Frontiers in Economics and Management Volume 5 Issue 10, 2024
ISSN: 2692-7608 DOI: 10.6981/FEM.202410_5(10).0002

Enterprise Technology Innovation and Total Factor Productivity -- Based on the Perspective of Enterprise Life Cycle

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Abstract

This article takes non-financial enterprises in China's A-share market as samples and explores the impact of technological innovation investment on total factor productivity from the perspective of enterprise lifecycle. Research has found that technological innovation investment in enterprises has a positive effect on total factor productivity in the introduction stage, growth stage, maturity stage, and elimination stage. Tthe intensity of its positive effect is stronger in the earlier stages of the enterprise's lifecycle, that is, the strongest in the introduction stage, followed by the growth stage, and gradually weakened in the mature stage and elimination stage. After discussing the samples, it was found that there is heterogeneity in the impact of technology innovation investment based on risk smoothing motivation and technology innovation investment inclined towards speculative profit seeking motivation on total factor productivity. After robustness testing, the original results remained significant. This study helps to explain the motivation behind technological innovation behavior in Chinese enterprises and provides practical reference for the investment intensity of technological innovation in enterprises at different stages of their lifecycle.

Keywords

Technological Innovation; Total Factor Productivity; Enterprise Lifecycle.

1. Introduction

Total factor productivity(TFP) and its influencing factors have always been a hot topic in the academic community. Domestic scholars Zuo Hui and Ai Danxiang (2022) pointed out that total factor productivity is the overall efficiency of converting total input into total output, which reflects the overall output level of all production factors in the production process of enterprises. Chen Lishan et al. (2021) believe that changes in total factor productivity are the result of technological improvements promoting efficiency gains. Scholars have studied the impact of enterprise technological innovation on total factor productivity from multiple perspectives. Liu et al. found that technological progress is the main driving force behind green total factor productivity[1]. Technological progress is the main factor in improving manufacturing efficiency[2]. Wang Yue and Liu Bingsickle believe that the flow of factors such as research and development capital has a positive impact on total factor productivity[3]. Wu Xiaoxu et al. found that independent innovation in the manufacturing industry can improve total factor productivity, but its effect is relatively low. The degree of coupling and coordination between independent innovation in the manufacturing industry in the eastern region is greater than that in the central and western regions. Wang Xiuting and Zhao Yulin's research shows that the R&D investment of the manufacturing industry itself is the main factor affecting total factor productivity, and the industry's R&D spillover effect is insufficient. Zhang Yanyan and Hu Shancheng measured the innovation level of various industries in the manufacturing industry

ISSN: 2692-7608 DOI: 10.6981/FEM.202410_5(10).0002

based on new product revenue, and found that innovation can improve green total factor productivity.

Based on existing literature, we can conclude that technological innovation in enterprises has a positive impact on total factor productivity. The theory of enterprise lifecycle holds that enterprises will go through different stages in their growth process, each with different characteristics. Does technological innovation have the same impact on the total factor productivity of enterprises in different stages of their lifecycle, as there are differences in their sensitivity to changes in external factors? In order to answer this questions, and taking into account the impact of the 2019 novel coronavirus epidemic on capital markets, this paper selects data from 2009 to 2018 as the research object. Based on 2329 non-financial listed companies and 9450 observations, this paper studies the impact of technological innovation on total factor productivity from the perspective of different life cycle stages.

2. Theoretical Analysis and Hypothesis Formulation

2.1. The Impact of Technological Innovation Investment on TFP of Enterprises

Scholars have different standards for dividing the life cycle of enterprises. This article draws on Dickinson's cash flow composition method to measure the stages of the enterprise's life cycle by combining the net cash flow of the three stages of operation, investment, and financing[4]. The specific classification criteria are shown in Table 1. When the financing cash flow is zero, according to the characteristics of operating cash flow and investment cash flow, it is included in the maturity period, elimination period, and decline period respectively; When the investment cash flow is zero, according to the characteristics of operating cash flow and financing cash flow, they are respectively included in the maturity period, elimination period, and decline period.

