Science and Technology Finance, Enterprise Digital Transformation, and Corporate Investment Efficiency: Evidence from the Pilot Policy of Combining Technology and Finance

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Abstract. The integration of technology and finance is an important measure to boost the high-quality development of the real economy. This paper takes the pilot project known as "Combining Technology and Finance" as a quasi-natural experiment, and employs the progressive Difference-in-Difference methodology to examine the impact of Science and Technology Finance Policy on enterprise investment efficiency and its mechanism. The results show that the science and technology finance policy can significantly improve the firm's investment efficiency. The effects of the science and technology finance policy are heterogeneous at the corporate level, among which, the effects are more obvious in the state owned and large enterprises. By investigating the action mechanism, it is found that the implementation of policy promotes firm's investment efficiency mainly through promoting digital transformation, easing financial constraints, and reducing agency costs. The research findings of this paper have clear policy implications for high-quality transformation and development in the new era in China.

Keywords: science and technology finance, investment efficiency, digital transformation.

1. Introduction

Since the 18th CPC National Congress, China has vigorously implemented the innovation-driven development strategy, placing science and technology innovation at the core of the overall situation of national development. The report of the Twentieth Party Congress emphasized that "we should insist on the self-reliance and self-improvement of science and technology, adhere to the central position of innovation in the overall situation of China's modernization, and strengthen the position of enterprises as the main body of scientific and technological innovation". Improving the independent innovation capability of enterprises plays a crucial role in the high-quality development of China's economy. Science and technology and finance are the two most active elements in social and economic development, and scientific and technological innovation and financial capital are mutually beneficial (Schumpeter, 1912; Carlota Perez, 2002), and economic development relies on science and technology to promote, while the development of science and technology also needs financial boost. Therefore, in the process of deepening the innovation-driven development strategy, establishing and improving the mechanism of combining science and technology and finance, guiding the allocation of financial resources to the field of science and technology and promoting the integration of science and technology and financial development are the basic requirements for stimulating the vitality of innovation and enhancing the kinetic energy of innovation, and the inevitable requirements for deepening the reform of the science and technology and financial systems.

Based on the policy of "promoting the pilot of combining science and technology and finance" as a quasi-natural experiment, this paper empirically examines the impact of the implementation of science and technology financial policy on the investment efficiency of enterprises and its mechanism of action by using the asymptotic double-difference method and the panel data of non-financial listed companies in the period of 2007-2019. The results find that the implementation of science and technology financial policies can significantly improve enterprise investment efficiency, and the above findings remain robust after using robustness tests such as the placebo test, and, through the mechanism analysis, this paper finds that science and technology innovation-driven, financial development-driven, and corporate governance-driven are the important paths through which science and technology financial policies affect enterprise investment efficiency. In addition, this paper also finds that the promotion effect of the implementation of science and technology financial policies on enterprise investment efficiency is mainly reflected in state-owned enterprises and large enterprises.

2. Literature Review and Theoretical Analysis

2.1 Literature review

2.1.1 Influencing factors of enterprise investment efficiency

International and domestic academics have accumulated relatively rich research on the issue of enterprise investment efficiency. First of all, for the definition of investment efficiency, neoclassical investment theory believes that investment efficiency is the optimal investment level when the marginal return of capital equals the marginal cost (Jorgenson, 1963). However, managers are affected by the complexity of the macro-environment and information asymmetry when making investment decisions, which can lead to "inefficient investment". "Inefficient investment" is mainly manifested as over-investment or under-investment, in which over-investment leads to overcapacity and waste of resources, while under-investment leads to factor constraints.

At the micro level, most of the existing studies focus on the two perspectives of information asymmetry and agency costs. Based on the perspective of information asymmetry, Biddle et al. (2009) found that the reporting quality of corporate financial information exerts a constraining effect on overinvestment and underinvestment by mitigating the problems of adverse selection and moral hazard brought about by information asymmetry.Chen et al. (2011) examined the relationship between the financial reporting quality (FRQ) of unlisted firms in emerging markets and the investment efficiency. relationship. Based on the agency cost perspective, Richardson (2006) found that overinvestment is concentrated in firms with higher levels of free cash flow, and analyzed the impact of a firm's governance structure on the overinvestment effect of free cash flow from the agency cost perspective.Chen et al. (2014) explored the important role of the type of firm's ownership in determining the investment behavior and efficiency of firms' role. Meanwhile, the personal characteristics of executives also have a crucial role in influencing the firm's investment decisions.

