The Impact Mechanism of Digital Transformation on Firm Investment Efficiency

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Abstract. How does the digital economy help the economy grow? Company can through digitalization better use own resource. Further, this help them more have competitive. This paper aim to look at digital change and invest efficiency between relation. We choose 2015 to 2024 year China A-share list company. We further look at digital change how affect invest efficiency. Result show, digital change big reduce wrong invest, this turn over improve all level invest efficiency. Our results are robust after controlling for other factors and sensitivity tests. Furthermore, we further explore how digital changes reduce bad investments. Better tech skills are the main way that digital changes improve investment efficiency. It reduces bad investment through better innovation and risks identification. We further explore different types of companies. The relationship between digital changes and ownership type reduces by different types of ownership. The positive effect is stronger in private company type. Furthermore, the relationship between digital changes and investment efficiency is more significant in large companies. Meanwhile, the relationship in eastern region companies is more significant. Because of their resources and environment, companies in eastern regions can see clearer benefits. The study provides important suggestions for improving digital plans. It further provides a basis for better investment decision-making and government policies.

Keywords: Digital transformation, Investment efficiency, Tech skills, Ownership type

1 Introduction

Global digital economy changes how do we do business. It's also changing how do we see industries. Chinese government has released some new policies. For example, “14th Five-Year Plan for Digital Economy Development”. They want to help digital technology companies. Corporate investments is very important on how do we use resources. It’s also influencing the company. It’s also influencing the company for the long run. But there is bad investment. Invest too little or too much and the company can’t grow in value. So here is a big question. Can digital transformation improve a firm’s investment efficiency? If yes, then how? This is worth answering. We can see what digital tech does for companies to decide. Also see how do they use their resources better.

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Many studies suggest that digital transformation can improve investment efficiency. Using Richardson's (2006) residual method, many empirical papers find that higher digitalization is linked to lower inefficient investment. Vial (2019) in the Journal of Strategic Information Systems points out that digital transformation is not only adding technology. It is also changing the organization. It can reduce human mistakes by automation and data-based decisions. Hsieh and Klenow (2009) stress that better resource allocation is important for total factor productivity growth, and digital technology can help reduce misallocation. However, existing research still does not fully explain how digital transformation affects corporate investment decisions, which are core financial actions. It also often lacks clear mechanism tests and context-based tests. Digital transformation may affect investment efficiency by improving information processing and decision-making. But the main channels (for example, better technology ability) and different effects across ownership, firm size, and regions still need more careful testing.

So it's looking at the impact and methods of digital change working on investment efficiency for Chinese listed companies. And it does three things. First it connects the new field of digital transformation to the old field of investment efficiency. Second it says digital transformation has immediate impact on investment efficiency. It says "better tech skills" is the first main step. Also looks at who owns things. Third it looks at different things depending on whether the company is large or small and where they are. This is specific advice for policymakers and managers.

2 Theoretical Analysis and Research Hypotheses

2.1 Digital Transformation & Corporate Investment Efficiency

Digital Transformation is Process. Company invest in digital technology. They use big data, AI to transform their business. Also change how they create value. Traditional investing have some problem. Don't have enough info. Agency problem. Outside problem. Cause bad result. Company may invest too much or too less. Company make digital system. They make decision with data. It can reduce those problem. Also more efficient.

Digital transformation can improve our ability to get info. Digital transformation can also help we process that info. Traditional company usually base on limited internal info. They use their experience based judgement. So they will make biased decision. Big data platform type tools can enter inside data with outside info. And do it instantly. And then they can also forecast and evaluate risk better. For example. Company can use computer programs to investigate changes in the supply chain. Changes in the demand. Prevent loss from careless growth. Also don't be too careful.

Digital transformation can improve our internal rules. Digital transformation can also reduce conflict between manager and owner. Digital platforms can improve transparency. Technology can track where does the money goes. So it can reduce the selfish behavior from manager.

From outside view. Digital transformation can improve our resistant to risk. When the economy change or policy change. Company with digital system can respond faster. They can see the signal in the market. And then they can adjust their investment faster.

This paper proposes:

H1:Digital transformation greatly cuts down on non-investment efficiency, so it raises investment efficiency.