Table 1. Types of cash flow combinations for different stages of a company's lifecycle

Activities	Introduction	Growth	Maturity	Elimination	Elimination	Elimination	Decline	Decline
Operating	-	+	+	-	+	+	-	-
Investing	-	-	-	-	+	+	+	+
Financing	+	+	-	-	+	-	+	_

2.1.1. Import Period

The introduction period, also known as the start-up period, refers to the initial stage of a company's establishment. The main purpose of enterprises in this stage is to expand their production scale in order to establish themselves in the market. At this stage, the production capacity of the enterprise is weak, and the enterprise will maximize the use of its resources for activities such as asset purchase, equipment purchase, and talent recruitment. At this stage, the company also has limited funds and limited financing channels. The investment in technological innovation at this stage may, on the one hand, encroach on the funds used by the enterprise to expand production and business activities, and reduce the production capacity of the enterprise; On the other hand, at this stage, the level of technological innovation of the enterprise is relatively low. Therefore, investing funds in innovation activities can effectively enhance market competitiveness, improve the production capacity of the enterprise, and the marginal effect of innovation investment is also the strongest. Based on the research of previous scholars, we can conclude that enterprise technological innovation investment has a positive effect on total factor productivity in the start-up stage. After analysis, we can conclude that the marginal effect of enterprise innovation investment on total factor productivity is the strongest in this

ISSN: 2692-7608 DOI: 10.6981/FEM.202410_5(10).0002

stage. However, due to capital misappropriation, the intensity of its positive effect may be reduced.

2.1.2. Growth Period

Enterprises in this stage are in a stage of rapid development after accumulating capital during the introduction period. The goal of enterprises has also shifted from a stable foothold in the market to enhancing their own market influence ability. In addition, at this stage, the enterprise is relatively stable, and there will be more funds for innovation input and output. The innovation level of the enterprise will directly determine the scale and market competitiveness of the enterprise. Therefore, in this stage, compared to the start-up stage, enterprises will have more funds for technological innovation, and technological innovation has a positive impact on the total factor productivity of enterprises.

2.1.3. Maturity Period

Enterprises entering the mature stage are the safest and most stable. At this stage, the sales speed of the enterprise will decrease, but after the initial development, the enterprise has stable sales channels, a certain market share, and high social awareness. Therefore, the performance level of the enterprise will reach its peak and the overall cash flow situation will be good. At this stage, enterprises have relatively abundant funds for technological innovation investment without affecting normal production and operation; On the other hand, due to the relatively mature market products at this stage, market competition situation, the difficulty of converting enterprise innovation investment into substantive output will increase. Therefore, the positive impact of enterprise technological innovation investment on total factor production capacity needs further exploration.

2.1.4. Elimination Period

At this stage, the business operation of the enterprise shows a trend of decline, deterioration, and even some losses. However, based on the current situation of the enterprise and its ability to bear losses, it is possible to reverse the current unfavorable situation of the enterprise. In order for enterprises to return to the normal track of development, they must adjust their business strategy, re plan their production lines, and explore new growth points. At this stage, many enterprises choose to develop new products in hopes of improving the current situation, entering the seemingly new life cycle of the enterprise, and returning to the initial stage of the development cycle. Therefore, at this stage, enterprises will still invest in technological innovation. When investing in technological innovation, on the one hand, they are limited by the current unfavorable operating conditions of the enterprise, and on the other hand, there will be an urgent need to improve the current situation and increase the opportunity for innovation investment to be converted into output.

2.1.5. Decline Period

This stage is the last and most dangerous stage of the enterprise lifecycle. There are many reasons for entering this stage, such as improper management and operation, industry recession, or the impact of the macroeconomic environment. At this stage, the competitive advantage of the enterprise is replaced by other enterprises, the financial situation continues to deteriorate, the turnover of funds is not smooth, and losses continue to occur. The enterprise enters the stage of liquidation or bankruptcy, and begins to sell existing assets to recover cash flow. In this situation, the motivation for enterprises to engage in technological innovation is clearly lacking, and the ability of enterprises to convert innovation input into output is insufficient.

Based on the above theoretical analysis, this article proposes :

Hypothesis 1A: The impact intensity of enterprise technological innovation on total factor productivity increases with the development of the lifecycle;

ISSN: 2692-7608 DOI: 10.6981/FEM.202410_5(10).0002

Hypothesis 1B: The intensity of the impact of enterprise technological innovation on total factor productivity decreases with the development of the lifecycle.

2.2. Heterogeneity Analysis of the Impact of Enterprise Technological Innovation on TFP

Different enterprises may have different motivations for investing in technological innovation, therefore, the impact on total factor productivity may also be heterogeneous, and the degree of related impact may also vary.