2.1.2 Technology finance and corporate investment efficiency

Thus, in general, existing studies have shown that financial factors such as the financial system and the financial market have an impact on the investment efficiency of firms at both the macro and the micro levels of firms.Schumpeter (1912) discussed for the first time the relationship between finance and technological innovation, proposing the use of financial instruments to promote the reallocation of resources.Carlota Perez (2002) described the relationship between technological innovation and financial capital. the basic paradigm of technological innovation and financial capital: venture capital invests in new technologies in search of high returns, which leads to a high degree of coupling between financial capital and technological innovation.Chowdhury (2012) found that there is a significant positive correlation between financial innovation and scientific and technological development in developed countries, suggesting that the two are interacting for mutual benefit.

It has been shown that science and technology finance will have an impact on enterprise innovation and digital transformation, but few scholars have paid attention to the impact of the policy of combining science and technology and finance on the investment efficiency of enterprises, not to mention empirical research on the path of its impact. Based on this, this paper will take the pilot policy of "promoting the integration of science and technology and finance" in 2011 and 2016 as a quasi-natural experiment, and use the progressive double-difference model to conduct an empirical study to identify the causal relationship between science and technology finance and enterprise investment efficiency, and confirm the robustness of the causal identification by using the placebo test method. In addition, this paper will also explore in depth the mechanism of the impact of science and technology finance on enterprise investment efficiency.

2.2 Theoretical analysis and research hypothesis

The integrated development of science and technology and finance is an important initiative based on the need for scientific and technological innovation to drive financial resources to support the development of science and technology and create a new driving force for economic development. In the strategic context of innovation-driven development, it may have far-reaching impact on enterprise investment efficiency. This paper mainly starts from the three paths of science and technology innovation-driven, financial development-driven and corporate governance-driven to explore the impact of the implementation of science and technology financial policy on enterprise investment efficiency and its role mechanism.

Science and technology financial policy can alleviate the information asymmetry problem between enterprises and the outside world, and reduce the underinvestment caused by financing constraints. For a long time, due to the insufficient supply of traditional financial services in China and the imperfect construction and operation of the capital market, the phenomena of mismatch of financial resources and credit discrimination widely exist in the financial market. According to the theory of sequential optimal financing, the cost of capital for enterprises will vary greatly with the source, and exogenous financing tends to be more costly compared to internal funds, thus forming a financing constraint for enterprises (Myers and Majluf, 1984). Science and technology financial policies can help reduce the principal-agent problem within the enterprise, effectively monitor and restrain the self-interested behavior of management in investment decision-making, and improve the quality of managers' decision-making. According to principal-agent theory, under the situation of information asymmetry and lack of monitoring mechanism, the agent is likely to make inefficient investment, which leads to the damage of the principal's interests (Jensen and Meckling, 1976), such as misuse of resources to build a business empire for over-investment (Jensen, 1986). The science and technology financial policy can introduce a more perfect supervision mechanism to inhibit the inefficient investment behavior of enterprises.

Based on the above theoretical analysis, this paper proposes research hypotheses:

H1: The implementation of science and technology financial policies can enhance the efficiency of enterprise investment.

3. Data, Empirical Design and Description of Variables

3.1 Samples and Data

There are two main sources of data in this paper, firstly, the data related to the pilot policy of science and technology and finance come from the official websites of the Ministry of Science and Technology and the People's Bank of China; secondly, the investment data of the enterprises as well as the relevant financial data of the enterprises come from the Cathay Pacific CSMAR database and the Wind database. This paper handles the data as follows: first, it removes all ST and ST* listed companies; second, it removes listed companies in the financial industry and retains only non-financial listed companies. Once again, this paper has shrunk all the firm-level control variables by 1% before and after in order to reduce the impact of extreme values on the analysis results. This paper obtains a panel dataset of 3,468 non-financial listed companies from 2007-2019.