2.2 Technological Capability as a Mediator

Digital transformation is not only about upgrade tools. And also big change in how we make new things and remember what we know. And it will be better for R&D process, and also let different departments to share their knowledge and do job together. And then you can increase your tech level, like with more patents.

In particular, digital tools collect and analysis huge amounts of tech info. Then they could discover new ways to innovate sooner, develop new products faster, and get more and better results.

Also, stronger technology capability is one of the important parts of core competitiveness. Firms with stronger technology can learn and absorb knowledge better, use resources better, and recognize market risk better. So their investment decision can be more careful and more accurate, and inefficient investment caused by information gap or technology mistake can be reduce. So, higher technology capability can be a channel through which digital transformation affect investment efficiency. This paper proposes:

H2:The technological level has an intermediary role between the impact of digital transformation and investment efficiency.

2.3 Moderating Role of Ownership Structure

Firms with different ownership types may demonstrate significant differences in resources, operational rules, and strategic goals. Thus, the ownership structure could substantially influence how digital transformation affects investment efficiency. State-owned enterprises (SOEs) might indicate that they possess important policy support. Moreover, these firms have easier access to credit. However, SOEs may also face agency problems. The firms have multiple goals that are not about money. These include employment and stability. Additionally, SOEs have stricter decision systems. Given that digital transformation can bring more transparent decisions to SOEs, it might strengthen internal checks. Therefore, digital transformation could reduce bad investment from agency problems. In contrast, private firms are usually more market-driven. These firms focus more directly on efficiency. For private firms, digital transformation mainly improves information processing. Nevertheless, it also improves risk management. Thus, ownership may change the strength of the relationship. This paper proposes:

H3:Digital transformation improves investment efficiency more for SOEs than for NSOEs.

2.4 Heterogeneous Effects Based on Firm Characteristics and External Environment

The effects of digital transformation may vary across companies. This paper examines the important differences by firm size and region.

Moreover, firm size could indicate whether digital transformation might succeed. Large firms appear to have significant economies of scale. However, these firms have more resources. Furthermore, they have more complete systems. Thus, they can afford the substantial initial costs. They can afford running costs of digital transformation. Nevertheless, they can integrate digital resources better. Given that integration occurs, firms may gain more efficiency from digitalization. Small and medium firms face constraints. They lack resources, talent, and technology. Therefore, they face barriers. The return from digital spending may be low. It may hurt operations. Thus efficiency gain may be weaker. This paper proposes:

H4a:Positive impact of Digital Transformation on Investment Efficiency is more for Large Firms.

The regional environment could demonstrate significant relevance. Moreover, Chinese regions may differ in the critical digital infrastructure. Furthermore, they might differ in human capital and markets. Eastern regions appear to show better digital infrastructure. Thus, these regions may have more talent. Additionally, regions have stronger finance markets. Nevertheless, regions have better business conditions. Given that a better "digital environment" exists, this could reduce costs. In light of the findings, the environment can increase benefits. However, the environment might help firms turn digital technology into real improvements. Firms in central and western regions may face more limits. Therefore, the effect might be weaker there.This paper proposes:

H4b:The positive effect of digital transformation on investment efficiency is greater for companies in the east.

3 Research Design

3.1 Sample Selection and Data Sources

This paper use 2015 to 2024 China A-share list company data. Sample clean process like below:(1) Remove finance company;(2) Remove ST or *ST etc. abnormal state company;(3) Remove key variable exist serious miss data observe company.For reduce abnormal value effect, all continuous variable do 1% and 99% two-side shrink tail process. Finally get 33,657 company-year observe value. Digital transform data come from year report text crawl get, and through key word frequency do count; other finance data come from CSMAR data base.

3.2 Variable Definitions

(1) Dependent variable: Non-investment efficiency (Lnv)

We use Richardson(2006). Non-investment efficiency is calculated as the absolute residual of an investment model. The higher the number, the greater the difference from the optimal investment level. It means less efficient.

(2) Independent Variable: Digital Transformation (DIG)

Using Wu Fei et al. (2021), we do text analysis. Find out terms such as "artificial intelligence", "big data", "cloud computing", "blockchain" and "digital technology application" in annual report. We count how many times it appears and then we use a special kind of math called log to see how much it changed.