2.2.1. Classification of Financialization Degree

Corporate financialization can be understood and defined from two aspects: behavior and outcome. Firstly, from a behavioral perspective, corporate financialization is a resource allocation method adopted by enterprises that emphasizes capital operation, manifested as more use of corporate assets for investment rather than traditional production and operation activities; Secondly, from the perspective of results, financialization of enterprises means that their profits come more from investment and capital operations in non production and operation businesses, pursuing pure capital appreciation rather than operating profits. According to the proportion of corporate financial investment, it is divided into enterprises with high and low levels of financialization, with the median as the breakpoint. The measurement of corporate financialization is based on the research approach of Wang Hongjian et al. (2017), using (monetary funds=trading financial assets+available for sale financial assets+investment real estate+held to maturity investments+dividends receivable+interest receivable)/total assets of the enterprise.

From the perspective of the degree of enterprise financialization, enterprises can be divided into those with high and low levels of financialization. In order to pursue higher investment returns, enterprises choose to invest in financial assets. Financial investment has the characteristics of short investment term and high profit margin, but it has greater uncertainty and risk. The continuation of this short-sighted behavior will squeeze out the technological innovation investment applied by enterprises to their main business, weaken their core competitiveness, and create a serious problem of "shifting from reality to illusion", which is not conducive to the development of China's real economy. At this point, enterprises with a high degree of financialization are more likely to invest in technological innovation with the motivation of hedging the risks of some financial investments, based on the purpose of risk smoothing. On the other hand, enterprises with low levels of financialization also have a higher degree of dependence on fixed assets such as factories and machinery for production and operation. The more resources owned by enterprises will benefit the real economy, with the aim of improving their production capacity and continuously expanding their influence in the product market. This type of enterprise places more emphasis on its main business operations and prefers stable and safe production and business models, resulting in lower overall risks for the enterprise. However, due to the continuous intensification of market competition, in order for enterprises to further expand in the market, they must make breakthroughs in their existing technological level, which requires high technological innovation capabilities. At this point, the investment in technological innovation by such enterprises is mainly based on the mentality of speculation, in order to bring greater technological innovation output through smaller technological innovation investment speculation and strengthen the innovation of the enterprise. Based on this, the motivation for companies with low levels of financialization to invest in technological innovation is based on speculative profit seeking motivation.

2.2.2. Classification from the Perspective of Equity Nature

From the perspective of equity nature, different types of enterprises may lead to differences in their motivation to invest in technological innovation, thereby having a differential impact on

ISSN: 2692-7608 DOI: 10.6981/FEM.202410_5(10).0002

their total factor productivity. On the one hand, the income from fixed assets investment of state-owned enterprises is generally lower than that of non-state-owned enterprises, and most of them are large in scale and stable in main business performance, but their potential development ability is low. Compared to non-state-owned enterprises, their funding sources are more secure, they have stronger financing advantages, lower financing costs, and their production and operation activities have a certain national policy orientation, with the support of the state. Based on the above reasons, state-owned enterprises tend to maintain their current stable state, and their motivation to expand their scale is not strong. Therefore, state-owned enterprises have lower motivation for technological innovation, and their long-term guaranteed production and operation model will also affect their ability to convert technological innovation into production. At this time, state-owned enterprises mainly invest in technological innovation based on speculative profit seeking motives. The market competition environment for non-state-owned enterprises is fierce, facing the problem of "difficult and expensive financing" and higher operating costs. In order to maintain normal production and operation, enterprises will choose to invest idle funds in high-risk projects with short terms and considerable returns. Compared to such projects, the relative risk of technological innovation investment is smaller. Converting technological innovation investment into technological innovation output can reduce the production cost of enterprises, Improve profit margins and expand market share. Therefore, in this situation, non-state-owned enterprises invest more in technological innovation for the purpose of risk smoothing.

Based on this, this article proposes:

Assumption 2: There is heterogeneity in the impact of technological innovation investment on total factor productivity between enterprises with speculative profit seeking motivation and risk smoothing motivation.

3. Research Design

3.1. Sample Selection and Data Sources

Considering the impact of the COVID-19 on enterprises' technological innovation investment in 2019 and subsequent years, this paper uses the initial sample of listed companies in China's A-share market not studied from 2009 to 2018. This article mainly focuses on non-financial enterprises, thus excluding listed companies in the financial industry. Considering the completeness and accessibility of the data, listed companies with missing parts of the sample data were excluded. In order to make the sample data more representative, companies with insufficient assets were excluded. A total of 2329 listed companies were ultimately used for research, with a total of 9450 observations. Among them, the financial data related to listed companies are all from the Guoan Taian Financial Research Database. In order to mitigate the potential impact of extreme values on the study, this paper applied 1% and 99% truncation to all continuous variables in the model.