3.2 Empirical Model Setting

This paper adopts the asymptotic double-difference model to examine the impact of the implementation of science and technology financial policies on the investment efficiency of enterprises. The People's Bank of China (PBOC) and the Ministry of Science and Technology (MOST) and other relevant departments carried out a pilot program of combining science and technology with finance in 2011 and 2016, involving 16 regions and 9 cities, respectively. This pilot policy is a typical exogenous shock event, providing an excellent sample of quasi-natural experiments for policy evaluation. Based on the research needs, this paper takes a total of 43 pilot cities as the experimental group and other non-pilot cities as the control group. The regression equation is shown below.

$$Inv_{it} = \beta * post_t * treated_i + X_{it} * \gamma + u_i + \varepsilon_{it} \quad (1)$$

Where, $\boldsymbol{Inv_{it}}$ is the investment efficiency of firm i in year t; $post_t$ is a time dummy variable, taking 1 after the year in which the policy occurs and 0 otherwise; represents a policy dummy variable, taking 1 if the firm's prefecture-level city is included in the pilot and 0 otherwise; X_{it} is other control variables; u_i is individual city fixed effects; and ε_{it} is a random perturbation term.

3.3 Description of variables

3.3.1 Explained variable: enterprise investment efficiency

The current methods on measuring the index of corporate capital investment efficiency mainly include Wurgler model, marginal Tobin's Q model and Richardson model. This paper adopts the classic Richardson (2006) company's expected investment model to measure corporate investment efficiency, the specific equations are as follows:

$$Inv_{ift} = \alpha_0 + \alpha_1 Inv_{ift-1} + \alpha_1 asset_{ift-1} + \alpha_1 cash_{ift-1} + \alpha_1 leve_{ift-1} + \alpha_1 roa_{ift-1} + \alpha_1 ficc_{ift-1} + u_i + e_t + \varepsilon_{ift} \quad (2)$$

Specifically, Inv_{ift} represents the investment level of firm f in industry i in year t, which is obtained by subtracting the firm's expenditure on constructing fixed assets, intangible assets, and other long-term assets from the firm's income from disposing of fixed assets, intangible assets, and other long-term assets, and then dividing by the firm's total assets. Inv_{ift-1} represents the lagged firm's investment level, $asset_{ift-1}$ represents the lagged firm's total assets, $cash_{ift-1}$ represents the lagged firm's money funds, $leve_{ift-1}$ represents the lagged firm's gearing ratio, roa_{ift-1} represents the lagged firm's return on assets, and $ficc_{ift-1}$ represents the lagged firm's free cash flow.

3.3.2 Core Explanatory Variable: Pilot Policies for Integrating Technology and Finance

The core explanatory variable, i.e., the cross term between the time dummy and the policy dummy, is denoted as Policy in the following. this cross term is 1 if the prefecture-level city where the firm is located is included in the pilot list in that year, and 0 otherwise.

3.3.3 Mechanism Variables

(1) Digital transformation (DIGITAL). In this paper, the frequency of keywords related to "digital transformation" in the annual reports of listed companies is used as a proxy indicator of enterprise digital transformation.

(2) In terms of data processing, this paper firstly obtains the annual report documents of all Chinese A-share listed companies, then extracts the text information in the PDF files through Java PDF tool, then pre-processes the text, including word division, removing stop words, eliminating the expression of negative words before the key words, and so on, and then searches, organizes and counts the key words in the text of the annual reports of all Chinese A-share listed companies, and finally summarizes the key words. Then this paper searches, organizes and counts the keywords in the text of the annual reports of all A-share listed companies in China, and finally summarizes the frequency of eligible words and conducts logarithmic processing, so as to get the comprehensive measurement index of enterprise digital transformation.

(3) Financing constraints (KZ). Referring to the classic paper of Kaplan and Zingales (1997), this paper adopts the KZ index as a measure of financing constraints, which has been more widely used in academia (Li Jianjun and Han Xun, 2019; He Dexu and Zhang Binbin, 2021), and the larger the index is, the higher the degree of financing of the enterprise is.

(4) Agency cost (dlfy). In this paper, the operating expense ratio is used as an index to measure the agency cost. The operating expense ratio is equal to the ratio of the sum of management expenses and selling expenses to operating income, the higher the operating expense ratio, the greater the on-

the-job consumption generated by managers, indicating that the agency cost between shareholders and managers is higher.