(3) Mediating Variable

Technological Level (Patent):Log(No. of Invention Patent Application + 1)

(4) Moderating Variable

Ownership Nature (Soe):A variable that is set to 1 if it's a state-owned enterprise and 0 otherwise.

(5) Control Variables

To control for others, we picked firm size(Size),debt ratio(Lev),return on assets(ROA),cash flow(CashFlow),revenue growth(Growth),board size(Board),and the biggest shareholder's share(Top1). Definitions in Table 1.

Table 1. Variable Definitions and Measurement Methods

Variable Nature	Variable Name	Variable Symbol	Measurement Method
Dependent Variable	Non-investment efficiency	Lnv	Investment forecasting model's absolute value of residual
Explanatory Variables	Digital transformation	DIG	Keyword log frequency in annual reports
Mediating Variables	Technological Level	Patent	Invention Patent Applications+1 Logarithm
Moderator variable	Nature of Property Rights	Soe	State-owned enterprise=1;Non-state-owned enterprise=0
Control variable	Enterprise size	Size	Log of total assets at year-end
	Debt-to-asset ratio	Lev	Total Liabilities at year-end / Total Assets at year-end
	Return on Assets	ROA	Net Profit for the Year / Total Assets as of End of Year
	Operating cash flow	Cash Flow	Net operating cash flow/Total liabilities at year end
	Revenue Growth Rate	Growth	Quarter on quarter growth rate of operating revenue
	Board Size	Board	Number of Board Members
	Major Shareholder Holdings	Top1	Largest shareholder's shareholding ratio

3.3 Model Specification

(1) Benchmark Regression Model

To examine the impact of digital transformation on corporate investment efficiency (Hypothesis H1), this paper constructs the following two-way fixed effects model:

$$Lnv_{i,t}=\alpha_0+\alpha_1 DIG_{i,t}+\sum\alpha_j Controls_{i,t}+\mu_i+\lambda_t+\varepsilon_{i,t} \quad (1)$$

Where i denotes firm, t denotes year. *Lnv* represents non-investment efficiency, *DIG* indicates digital transformation level. *Controls* constitutes the set of control variables. μ_i represents individual fixed effects, λ_t denotes year fixed effects, and $\varepsilon_{i,t}$ is the random disturbance term.

(2) Mediating Effect Model

To test the mediating path of technological level (Hypothesis H2), following the methodology of Wen, Zhonglin et al. (2014), the following steps are established based on Model (1):

$$Patent_{i,t}=\beta_0+\beta_1 DIG_{i,t}+\sum\beta_j Controls_{i,t}+\mu_i+\lambda_t+\varepsilon_{i,t} \quad (2)$$

$$Lnv_{i,t}=\gamma_0+\gamma_1 DIG_{i,t}+\gamma_2 Patent_{i,t}+\sum\gamma_j Controls_{i,t}+\mu_i+\lambda_t+\varepsilon_{i,t} \quad (3)$$

4 Empirical Results Analysis

4.1 Descriptive Statistics

Table 2 shows the stats. The mean value of non-investment efficiency (Lnv) is 0.0370. The max is 0.285. So, it means that bad investment exist and there are big differences between firms. The mean value of digital transformation (DIG) is 1.762. So, digital change in Chinese companies still start and the speed is very different. And the other variables like size and debt are in a normal range. So, I think the data is relatively stable and suitable to do research.

Table 2. Descriptive Statistics

variable	N	min	max	mean	sd	p25	p50	p75
lnv	33657	0	0.285	0.0370	0.0470	0.0100	0.0220	0.0440
DIG	33657	0	5.278	1.762	1.411	0.693	1.609	2.708
Size	33657	19.79	26.42	22.39	1.317	21.47	22.21	23.14
Lev	33657	0.0640	0.972	0.439	0.210	0.274	0.428	0.585
ROA	33657	-0.387	0.197	0.0210	0.0820	0.00700	0.0290	0.0590
Cash Flow	33657	-0.164	0.244	0.0460	0.0680	0.00900	0.0450	0.0850
Growth	33653	-0.645	2.359	0.122	0.398	-0.0670	0.0690	0.224
Board	33655	1.609	2.639	2.098	0.198	1.946	2.197	2.197
Top1	33657	0.0780	0.720	0.321	0.145	0.210	0.299	0.415

4.2 Correlation Analysis

Table 3 Linkage of variables. Link between dependent variable Digital Transformation (DIG) and Non-Investment Efficiency (Lnv) is -0.101. It is a significant negative link.