3.2. Variable Selection and Description

3.2.1. Classification from the Perspective of Equity Nature

Olley and Pakes (1996) first proposed a two-step estimation method to overcome endogeneity: using investment level as a proxy variable for productivity. This method has been further improved by Levinsohn and Petrin (2003) and Ackerberg, Caves, and Frazer (2015). Wooldridge (2009) proposed a one-step estimation method: obtaining Levinsohn Petrin (LP) estimation results within the GMM framework. Referring to existing literature, this article also uses two methods, the OP method and the LP method, to measure the total factor productivity of enterprises. Drawing on the methods of Lu Xiaodong and Lian Yujun (2012), Liu Liya et al. (2018), this paper estimates the following model using the OP method[5], as shown in (1):

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$$LnY_{i,t}=\beta_0+\beta_k lnK_{i,t}+\beta_t lnL_{i,t}+\beta_m lnM_{i,t}+\beta_a Age_{i,t}+\beta_p POE_{i,t}+\Sigma_m\delta_m Year_j+\Sigma_n\lambda_n Prov_n+\Sigma_k\gamma_k Ind_k+\varepsilon_{i,t} \quad (1)$$

Among them, $Y_{i,t}$ represents sales revenue; $K_{i,t}$ is capital investment, measured by the book value of fixed assets; $L_{i,t}$ is labor input, measured by the number of employees in the enterprise; $M_{i,t}$ is an intermediate input, measured using the distribution method by subtracting labor compensation, operating surplus, depreciation, and net production tax from sales revenue; $Age_{i,t}$ is the age of the enterprise; $POE_{i,t}$ is a dummy variable to determine whether the enterprise is a private enterprise; Year, Prov, and Ind represent fixed effects of time, region, and industry, respectively; $\varepsilon_{i.t}$ is the residual term.

3.2.2. Explanatory Variables

One dimension of measuring enterprise technological innovation in existing literature is the technology investment indicator, which includes investment in research and development funds, investment in research and development personnel, and investment in fixed assets. Based on this, this article selects technological innovation investment (rd) as the explanatory variable. And referring to the practices of scholars such as Yang Guochao et al. (2017) and Kong Dongmin et al. (2017), the natural logarithm of R&D investment amount and the natural logarithm of effective invention patents were respectively used to measure[6]. In order to comprehensively measure the level of technological innovation in enterprises, referring to the relevant research of Jie Weimin and Fang Hongxing (2011), Liu Xin and Xue Youzhi (2015), this paper uses the relative index of R&D investment intensity (rda) to replace the original dependent variable of technological innovation investment (rd) for stability testing, and measures the proportion of R&D investment in total assets[7].

3.2.3. Control Variables

Following existing literature, this article introduces a total of six control variables that may have an impact on the total factor productivity of enterprises: (1) enterprise size(size), measured by the natural logarithm of total assets of the enterprise; (2) Financial leverage (lev), measured by dividing a company's total liabilities by owner's equity; (3) Enterprise growth(grow), measured by the growth rate of operating revenue; (4) Share concentration(share), measured by the proportion of shares held by the largest shareholder; (5) Board structure(Board), measured by the proportion of independent directors in the board of directors; (6) Salary incentives (ip), measured by the total annual salaries of directors, supervisors, and executives. The specific description of the variables is shown in Table 2.

Table 2. Detailed Description of Control Variables

Variable type	Variable symbol	Description of the variable
Dependent variable	TFP_LP	Calculated by the LP method
	TFP_OP	Calculated by the OP method
Explanatory variables	rd	Log(R&D investment)
	rda	R&D investment/total assets
Control variables	size	Log(total assets)
	lev	Total Liabilities/Owners' Equity
	grow	Growth rate of operating income
	share	The shareholding ratio of the largest shareholder
	board	Proportion of independent directors on the board of directors
	ip	The total annual salaries of directors, supervisors and senior executives

ISSN: 2692-7608 DOI: 10.6981/FEM.202410_5(10).0002

3.2.4. Descriptive Statistical Characteristics

Table 3. Descriptive statistical results of variables

Variable	N	Mean	SD	Min	p50	Max
TFP_LP	9540	8.003	0.838	5.162	7.936	12.431
TFP_OP	9450	6.344	0.692	4.033	6.28	10.282
rd	9450	17.586	1.208	13.731	17.6	20.600
rda	9450	0.024	0.019	0.000	0.02	0.107
size	9450	21.681	0.943	19.886	21.594	24.512
lev	9450	0.459	0.258	0.047	0.428	0.984
grow	9450	0.02	0.004	-0.004	0.001	0.020
share	9450	0.335	0.140	0.089	0.315	0.709
board	9450	0.376	0.053	0.333	0.333	0.571
ip	9450	0.049	0.036	0.009	0.038	0.218

Olley and Pakes (1996) According to the descriptive statistical results in Table 3, the mean total factor productivity calculated using the LP method is not 8.003, which is higher than the OP method's 6.344, and the median values are 7.936 and 6.280, respectively, indicating that the results are not significantly skewed. The mean values of technological innovation investment in rd and rda are 17.586 and 0.024, respectively, with median values of 17.600 and 0.020, indicating no significant skewness.