3.4 Control Variables

Considering that other factors of the enterprise may also have a potentially important impact on the investment efficiency of the enterprise, drawing on the existing literature, this paper adds the following control variables in the double-difference model: (1) Size, reflecting the size of the enterprise; (2) Leverage, reflecting the overall level of assets and liabilities of the enterprise; (3) ROA, reflecting the profitability; (4) Growth, reflecting the growth; (5) Board size, reflecting corporate governance; (6) Tobin's Q, reflecting corporate governance; and (7) Tobin's Q, reflecting corporate governance. ability; (4) growth rate of the enterprise's main business income (Growth), reflecting the growth of the enterprise; (5) board size (Board), reflecting the corporate governance; (6) Tobin Q (TobinQ), reflecting the value of the enterprise; (7) liquidity ratio (ldbl), reflecting the solvency of the enterprise.

4. Empirical results

4.1 Benchmark regression results

Table 1 presents the results of the asymptotic double-difference test of the impact of science and technology financial policies on investment efficiency. Column (1) shows the regression results of firms' inefficient investment on Policy, column (2) introduces industry fixed effects and province fixed effects on the basis of column (1), and column (2) further controls for other control variables. The regression results show that the estimated coefficients of Policy are significantly positive regardless of whether the fixed effects are controlled or not and whether the control variables are added or not, which indicates that the implementation of science and technology financial policies has a significant role in promoting the efficiency of enterprise investment.

Table 1. Benchmark regression results

VARIABLES	(1) Eff	(2) Eff	(3) Eff
Policy	-0.0036***	-0.0043***	-0.0019***
	(-6.83)	(-7.37)	(-3.17)
Size			-0.0037***
			(-12.72)
Lev			0.0208***
			(10.11)
ROA			0.0301***
			(6.28)
Growth			0.0015***
			(2.67)
Board			-0.0001
			(-0.09)
TobinQ			-0.0009***
			(-4.20)
ldbl			-0.0002
			(-1.48)
Constant	0.0368***	0.0472***	0.1221***
	(75.48)	(17.88)	(16.26)
Observations	20,476	20,476	20,062
Number of id	2,960	2,960	2,959
Industry FE	NO	YES	YES
Province FE	NO	YES	YES

Note: *, ** and *** indicate 10%, 5% and 1% significance levels, respectively, with p-values in parentheses. The following tables are identical.

4.2 Parallel trend test

Satisfying the parallel trend assumption is a prerequisite for policy evaluation using the double-difference method, and this paper draws on the method of Beck & Levine (2007) to conduct the parallel trend test on the model. Specifically, this paper constructs the following regression model:

$$eff_{it} = \alpha + \beta_1 * pre * treated_i + X_{it} * \gamma + u_i + \varepsilon_{it} \tag{1}$$

$$eff_{it} = \alpha + \beta_1 * current * treated_i + X_{it} * \gamma + u_i + \varepsilon_{it} \tag{2}$$

$$eff_{it} = \alpha + \beta_1 * post * treated_i + X_{it} * \gamma + u_i + \varepsilon_{it} \tag{3}$$

Where 2010 is the year of policy implementation, the current dummy variable is defined, with 2010 taking the value of 1 and the rest taking the value of 0. By analogy, pre_n is defined as the nth year before the policy occurs, and post_n is defined as the nth year after the policy occurs. The results are shown in Figure.1, none of the years before the implementation of the policy passes the significance test, indicating that there is no difference between the investment efficiency of the experimental group and the control group before the implementation of the science and technology financial policy, and to a certain extent, it can be assumed that the research design of this paper basically conforms to the parallel trend hypothesis. In addition, in the years after the implementation of the policy, the impact of the policy on investment efficiency can pass the significance test, indicating that the implementation of the science and technology financial policy on the investment efficiency of enterprises has a certain lag and continuity.

