deviation	minimum value	maximum values
Innovation	16,258	3.780	4.892	4.723	0.030	26.900
Digi	16,258	1.386	1.602	1.451	0.000	4.990
ROA	16,258	0.052	0.052	0.068	-0.259	0.237
Size	16,258	22.055	22.222	1.207	20.104	26.024
Age	16,258	2.197	2.141	0.764	0.693	3.367
Tobinq	16,258	1.683	2.090	1.281	0.854	8.137
Growth	16,258	0.141	0.311	0.660	-0.613	4.081
Top1	16,258	0.313	0.336	0.141	0.091	0.722
Board	16,258	2.303	2.230	0.172	1.792	2.708
Leverage	16,258	0.399	0.406	0.194	0.056	0.870
Liquid	16,258	0.595	0.584	0.177	0.155	0.927
Indep	16,258	0.364	0.376	0.053	0.333	0.571
Dual	16,258	0.000	0.305	0.460	0.000	1.000
owner	16,258	0.000	0.305	0.460	0.000	1.000

4.2 Analysis of Baseline Regression Results

Table 3 reports the results of the overall test of the impact of digital transformation on firms' investment in innovation. Column (1) in Table 3 shows the regression results with only the core explanatory variables. The regression coefficient of the firm's digital transformation indicator (*Digi*) is 0.2724 and passes the 1% statistical significance test, the impact of digital transformation on firms' innovation investment is significantly positive. Column (2) shows the regression results after adding control variables, the regression coefficient of *Digi* is reduced, which may be because some factors affecting enterprise innovation investment are absorbed after adding control variables, but the significance remains unchanged. From the perspective of control variables, firms with large size, high value, good performance, growth, and high current ratio have higher levels of corporate innovation investment. This paper also conducts regressions while controlling for both year-fixed effects and industry-fixed effects, as shown in column (3) of Table 3, digital transformation still significantly increases the level of firms' innovation investment at the 1% confidence level. This implies that digital transformation can positively contribute to innovation investment. The higher degree of enterprise digital transformation will significantly increase the level of enterprise innovation investment, and Hypothesis 1 is verified.

Table 3 Empirical results on the impact of digital transformation on firms' investment in innovation

variable name	(1) Innovation	(2) Innovation	(3) Innovation
Digi	0.2724*** (6.2395)	0.1746*** (5.1428)	0.1187*** (3.7676)
Roa		-15.2290*** (-8.0201)	-13.3797*** (-11.9810)
Size		0.4142** (2.7631)	0.3989*** (5.1471)

Age		-0.8809*** (-10.5463)	-0.8112*** (-6.3869)
Tobinq		0.8607*** (3.8533)	0.7810*** (6.8350)
Growth		0.7669** (2.4182)	0.5684*** (10.4412)
Top1		-3.7844** (-2.6210)	-2.1111*** (-7.4814)
Board		-0.0088 (-0.0627)	0.2587** (2.6459)
Leverage		-6.9208*** (-3.0153)	-5.6304*** (-4.4301)
Liquid		2.0633*** (3.8026)	0.9806 (1.3917)
Indep		3.3079*** (3.6225)	2.6880*** (4.7443)
Dual		0.6175*** (4.9052)	0.5238*** (8.2402)
Owner		-0.2327 (-1.0733)	-0.0508 (-0.2328)
Constant	4.4561*** (8.3414)	-2.4127 (-0.9879)	-6.3476*** (-4.7512)
Year fixed effects	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes
Observations	16,258	16,258	16,258
R-squared	0.007	0.240	0.366

Note: *** p<0.01, ** p<0.05, * p<0.1 following table is the same

4.3 Robustness tests

4.3.1 Substitution of variables

To ensure the reliability of the study, this paper uses replacement variable measures for robustness testing. The first is to replace the core explanatory variables. Firstly, this paper refers to Yongshen Zhang's approach[20] to measuring the digitization level of firms by the ratio of the portion of year-end intangible assets related to digital transformation to the total intangible assets of listed firms. The regression results are shown in column (1) of Table 4, and it can be found that there is no substantial change in the empirical results of digital transformation under the new measure, and the regression coefficient is still significantly positive. Second, the explanatory variables are replaced. Change the measure of innovation investment based on sales revenue to measure innovation investment from the perspective of absolute size [21], and take the natural logarithm of the total R&D expenditure of enterprises. It can be found that as shown in column (2), the digital transformation of enterprises is still significant at the 1% level. Even with the substitution of core variables, the regression results are not substantially changed from the previous results, confirming that the findings of this paper are reliable and robust.