Table 4. Results of variable correlation test

	TFP_LP	rd	size	lev	grow	share	board	ip
TFP_LP	1							
rd	0.531***	1						
size	0.753***	0.542***	1					
lev	0.364***	0.191***	0.376***	1				
grow	0.127***	0.080***	0.059***	0.059***	1			
share	0.116***	-0.01	0.116***	0.014	-0.054***	1		
board	-0.043***	-0.009	-0.039	-0.018*	-0.016	0.058***	1	
ip	0.462***	0.439***	0.496***	0.126***	0.029***	-0.044***	0.327***	1

The results of the sex test in Table 4 show that the correlation between variables is basically significant. There is a strong positive correlation between Size and total factor productivity of enterprises. Based on the classification discussion of different lifecycle stages, this article can effectively weaken the correlation between the two.

3.3. Design of Benchmark Regression Model

In order to explore the impact of non-financial enterprise technological innovation behavior on total factor productivity, a model (2) was constructed based on research hypotheses, with total factor productivity (TFP_LP) as the dependent variable and enterprise technological innovation investment (rd) as the explanatory variable. Considering the lag effect of non-financial enterprise technology innovation investment on total factor productivity, the model (3) that

ISSN: 2692-7608 DOI: 10.6981/FEM.202410_5(10).0002

uses the previous period's technology innovation investment (prd) to replace the original explanatory variable (TFP_LP) for estimation is shown below.

$$TFP\_LP_{it} = \alpha_0 - \alpha_1 rd_{it} + \alpha_j\ control_{it} + year_t + cp_i + \varepsilon_{it} \quad (2)$$

$$TFP\_LP_{it} = \alpha_0 - \alpha_1 prd_{it} + \alpha_j\ control_{it} + year_t + cp_i + \varepsilon_{it} \quad (3)$$

4. Empirical Analysis and Testing

4.1. Analysis of Benchmark Model Estimation Results

Table 5. OLS Model Regression Results

TFP-LP	introduction	Growth	Maturity	Elimination	Decline
rd	0.191***	0.188***	0.111***	0.101***	0.08
	2.601	5.864	5.087	2.721	1.342
contral	√	√	√	√	√
id fe	√	√	√	√	√
year fe	√	√	√	√	√
N	1052	3113	3888	971	426
R^2	0.622	0.635	0.621	0.579	0.331
TFP-LP	introduction	Growth	Maturity	Elimination	Decline
prd	0.157	0.102***	0.166***	-0.045	-0.123
	1.04	2.03	5.26	-0.78	---
contral	√	√	√	√	√
id fe	√	√	√	√	√
year fe	√	√	√	√	√
N	193	1006	1451	118	43
R^2	0.665	0.656	0.5900	0.928	1

Table 5 shows the OLS estimation results of the impact of technological innovation investment and total factor productivity on non-financial enterprises at different stages of their lifecycle. The estimation results from the first four stages show that the explanatory variable of technological innovation investment in enterprises has a positive effect on their total factor productivity, and the results are highly significant. From a horizontal comparison, its positive correlation is strongest in the initial stage of the enterprise, with each unit of enterprise's technological innovation investment increasing total factor productivity by 19.1% and a growth stage of 18.8%. With the development of enterprises and the transition of subsequent life cycle stages, the positive effect has significantly decreased. In the mature stage, the positive effect of one unit of technological innovation investment on the total factor productivity of enterprises is 11.1%, and in the elimination stage it is 10.1%. However, the two are still significantly positively correlated. From the perspective of lagged effects, as measured by the technological innovation investment of enterprises in the previous year, the total factor productivity of this year only shows a significant positive correlation in the growth and maturity stages, while the results are not significant in the other three stages. The lag effect of technological innovation investment only exists in the growth and maturity stages, and the positive correlation disappears in the introduction and elimination stages of enterprises.