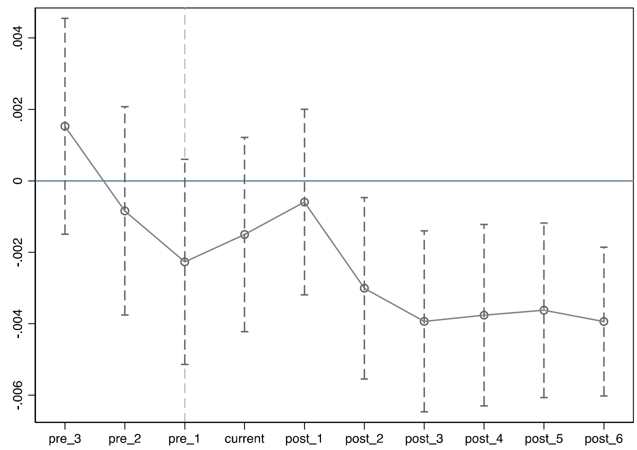

Figure 1. Parallel trend test

4.3 Robustness tests

4.3.1 Placebo test

This paper adopts the method of randomly dividing the treatment group and control group to carry out the placebo test for the implementation of the pilot policy of science and technology financial integration, and repeats the process of one group randomly 500 times, and records the results of each regression to form a distribution. Since the placebo group is randomly generated and not affected by the real policy itself, that is to say, the "dummy" policy dummy variable will not have a significant impact on the explained variables, and the coefficient of its policy dummy variable should be around zero. As shown in Figure.2, the coefficient estimates form a distribution with a mean of 0 and are significantly far from the coefficients estimated by the baseline model, which indicates that the empirical design of this paper passes the placebo test, and also proves that the baseline regression results are robust.

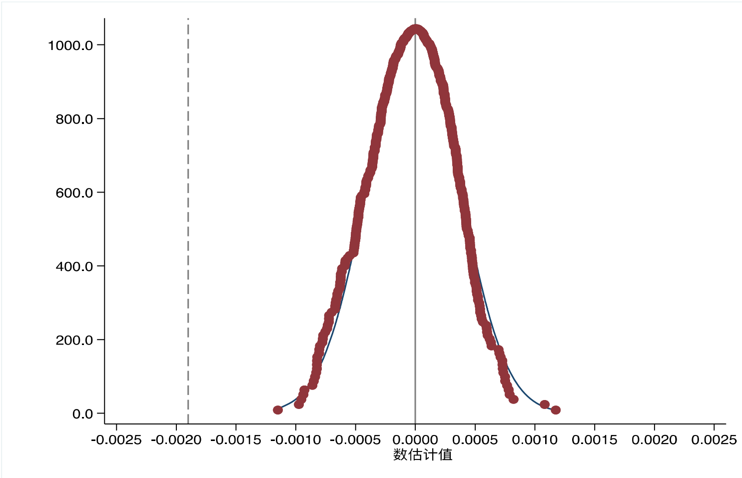

Figure 2. Placebo test

4.3.2 Re-test based on PSM-DID

In addition, the reliability of the estimation results of the double difference method may be related to the selection of the control group. Enterprises in the pilot region of science and technology finance are taken as the experimental group, while other enterprises are taken as the pre-treatment group, and matched with variables such as enterprise size, leverage, and profitability, and the matched samples are subjected to regressions shaped like the benchmark regression. The regression results are shown in columns of Table 2(1)(2), and the coefficients before the policy dummy variables are still significantly negative, confirming the role of science and technology financial policies in promoting enterprise investment efficiency, indicating that the core conclusions have good robustness.

2.Balanced panel regression

Considering that during the sample period of 2007-2019, there may be a self-selection problem of delisting of some enterprises with excessive investment inefficiency and listing of new enterprises, only the enterprise variables that existed in the dataset in all the years 2007-2019 are retained to construct the balanced panel data. The regression results are shown in columns (3)(4) of the table below, where the coefficients before the policy dummy variables remain significantly negative, and Table 2 verifies the robustness of the paper's core findings.

Table 2. Robustness tests based on PSM-DID and balanced panel regressions

	PSM-DID		Balance-panel	
	(1)	(2)	(3)	(4)
VARIABLES	Eff	Eff	Eff	Eff
Policy	-0.0039***	-0.0019***	-0.0044***	-0.0022***
	(-5.54)	(-2.71)	(-6.48)	(-3.01)
Size		-0.0037***		-0.0023***
		(-11.18)		(-6.13)
Lev		0.0198***		0.0164***
		(8.46)		(5.83)
ROA		0.0335***		0.0201***
		(5.98)		(2.77)
Growth		0.0017**		0.0024***
		(2.53)		(3.08)
TobinQ		-0.0010***		-0.0005
		(-3.95)		(-1.38)
ldbl		-0.0002		-0.0004
		(-0.99)		(-1.39)
Constant	0.0447***	0.1188***	0.0456***	0.0834***
	(16.35)	(14.24)	(15.39)	(8.46)
Observations	14,983	14,983	10,136	9,936
Number of id	2,870	2,870	921	921
Industry FE	YES	YES	YES	YES
Province FE	YES	YES	YES	YES

4.4 Heterogeneity analysis

This paper further analyzes the heterogeneity of enterprises of different ownership types and different sizes to explore whether there are differences in different enterprise characteristics in terms of the impact of the construction of pilot cities combining science and technology with finance on the investment efficiency of enterprises.