It supports the hypothesis that digital transformation affects investment efficiency. Links between control variables and Lnv are significant too. For example ROA has positive link. It means that in the case of worse profits, a firm invest worse. Biggest link between variables is low. It means that there is no serious math problems. The results are reliable.

Table 3. Correlation Analysis

	lnv	DIG	Size	Lev	ROA	Cash Flow	Growth
Investment	1						
DIG	-0.101***	1					
Size	-0.155***	0.00400	1				
Lev	-0.040***	-0.048***	0.398***	1			
ROA	0.051***	-0.054***	0.127***	-0.355***	1		
Cash Flow	-0.018***	-0.055***	0.110***	-0.175***	0.414***	1	
Growth	0.164***	-0.015***	0.037***	0.00400	0.251***	0.049***	1
Board	-0.039***	-0.060***	0.271***	0.105***	0.068***	0.054***	0.00700
Top1	-0.028***	-0.116***	0.217***	0.00500	0.182***	0.131***	0.011**
	Board	Top1					
Board	1						
Top1	0.034***	1					

4.3 Multicollinearity Test

We see whether there's too much overlap between variables. We use VIF. Table 4 shows that all values are less than 2. It is much less than 10. This means there are no big problems. So we can trust the results.

Table 4. VIF Test

Variable	VIF	1/VIF
ROA	1.580	0.632
Lev	1.530	0.656
Size	1.460	0.683
Cash Flow	1.230	0.815
Top1	1.100	0.912
Board	1.090	0.920
Growth	1.090	0.921
DIG	1.030	0.971
Mean	VIF	1.260

4.4 Benchmark Regression Analysis

As shown in Table 5. Column (1) controls for year and city. Column (2) includes the firm fixed effects and all controls. The number for DIG stays negative and it is significant. Lnv means inefficiency. Negative number means inefficiency decreases. So investment inefficiency decreases which means investment efficiency increases. It supports Hypothesis H1. In control variables, having high profits and high growth means the firm has a higher possibility to have bad investment. On the other side, having much cash decreases bad investment.

Table 5. Benchmark Regression Test

	(1)	(2)
VARIABLES	lnv	lnv
DIG	-0.003***	-0.003***
	(-5.83)	(-6.74)
Size		0.001
		(1.30)
Lev		0.006
		(1.50)
ROA		0.052***
		(9.09)
Cash Flow		-0.031***
		(-5.60)
Growth		0.011***
		(10.16)
Board		-0.001
		(-0.37)
Top1		-0.003
		(-0.53)
Constant	0.041***	0.012
	(49.99)	(0.55)
Observations	33,221	33,215
R-squared	0.323	0.338
city FE	YES	
Year FE	YES	YES
ID FE		YES

4.5 Robustness Test

We conducted the following robustness checks to validate the benchmark regression conclusions.

(1) COVID-19 pandemic could be impact it. So we dropped 2020 sample. We did it again. Column(1) of Table 6, DIG number is -0.003 still significance. Conclusion does not change.

(2) We used more strict test. We added province and industry control. Column(2) of Table 6, DIG number is -0.003. It is very significant. Our main conclusion is supported.

Table 6. Robustness Test: Excluding COVID-19 Samples and Joint Fixed Effects

	(1)	(2)
VARIABLES	lnv	lnv
	Excluding the pandemic	Joint fixed
DIG	-0.003***	-0.003***
	(-6.20)	(-6.68)
Size	0.001	0.001
	(0.98)	(1.29)
Lev	0.005	0.006
	(1.33)	(1.61)
ROA	0.056***	0.050***
	(9.00)	(8.86)
Cash Flow	-0.030***	-0.031***
	(-5.16)	(-5.68)
Growth	0.010***	0.011***
	(9.15)	(10.10)
Board	0.000	-0.000
	(0.09)	(-0.10)
Top1	-0.001	-0.005
	(-0.22)	(-0.83)
Constant	0.016	0.011
	(0.69)	(0.49)
Observations	29,801	33,215
R-squared	0.350	0.348
ID FE	YES	YES
Year FE	YES	YES
Province#Year FE		YES

4.6 Endogeneity Tests

To address the possible cause-and-effect confusion, we applied 2SLS method and employed the past value of Digital Transformation as tool.