ISSN: 2692-7608 DOI: 10.6981/FEM.202410_5(10).0002

In summary, technological innovation investment shows a significant positive correlation with the total factor productivity of enterprises in the normal development stage. The earlier the enterprise develops, the more significant the effect of technological innovation investment on improving the current total factor productivity of enterprises. And the positive correlation has a sustained effect in the growth and maturity stages of enterprises, that is, the investment in technological innovation this year still has a positive effect on the total factor productivity of the next year. For enterprises in the introduction and elimination stages, in order to quickly expand their scale in the introduction stage and enter the subsequent development stage, or in the elimination stage, they strive to return to the normal development stage to save the enterprise from a precarious situation, The conversion of technological innovation investment into output efficiency will be higher, and its technological innovation investment is mainly reflected in the current total factor productivity, with its continuity disappearing.

4.2. Robustness Discussion

4.2.1. Alternative Explanatory Variable Model Estimation

Considering the issues of omitted variables and measurement bias, this article also uses the relative indicator of R&D investment as a proportion of total assets (rda) to replace the original explanatory variable of technological innovation investment (rd). According to Table 6, the positive impact intensity of enterprise technological innovation investment on different lifecycle stages is consistent with the previous results showing a downward trend. In the lag test, the significance of the growth stage disappears and only shows a significant positive correlation in the mature stage. But overall, the regression results are basically consistent with the original model, indicating that the original conclusion has a certain degree of robustness.

Table 6. Estimated results of alternative explanatory variable model

TFP-LP	introduction	Growth	Maturity	Elimination	Decline
rda	9.074***	8.239***	5.551***	5.285***	3.901
	3.483	7.162	4.883	2.591	1.060
contral	√	√	√	√	√
id fe	√	√	√	√	√
year fe	√	√	√	√	√
N	1052	3113	3888	971	426
R^2	0.613	0.632	0.620	0.580	0.323
TFP-LP	introduction	Growth	Maturity	Elimination	Decline
prda	-4.091	-0.262	3.692***	-0.861	0.25
	-1.521	-0.142	2.943	-0.096	---
contral	√	√	√	√	√
id fe	√	√	√	√	√
year fe	√	√	√	√	√
N	194	1006	1451	118	43
R^2	0.665	0.648	0.563	0.926	1

4.2.2. Model Estimation of Alternative Dependent Variables

Considering the issues of omitted variables and measurement bias, this article also uses the total factor productivity (TFP_OP) calculated using the OP method to replace the original dependent variable (TFP_LP). In the regression results of Table 7, the regression coefficient of

ISSN: 2692-7608 DOI: 10.6981/FEM.202410_5(10).0002

0.11 in the introduction stage is slightly smaller than 0.15 in the growth stage, which is different from the original regression results in a decreasing positive effect with the development of the enterprise lifecycle. In addition, all other regression results and trends are consistent with the original regression results, indicating that the original conclusion has a certain degree of stability.

Table 7. Estimated results of the substitute dependent variable model

TFP-OP	introduction	Growth	Maturity	Elimination	Decline
rd	0.111***	0.147***	0.076***	0.061	0.017
	1.756	5.036	3.964	1.404	0.273
contral	√	√	√	√	√
id fe	√	√	√	√	√
year fe	√	√	√	√	√
N	1052	3113	3888	971	426
R^2	0.543	0.536	0.545	0.441	0.213
TFP-OP	introduction	Growth	Maturity	Elimination	Decline
rda	0.135	0.075	0.138***	-0.043	0.202
	1.110	1.634	4.542	-0.912	---
contral	√	√	√	√	√
id fe	√	√	√	√	√
year fe	√	√	√	√	√
N	194	1006	1451	118	43
R^2	0.643	0.566	0.534	0.964	1

4.2.3. Sample Subinterval Model Estimation Descriptive Statistical Characteristics

Table 8. Sample Subinterval Model Estimation Results

TFP-OP	introduction	Growth	Maturity	Elimination	Decline
rd	0.200***	0.156***	0.106***	0.104**	0.09
	2.514	4.382	4.426	2.004	1.376
contral	√	√	√	√	√
id fe	√	√	√	√	√
year fe	√	√	√	√	√
N	948	2893	3540	929	411
R^2	0.525	0.586	0.602	0.517	0.317
TFP-OP	introduction	Growth	Maturity	Elimination	Decline
rda	0.168	0.077*	0.176***	-0.045	0.63
	1.132	1.584	5.093	-0.786	---
contral	√	√	√	√	√
id fe	√	√	√	√	√
year fe	√	√	√	√	√
N	189	969	1369	114	43
R^2	0.599	0.616	0.557	0.927	1

ISSN: 2692-7608 DOI: 10.6981/FEM.202410_5(10).0002

The financial crisis that occurred in 2008 has had a sustained impact on the technological innovation investment of Chinese enterprises. Therefore, excluding the three-year data from 2009, 2010, and 2011 after the financial crisis, the model estimation performance of the sample sub interval was examined, and the estimation results are shown in Table 8. It was found that the model estimation results were consistent with the previous conclusions, reflecting the robustness of the research findings.