4.4.1 Enterprise ownership heterogeneity

Due to the differences in the nature of property rights, there are significant differences between state-owned enterprises and non-state-owned enterprises in China in terms of business objectives, corporate governance and other aspects. In this paper, based on the differences in the nature of enterprise property rights, the sample is divided into two groups of state-owned enterprises and non-state-owned enterprises for regression, and the regression results are shown in Table 3. Columns (1) and (2) show the results of investment efficiency improvement of state-owned enterprises; columns (3) and (4) show the results of investment efficiency improvement of non-state-owned enterprises. The regression results show that the policy of combining science and technology with finance has a more obvious promotion effect on the investment efficiency of state-owned enterprises, but it is not significant in non-state-owned enterprises.

Table 3. Grouping test based on business ownership perspective

	State-owned enterprises		Non-state-owned enterprises	
	(1)	(2)	(3)	(4)
VARIABLES	Eff	Eff	Eff	Eff
Policy	-0.0052***	-0.0034***	-0.0017**	0.0001
	(-7.01)	(-3.98)	(-2.21)	(0.12)
Size		-0.0036***		-0.0035***
		(-8.07)		(-8.72)
Lev		0.0217***		0.0189***
		(6.90)		(6.86)
ROA		0.0439***		0.0200***
		(5.46)		(3.35)
Growth		0.0015*		0.0015**
		(1.68)		(2.02)
Board		0.0043**		-0.0034*
		(1.97)		(-1.69)
TobinQ		-0.0003		-0.0012***
		(-0.76)		(-4.63)
ldbl		-0.0005*		-0.0002
		(-1.71)		(-1.03)
Constant	0.0378***	0.1075***	0.0355***	0.1314***
	(54.20)	(9.37)	(54.24)	(12.67)
Observations	8,643	8,490	11,833	11,572
Number of id	1,028	1,027	2,099	2,099
Industry FE	NO	YES	NO	YES
Province FE	NO	YES	NO	YES

4.4.2 Firm size heterogeneity

This paper further examines the heterogeneity of policy effects that may result from differences in firm size. Specifically, this paper calculates the industry median assets, if the total assets of enterprises are above the industry median assets, they are classified as large enterprises, and vice versa, they are classified as small and medium-sized enterprises, and group regression is conducted, and the regression results are shown in Table 4. Columns (1) and (2) show the results of investment efficiency of large enterprises enhanced by the policy, and columns (3) and (4) demonstrate the extent to which the investment efficiency of SMEs is affected by the policy. Overall, it seems that the policy of combining science and technology with finance enhances the investment efficiency of large enterprises more and significantly, while this policy fails to significantly enhance the investment efficiency of SMEs.

The reasons for this are, firstly, because there is a certain threshold for scientific and technological innovation, large enterprises, which generally have been in business for a long time, are large in scale, have accumulated strong resources such as technology, capital and talents, and have relatively sound infrastructure and mature business models, tend to be more active in innovation and R&D activities. Second, large enterprises generally have longer operating histories and transaction histories with banks, and have better operating performance; therefore, large enterprises are more likely to obtain more financial resources in the construction of pilot cities combining science and technology with finance. However, the result reflects that although the introduction of science and technology financial policies can, to a certain extent, change the financing environment faced by SMEs, the introduction of science and technology financial policies has not significantly improved the efficiency of their resource allocation due to insufficient policy tilting and the lack of incentives for SMEs to transform.

Table 4. Grouping test based on firm size perspective

	Large enterprises		Small and medium-sized enterprises	
	(1)	(2)	(3)	(4)
VARIABLES	Eff	Eff	Eff	Eff
Policy	-0.0064***	-0.0058***	-0.0031***	-0.0009
	(-5.37)	(-4.23)	(-5.13)	(-1.37)
Size		-0.0025***		-0.0046***
		(-2.59)		(-11.34)
Lev		0.0318***		0.0195***
		(5.25)		(8.64)
ROA		0.0571***		0.0263***
		(3.90)		(5.15)
Growth		0.0038***		0.0007
		(3.27)		(1.06)
Board		-0.0001		-0.0015
		(-0.05)		(-0.88)
TobinQ		0.0019*		-0.0011***
		(1.67)		(-5.09)
ldbl		-0.0005		-0.0003*
		(-0.50)		(-1.93)
Constant	0.0403***	0.0945***	0.0369***	0.1413***
	(35.36)	(3.81)	(66.92)	(14.32)
Observations	3,667	3,626	16,809	16,436
Number of id	621	621	2,780	2,778
Industry FE	NO	YES	NO	YES
Province FE	NO	YES	NO	YES