In Table 7, we presented the results. In column (1), we found that the tool works well with Digital Transformation. While in column (2), even after the first step, the Digital Transformation still be negative with Non-Investment Efficiency (Lnv). It shows that the result is not confounded by endogenous problem.

Table 7. Endogeneity Test

VARIABLES	(1) lnv	(2) lnv
L.DIG	0.359***	
	(43.33)	
Size	0.172***	0.002**
	(12.21)	(2.38)
Lev	-0.206***	0.004
	(-4.40)	(1.29)
ROA	-0.001	0.044***
	(-0.01)	(10.34)
Cash Flow	-0.202***	-0.028***
	(-2.86)	(-6.07)
Growth	0.041***	0.010***
	(3.38)	(14.32)
Board	0.099**	-0.002
	(2.40)	(-0.68)
Top1	-0.048	-0.002
	(-0.55)	(-0.47)
DIG		-0.003***
		(-2.65)
Constant	-2.797***	
	(-8.85)	
Observations	27,693	27,693
R-squared	0.867	0.022
ID FE	YES	YES
Year FE	YES	YES

4.7 Testing the Transmission Mechanism

We wanted to prove that digital transformation helps by improving tech (H2). We did that. Table 8 presents the results. Column (1) proves that digital transformation helps tech patent (Patent).Column (2) adds Patent to the main model. Patent number is negative. Also, DIG number becomes smaller but still significant. It means that technological level is a bridge. Digital transformation helps management. Digital transformation helps tech patent innovation. It avoids bad investment. It supports Hypothesis H2.

Table 8. Mechanism Test: Mediating Effect of Technological Level

VARIABLES	(1) Patent	(2) Innv
Patent		-0.002***
		(-5.67)
DIG	0.033***	-0.003***

	(4.99)	(-6.59)
Size	0.115***	0.002
	(8.86)	(1.52)
Lev	-0.208***	0.005
	(-4.97)	(1.39)
ROA	0.197***	0.052***
	(3.04)	(9.16)
Cash Flow	-0.136*	-0.031***
	(-1.95)	(-5.65)
Growth	-0.011	0.011***
	(-1.20)	(10.15)
Board	-0.046	-0.001
	(-1.12)	(-0.40)
Top1	0.188**	-0.003
	(2.21)	(-0.47)
Constant	-1.362***	0.010
	(-4.59)	(0.43)
Observations	33,215	33,215
R-squared	0.811	0.338
ID FE	YES	YES
Year FE	YES	YES

4.8 Testing the Transmission Mechanism

We test if ownership makes a difference to the relationship (H3). Table 9 positive sign of interaction term (0.002). Digital transformation benefits less state owned enterprises than private ones. Supported H3. One possible explanation is that state companies have problems they have policy problems. They have to carry policy. Perhaps their digital decision is from above. Maybe they listen to the order. Maybe they just follow the market. So they have less benefit.

Table 9. Moderation Effect Test: The Moderating Role of Ownership Structure

	(1)
VARIABLES	lnv
DIG	-0.004***
	(-7.08)
SOE	-0.011***
	(-4.65)
c.DIG#c.SOE	0.002***
	(3.29)
Size	0.001
	(1.26)
Lev	0.006

	(1.62)
ROA	0.052***
	(9.07)
Cash Flow	-0.031***
	(-5.66)
Growth	0.011***
	(10.12)
Board	-0.000
	(-0.08)
Top1	-0.005
	(-0.85)
Constant	0.016
	(0.70)
Observations	33,215
R-squared	0.338
ID FE	YES
Year FE	YES

4.9 Heterogeneity Analysis

(1) Heterogeneity Test Based on Firm Size

We split the sample into large and small groups. Table 10 presents the result. The negative effect of digital transformation is significant only for large firms. It is not significant for small firms. It means that large firms are able to make big changes. So they get better results.