4.3.2 Instrumental Variables Approach

To mitigate possible reverse causation problems, this paper also uses the instrumental variable approach. The average value of the degree of digital transformation of enterprises other than ours in the same city and industry is calculated as an instrumental variable for the enterprise's digital transformation, i.e., the industry average level of digital transformation. The digital transformation of an individual enterprise is related to the overall digital transformation of the same city and the same industry, which satisfies the relevance condition of the instrumental variable, and the industry average level of digital transformation makes it difficult to produce a direct correlation with the level of

innovation investment in a separate enterprise, which satisfies the condition of homogeneity, so the selection of this instrumental variable is reasonable. On this basis, the constructed industry average level of digital transformation (*Digi. IV*) is subjected to a two-stage least squares regression. Table 4 columns (3) (4) show the results of the two-stage regression, and column (3) shows the regression of the first stage instrumental variable (*Digi. IV*) on *Digi*, in which the industry average of digital transformation is significant at the 1% level, which indicates that the instrumental variable is strongly correlated with the endogenous explanatory variables, and at the same time the first stage of the F-value of 47>10, the instrumental variable is selected with rationality, and its validity is supported by the weak instrumental variable test, column (4) shows the second stage regression results, and it is found that the coefficient of its *Digi* is still significantly positive, indicating that the main conclusion of this paper is robust.

Table 4 Robustness test

variable name	(1) Innovation	(2) RD	(3) Digi	(4) Innovation
Digi.IV			0.000*** (8.714)	
Digi	70.2194*** (7.2818)	0.0268*** (2.9892)		1.225*** (3.629)
Control variable	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes
Constant	-5.5443*** (-2.9472)	-13.2642*** (-25.2161)	0.127 (0.358)	-6.447*** (-6.163)
Observations	16,258	16,258	16,258	16,258
R-squared	0.384	0.981	0.097	0.261

5. Further testing

Combined with the previous theoretical analysis, this part studies the specific channel mechanism of enterprise digital transformation affecting innovation investment and tests the path of digital transformation affecting enterprise innovation investment from human capital and surplus management. Considering the serious endogeneity of the mediating effect model, this paper will construct the following equation model by focusing on the influence of the core explanatory variables on the mechanism variables:

$$Inter_{i,t} = \alpha_0 + \alpha_1 Digi_{i,t} + \alpha_2 Controls + \sum Industry + \sum Year + \varepsilon_{i,t}$$

where *Inter* denotes the mechanism variable.

For the mechanism test of human capital, the proportion of employees with bachelor's degrees or above in the total employees of the enterprise (*Degrees*) is used as the mediator variable; for the mechanism test of surplus management, the modified JONES model index is used as the measure and the absolute value (*DA*) is taken as the mediator variable; for the mechanism test of the level of cash holdings (*Cash*), the mediator variable is taken as the mediator variable as the result of the calculation of the following formula, i.e. (Money Funds + Trading Financial Assets)/Total Assets. Table 5 shows the results of the mechanism test, in Column (1) *Digi* and *Degrees are* significantly and positively correlated at the 5% level, which indicates that digital transformation helps firms to improve the level of human capital and adjust the structure of human capital, which in turn improves the level of investment in innovation to a certain extent. Column (2) reports the regression results of medium surplus management on digital transformation, and the coefficient of *Digi* is significantly negative at the 5% level, which represents that the higher the degree of digital transformation of firms, the more beneficial it is to alleviate the surplus management of firms. Therefore, the mechanism of hypothesis 2 is that enterprise digital transformation improves innovation investment by improving human capital level and reducing surplus management.

Table 5 Mechanisms tested for the impact of digital transformation on investment in innovation

variable name	(1) Degrees	(2) DA
Digi	0.0041** (1.9751)	-0.0007** (-2.2485)
Control variable	Yes	Yes
Year fixed effects	Yes	Yes
Industry fixed effect	Yes	Yes
Constant	-0.7199*** (-7.0796)	0.0671 (1.7526)
Observations	11,991	16,258
R-squared	0.470	0.134

6. Conclusions and insights

This paper expands the literature on the digital transformation of enterprises and also enriches the research on innovation investment of enterprises, etc. The main conclusions are as follows. (1) Overall, this paper confirms the positive promotional impact of digital transformation on the level of corporate innovation investment, and the positive impact remains significant after a series of robustness tests. (2) It clarifies the mechanism by which digital transformation affects innovation investment, i.e., enhancing the level of human capital and reducing surplus management. Based on the results of the study, this paper puts forward the following suggestions for seizing the opportunities of digital transformation and improving the level of corporate innovation investment.

First of all, enterprises should pay attention to the powerful role of digital transformation in enhancing the level of investment in innovation, tapping the transformation and upgrading potential of digital technology, empowering enterprise R&D decision-making, timely access to innovation demand, and encouraging enterprises to increase investment in innovation; enterprises should pay attention to the introduction and cultivation of digital talents, and provide knowledge and skill-based workforce to accelerate the realization of digital transformation. Secondly, the government should actively take measures to promote the digital transformation of enterprises. On the one hand, the government should formulate financial, tax, and other policies at the right time and place, or targeted subsidies to ease the pressure on enterprises. On the other hand, the government should continue to improve the legal and regulatory system, and supervisory system and implement penalties for the theft of data resources and infringement of innovative achievements. Finally, employees should actively improve their knowledge and constantly upgrade themselves to meet the demand for knowledge-based and technology-based employees in the context of digital transformation. All in all, the digital transformation of enterprises requires the joint efforts of all parties in society, and through the extensive convergence of resources from all walks of life, digital transformation will surely stimulate the innovative vitality of enterprises and become a powerful booster for enterprise innovation and investment.

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