5. Analysis of the impact mechanism

From the empirical results of the previous section, it can be seen that the implementation of science and technology financial policy has a significant role in improving corporate investment efficiency. In order to open the "black box" of science and technology financial policies affecting corporate investment efficiency, this paper explores the internal mechanism of the impact of policy implementation on corporate investment efficiency from three aspects: enterprise digital transformation, financing constraints and agency costs.

5.1 Enterprise digital transformation

This paper utilizes the formula (6) to test the impact of science and technology financial policies on corporate investment efficiency.

$$digital_{it} = \beta * post_t * treated_i + X_{it} * \gamma + u_i + \varepsilon_{it} \quad (4)$$

Table 5 presents the regression results for the Digital Transformation mechanism, with column (1) being the regression result of the firm's degree of digital transformation on Policy, column (2) further controlling for industry fixed effects and province fixed effects, and column (3) further including control variables. The regression results show that the estimated coefficient on Policy is significantly positive regardless of the form of regression performed. This suggests that the implementation of tech-finance policies helps to promote firms' digital transformation. By supporting the innovative activities of enterprises, science and technology finance enhances their innovative capabilities and promotes the application of more cutting-edge technologies to achieve faster and higher degrees of digital transformation. This paper argues that the policy of combining science and technology with finance can enhance the investment efficiency of enterprises by improving the degree of their digital transformation.

Table 5. Institutional analysis: digital transformation

VARIABLES	(1) digtial	(2) digtial	(3) digtial
Policy	0.1507***	0.1060***	0.1089***
	(8.58)	(5.98)	(5.44)
Size			0.0040
			(0.40)
Lev			-0.0182
			(-0.27)
ROA			0.2773*
			(1.80)
Growth			0.0186
			(1.07)
Board			-0.0527
			(-1.05)
TobinQ			-0.0035
			(-0.51)
ldbl			-0.0046
			(-1.16)
Constant	1.2486***	1.2401***	1.2400***
	(57.33)	(11.26)	(4.65)
Observations	26,634	26,634	24,310
Number of id	3,226	3,226	3,058
Industry FE	NO	YES	YES
Province FE	NO	YES	YES

5.2 Financing constraints

In this paper, the KZ index is chosen as a proxy variable to indicate the degree of financing constraints faced by enterprises, and the larger the KZ index, the higher the degree of enterprise financing constraints. Similar to the previous paper, this paper replaces the explanatory variables with the degree of financing constraints and regresses the policy dummy variables, and the regression results are shown in Table 6. The results show that the development of science and technology financial policies can significantly reduce the financing constraints faced by enterprises. Under the traditional financial system, it is difficult for science and technology enterprises to obtain bank loans due to the relatively low proportion of physical assets, high proportion of intangible assets and insufficient collateral, and it is also difficult for them to obtain external financing support due to the high risk of R&D activities. The science and technology financial policy can help alleviate the financing constraints of this part of the enterprises through the tendency to support the R&D activities, and then alleviate the under-investment brought by the financing constraints, and enhance the investment efficiency of the enterprises.

Table 6. Mechanism analysis: financing constraints

VARIABLES	(1) KZ	(2) KZ	(3) KZ
Policy	-0.0950***	-0.0725**	-0.1183***
	(-3.13)	(-2.34)	(-3.48)
Size			-0.0561***
			(-3.44)
Lev			2.1232***
			(18.68)
ROA			-3.3870***
			(-12.49)
Growth			0.0763**
			(2.45)
Board			-0.0883
			(-1.06)
TobinQ			-0.0099
			(-0.81)
ldbl			-0.0359***
			(-5.22)
Constant	0.6611***	0.6080***	1.6242***
	(16.68)	(2.63)	(3.84)
Observations	26,592	26,592	24,275
Number of id	3,220	3,220	3,052
Industry FE	NO	YES	YES
Province FE	NO	YES	YES