Table 10. Heterogeneity Analysis: Regression Grouping by Firm Size

	(1)	(2)
VARIABLES	lnv	lnv
DIG	-0.006***	0.001
	(-11.83)	(1.20)
Size	0.003**	0.005**
	(2.43)	(2.43)
Lev	-0.011**	0.019***
	(-2.17)	(3.42)
ROA	0.022***	0.058***
	(2.93)	(7.68)
Cash Flow	-0.016***	-0.034***
	(-2.85)	(-3.83)
Growth	0.012***	0.010***
	(8.82)	(6.09)
Board	-0.000	-0.004
	(-0.12)	(-0.73)

Top1	0.011*	-0.013
	(1.70)	(-1.22)
Constant	-0.040	-0.062
	(-1.22)	(-1.38)
Observations	16,578	16,183
R-squared	0.356	0.376
ID FE	YES	YES
Year FE	YES	YES

(2)Test for regional differences between companies.

We divided our samples into two parts: Eastern and Non-Eastern. Table 11: Result. Positive effect only exists in the east. As we expected, East has better digital tools. It has better talents and markets, so the companies in East are easier to use good digital technology.

Table 11. Heterogeneity Analysis: Regression Grouping by Enterprise Region

	(1)	(2)
VARIABLES	lnv	lnv
	Eastern	Non-Eastern
DIG	-0.005***	0.001
	(-8.76)	(0.87)
Size	0.001	0.003*
	(1.04)	(1.69)
Lev	0.004	0.006
	(0.99)	(0.91)
ROA	0.043***	0.073***
	(6.48)	(6.62)
Cash Flow	-0.031***	-0.027**
	(-4.94)	(-2.52)
Growth	0.010***	0.012***
	(7.92)	(6.11)
Board	-0.002	0.000
	(-0.46)	(0.05)
Top1	0.003	-0.022**
	(0.45)	(-2.10)
Constant	0.017	-0.034
	(0.63)	(-0.80)
Observations	23,636	9,571
R-squared	0.343	0.340
ID FE	YES	YES
Year FE	YES	YES

5 Conclusions and Policy Implications

5.1 Conclusions

This study could apply Chinese A-share listed companies from 2015 to 2024 as research objects, to explore the influence of digital transformation on corporate investment efficiency.

First, digital transformation may greatly narrow non-investment efficiency, and further improve investment efficiency in total. Or perhaps, by embedding big data and AI into enterprise's operational framework, digital transformation may ease information asymmetry and reduce agency problems, which are the main source of investment distortion. But it should be noted that above conclusions are still valid when controlling for pandemic shock and endogeneity.

Second, this study could further explore its mechanism, and find out technological capability as its mediating channel. Considering that digital transformation is not only upgrading technology itself, but also becoming an innovation driver. By improving R&D process optimization and knowledge management, digitalization may enhance firm's patenting and technical capability, and then enables it to make more accurate market forecast and resource allocation.

Third, this study could further explore that benefits of digitalization are not aggregated. Or maybe, we could find that benefits of digitalization would be more obvious in private firm than state-owned ones. It's because that decision-making structure of private firm is more flexible, and its market-oriented incentive is stronger. However, the heterogeneous analysis would find that large-sized firm and enterprise in eastern of China could get more benefits. Given the needed capital, talent and infrastructure, these firms have the ability to bear high initial cost of digitalization, and transfer inputs of technology into outputs of efficiency.

In summary, digital transformation may be the key driver of high-quality development of corporation. Therefore, if digitalization could be fully effective, regional infrastructure support and organization characteristic of firm should be considered.

5.2 Policy Implications

So with this, we have the following suggestions.

First of all, Government should continue to promote digitalization, they need to strengthen their digital laws and develop their infrastructure as well because it’s not only east like this, some subsidies and tax cuts that can decrease cost. They can help to fill the gap.

Second, company should mix digital changes and tech development. Company shouldn’t just put digital on top of everything. Use it for research. Big data makes innovation better. And this would be the decision.

Finally, different policies for different people. The authorities should support small companies. They should also help out with tech. State owned enterprises should also change their ways on how they are running. At same time, in their manage in, use digital tech, for make sure digital plan not only stay on paper face.

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