4.2.4. Reduce Enterprise Sample Model Estimation

Most companies on the ChiNext board engage in high-tech businesses, with an average R&D intensity of 5% in recent years, which is higher than the average level of ordinary enterprises. Therefore, in order to exclude the particularity of enterprises on the ChiNext board and test the stability of the model conclusions, this article chooses to exclude the relevant sample data of the ChiNext board. By narrowing the sample range of enterprises, the model is estimated. The results shown in Table 9 show that the trend of the impact of enterprise innovation investment on total factor productivity at different stages is different from the original text. However, overall, the impact of enterprise innovation investment on total factor productivity is in the import stage The positive effect of the growth stage is still stronger than that of the mature stage and the elimination stage. Therefore, the conclusions obtained in the previous text are relatively reliable.

Table 9. Model estimation results for narrowing the sample range

TFP-OP	introduction	Growth	Maturity	Elimination	Decline
rd	0.134*	0.183***	0.090***	0.105***	0.042
	1.703	5.216	4.264	2.975	0.701
contral	√	√	√	√	√
id fe	√	√	√	√	√
year fe	√	√	√	√	√
N	701	2213	2933	771	330
R^2	0.594	0.635	0.611	0.618	0.321
TFP-OP	introduction	Growth	Maturity	Elimination	Decline
rda	0.295**	0.085**	0.124***	-0.046	0.63
	2.094	1.576	4.483	-0.784	---
contral	√	√	√	√	√
id fe	√	√	√	√	√
year fe	√	√	√	√	√
N	120	682	1132	100	39
R^2	0.866	0.695	0.541	0.928	1

4.3. Heterogeneity Analysis

In order to explore the heterogeneity of the impact of enterprise technological innovation investment on total factor productivity, a sample wise regression was conducted based on the previous analysis and research design, and the benchmark model estimation results of the two component samples were obtained.

ISSN: 2692-7608 DOI: 10.6981/FEM.202410_5(10).0002

4.3.1. Classification of Financialization Degree

Table 10. Estimation results of models classified by degree of financialization

Panel A: high degree of financialization					
TFP-OP	introduction	Growth	Maturity	Elimination	Decline
rd	0.346***	0.146***	0.139***	0.134**	-0.113
	4.423	2.574	4.123	2.324	-1.235
contral	√	√	√	√	√
id fe	√	√	√	√	√
year fe	√	√	√	√	√
N	395	1358	2052	609	207
R^2	0.777	0.646	0.667	0.632	0.515
PanelB: low degree of financialization					
TFP-OP	introduction	Growth	Maturity	Elimination	Decline
rda	0.129	0.133***	0.549**	0.096***	0.519
	1.493	4.132	2.506	3.351	3.362
contral	√	√	√	√	√
id fe	√	√	√	√	√
year fe	√	√	√	√	√
N	657	1755	1836	362	219
R^2	0.600	0.640	0.537	0.716	0.700

From the perspective of the degree of financialization, the differences between enterprises may affect the motivation for technological innovation investment, and thus have different impacts on the total factor productivity of enterprises. From the regression results in Table 10, it can be seen that regardless of whether the degree of financialization is low or high, the positive effect of technological innovation investment on total factor productivity is basically significant for enterprises. From a horizontal comparison, at each stage of the lifecycle, enterprises with high financialization have a greater impact on total factor productivity through technological innovation investment. Because companies with a high degree of financialization allocate more of their resources to high-risk financial investment activities, financial investment has greater uncertainty and risk compared to other investments. Enterprise technology innovation investment is based on hedging the risks of some financialization investments and smoothing out risks. In addition, enterprises with low levels of financialization are expected to achieve greater technological innovation output through leverage effects and less speculative investment in technological innovation, enhancing their innovation and expanding their market share. At this point, it is mainly based on speculative behavior for technological innovation. From the above table, it can be estimated that the impact of technological innovation investment on the total factor productivity of this type of enterprise is still positive in each lifecycle stage, indicating that technological innovation investment has a promoting effect on the total factor productivity of enterprises with low financialization.