5.3 Agency costs

Existing research shows that in a frictional real-world environment, the severity of a firm's agency problem can seriously affect the investment efficiency of the firm. According to the theoretical analysis in the previous section, science and technology financial policies can reduce agency costs through three ways. First, the enhancement of information transparency is conducive to alleviating the agency problem, and science and technology financial policies can promote the disclosure of corporate information towards openness, transparency and timeliness, and play the role of incentives for enterprises to prevent managers from abusing their power. Second, through the establishment of risk compensation and risk-sharing mechanisms, it can alleviate the underinvestment due to risk avoidance by managers. Thirdly, through the introduction of investor supervision mechanism, managers are prompted to reduce self-reliant behavior.

Based on this, this paper uses the operating expense ratio as a measure of agency cost, the higher the company's operating expense ratio, the greater the agency cost between shareholders and management. The regression results in Table 7 show that regardless of the form of regression, the estimated coefficient of Policy is significantly positive, i.e., the development of science and technology financial policy can significantly reduce the agency cost of enterprises. Therefore, science and technology financial policies can reduce the agency costs of enterprises and ultimately improve the efficiency of enterprise investment.

Table 7. Mechanism analysis: agency costs

VARIABLES	(1) dlfy	(2) dlfy	(3) dlfy
Policy	-0.0570***	-0.0586***	0.0726***
	(-8.10)	(-8.31)	(9.96)
Size			-0.2061***
			(-54.84)
Lev			-0.1909***
			(-8.01)
ROA			-0.1179**
			(-2.22)
Growth			0.0392***
			(6.74)
Board			0.1019***
			(5.50)
TobinQ			0.0502***
			(21.27)
ldbl			-0.0267***
			(-19.26)
Constant	-2.6622***	-3.5400***	0.8707***
	(-195.01)	(-47.90)	(7.45)
Observations	26,133	26,133	24,036
Number of id	3,258	3,258	3,087
Industry FE	NO	YES	YES
Province FE	NO	YES	YES

6. Conclusion and Policy

Improving the mechanism of combining science and technology and finance is an important measure to promote the transformation and development of enterprises, and lead the real economy to improve quality and efficiency. On this basis, this paper takes the implementation of the policy of "Promoting the Pilot Combination of Science and Technology and Finance" as a quasi-natural experiment, selects the panel data of 3,468 non-financial listed companies in 2007-2019, and examines the impact of the implementation of science and technology financial policy on the investment efficiency of enterprises and the mechanism of the implementation of science and technology financial policy by adopting the asymptotic double-difference model. It is found that the implementation of science and technology financial policies significantly improves corporate investment efficiency, and the findings remain reliable after a series of robustness tests such as parallel trend test, placebo test, and PSM-DID. Heterogeneity analysis found that the promotion effect of science and technology financial policies on enterprise investment efficiency is mainly reflected in state-owned enterprises and large enterprises. Through the analysis of the mechanism of action, it is found that the implementation of science and technology financial policies mainly promotes the improvement of enterprise investment efficiency by promoting the digital transformation of enterprises, alleviating the problem of enterprise financing constraints, and reducing the agency cost of enterprises. The findings of this paper are of great significance for the construction of pilot cities combining science and technology with finance, the enhancement of enterprises' independent innovation capability and the construction of an innovative country.

Based on the above research conclusions, this paper puts forward the following policy recommendations: first, science and technology finance helps to improve enterprise investment efficiency, and should further strengthen the top-level design, continue to deepen the reform of the policy system for the effective combination of science and technology and finance, improve the match between financial supply and the real economy, and regulate and guide the healthy development of capital in accordance with the law. Second, the implementation of science and technology financial policies should strengthen the policy tilt for non-state-owned enterprises and small and medium-sized enterprises, strengthen the precision of the implementation of science and technology financial policies, and create a favorable environment conducive to the growth of science and technology-based small and medium-sized enterprises, so as to bring more opportunities and vitality to the development of enterprises. Thirdly, the digital transformation of enterprises is one of the important ways to bring into play the effects of the policy of combining science and technology with finance in the construction of pilot cities, so the implementation of the policy can take the promotion of scientific and technological innovation activities represented by the digital transformation as the focus point, and then drive the scientific, standardized and accurate enterprise investment decision-making.

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