ISSN: 2692-7608 DOI: 10.6981/FEM.202410_5(10).0002

4.3.2. Classification of equity nature

Table 11. Estimated results of the model classified by equity nature

Panel A: State-owned enterprises					
TFP-OP	introduction	Growth	Maturity	Elimination	Decline
rd	0.017	0.082**	0.358*	0.053	0.064
	0.316	2.231	1.713	1.324	0.612
contral	√	√	√	√	√
id fe	√	√	√	√	√
year fe	√	√	√	√	√
N	196	527	969	225	122
R^2	0.614	0.578	0.488	0.803	0.608
PanelB: Non-state-owned enterprises					
TFP-OP	introduction	Growth	Maturity	Elimination	Decline
rda	0.275***	0.206***	0.160**	0.212***	0.081
	4.593	5.423	5.400	4.127	1.084
contral	√	√	√	√	√
id fe	√	√	√	√	√
year fe	√	√	√	√	√
N	856	2586	2919	746	304
R2	0.676	0.646	0.661	0.630	0.298

From the regression results in Table 11, after classification by equity nature, it can be seen that for state-owned enterprises, the significant decrease in the impact of technological innovation investment on their total factor productivity is more significant, only showing a weak positive correlation in the growth stage. For non-state-owned enterprises, there is a significant positive correlation in the first four lifecycle stages, with a coefficient significantly higher than that of state-owned enterprises. Moreover, the impact of innovation investment on total factor productivity is strongest in the initial stage of the enterprise, and gradually decreases with the development of the enterprise. Based on the motivation of enterprise technological innovation investment, state-owned enterprises have stronger stability, and their development relies more on state investment in enterprises. Their motivation for technological innovation is lower, so their investment in technological innovation is mainly based on speculative profit seeking motivation. Non state-owned enterprises face a severe market competition environment, with limited funding sources and high capital costs, forcing them to invest idle funds in high-risk and high-yield projects. Therefore, the overall risk of the enterprise is relatively high. Compared to other investment activities conducted by enterprises, technological innovation investment has lower risks, and the conversion of technological innovation investment into technological innovation output can improve the innovation of enterprises and help them produce differentiated products. Based on this, non-state-owned enterprises mainly hedge the risk smoothing motivation of daily high-risk investment activities by investing in technological innovation.

In the inter group comparison results, it can be concluded that the coefficients of non-state-owned enterprises are greater than those of state-owned enterprises. This indicates that the impact of technology innovation investment in non-state-owned enterprises with a tendency towards risk smoothing motivation on total factor productivity is greater than that of technology innovation investment in state-owned enterprises with a tendency towards speculative profit seeking motivation on total factor productivity.

In summary, from the perspectives of corporate financialization degree and corporate equity nature, it is found through sample discussions that there is heterogeneity in the impact of technological innovation investment inclined towards speculative profit seeking motivation and technological innovation investment inclined towards risk smoothing motivation on total factor productivity, which verifies hypothesis 2. The impact of technological innovation investment inclined towards risk smoothing motivation on total factor productivity is greater than that inclined towards speculative profit seeking motivation.

5. Conclusion

This article is based on panel data of non-financial enterprises in the Chinese A-share market from 2009 to 2018, exploring the impact of technological innovation investment on the total factor productivity of enterprises in different stages of their lifecycle. After empirical analysis, it was found that the investment in technological innovation of enterprises is significantly positively correlated with the total factor productivity of enterprises in the introduction stage, growth stage, maturity stage, and launch stage, that is, the investment in technological innovation of enterprises can improve their total factor productivity. And its impact gradually weakens with the backward development of the lifecycle, that is, the improvement of the total factor productivity of enterprises in the introduction stage is the greatest for each unit of innovation investment in enterprise technology, and weakens in the growth stage, mature stage, and elimination stage in sequence. In addition, robustness tests were conducted on alternative explanatory variable model estimation, alternative dependent variable model estimation, sample sub interval model estimation, and reduced enterprise sample model estimation, and the results were generally consistent with the previous text, proving the robustness of the original results. After discussing the samples, it was found that technological innovation investment in enterprises still has a positive effect on total factor productivity. However, there is heterogeneity in the impact of technological innovation investment inclined towards risk smoothing motivation and speculative profit seeking on total factor productivity. The estimation results show that the impact of technological innovation investment on total factor productivity is stronger in enterprises with high degree of financialization than in enterprises with low degree of financialization, and stronger in non-state-owned enterprises than state-owned enterprises. Therefore, it can be concluded that the impact of technological innovation investment driven by risk smoothing motivation on total factor production is stronger at all stages than that of technological innovation investment driven by speculation and profit seeking.

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