

Nonlinear Relationship Between R&D Investment and Financial Performance of Listed Manufacturing Companies Against the Background of the COVID-19 Pandemic

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This study conducts an empirical analysis on the influence of lagged R&D investment on the financial performance of manufacturing companies listed on mainland China exchanges (A-shares) from 2015 to 2023. It investigates the dynamic relationship between R&D investment and financial performance during the COVID-19 pandemic. First, it examines the relationship between R&D investment and financial performance in the manufacturing companies of different ownership structures. It concludes that a lag in R&D investment will significantly affect financial performance and their relationship follows an inverted “U”-shape pattern. Second, it found that the COVID-19 pandemic disrupted this inverted “U”-shaped relationship. Third, it discovered that in non-state-owned manufacturing companies, the inverted “U”-shaped relationship between R&D investment and financial performance is significant, while this relationship is not significant in state-owned manufacturing companies.

Keywords: *R&D Investment; Financial Performance; Inverted “U”-shaped Relationship.*

Introduction

The report of the 20th National Congress of the Communist Party of China (CPC) clearly indicates that in the past decade, remarkable progress has been made in China's pursuit of self-reliance and strength in science and technology. The expenditure on R&D across the society has witnessed a significant increase, rapidly growing from one trillion yuan to 2.8 trillion yuan, ranking the second in the world. Meanwhile, the total number of R&D personnel in China has also risen to the top in the world. Currently, China is in an important stage of rapid development, and the development situation of manufacturing enterprises plays a crucial role in China's R&D innovation and continuous progress. As an important pillar of the national economy, the R&D capabilities and development level of manufacturing enterprises are directly related to the enhancement of the country's overall scientific and technological strength, as well as its position and influence in international competition.

Only when R&D investment can truly bring obvious advantages and considerable profits to enterprises, will enterprises pay attention to R&D investment. This is because the primary goal of an enterprise is to achieve profitability and sustainable development, and R&D investment often requires a large amount of capital and time costs. Numerous studies have shown that scientific research activities and technological R&D investment can bring high returns to enterprises. Specifically, enterprises can reduce the production cost of products and improve production efficiency through process technology innovation, thereby enhancing the profitability of enterprises. At the same time, through product innovation, enterprises can launch products with the heterogeneity and rarity of new types of products

to meet the diverse needs of the market, enhance consumers' purchase intention, and thereby improve the core competitiveness of enterprises (Yang *et al.*, 2021). It should be noted that although the increase in R&D investment can improve the financial performance of enterprises, this process is not achieved overnight. The R&D activities of enterprises often require a relatively long period of time, and the realization of new products and new technologies also takes some time. There is a lag in the impact on financial performance, and enterprises need to have enough patience and a long-term perspective to treat R&D investment (Guo *et al.*, 2020). In addition, R&D investment is not the more the better. In fact, there is a "inverted V-shaped" nonlinear relationship between R&D investment and financial performance. If the R&D investment is too high, it may have an adverse impact on the growth of enterprises. Excessive R&D investment will occupy a large amount of capital, resulting in the impact on the operation of other aspects of the enterprise, and then affecting the overall development of the enterprise. Managers of listed companies should make appropriate R&D investment and grasp the reasonable range of R&D intensity. Otherwise, excessive R&D investment may lead to excessive capital occupation, thereby reducing profits and affecting the development prospects of enterprises (Zhang *et al.*, 2015; Wang *et al.*, 2021).

While many studies have focused on the relationship between R&D investment and financial performance, some of their findings are contradictory. Therefore, we need to analyze various conclusions reached by the scholars. This study will explore several aspects concerning the relationship between R&D investment and financial performance. Lag Effect of R&D Investment: Given the long-term nature of R&D activities, new research outcomes

take time to be applied on products and generate returns. This study will consider the impact of lagged R&D investment on companies' financial performance; Balance of R&D Investment: R&D activities involve substantial capital investment. The relationship between R&D investment and financial performance exhibits dual features; insufficient or excessive R&D spending can lead to suboptimal outcomes. Besides linear analysis, we also explore the non-linear relationship between R&D investment and companies' financial performance; Impact of the COVID-19 Pandemic: The global COVID-19 pandemic in 2020 has greatly affected industries worldwide. This study will examine its implications for Chinese manufacturing companies; Impacts of Different Ownership Structures: Different companies ownership may influence how R&D investment affects their financial performance. This study will categorize companies into state-owned enterprises (SOEs) and non-state-owned enterprises to investigate how R&D investment will affect the financial performance of companies with different ownership structures. This paper better explains the complex dynamics between R&D investment and companies' financial performance, thus contributing to companies' strategy making.

Literature Review

R&D investment is becoming more and more important to the development of enterprises. Relevant scholars have proved that R&D investment will have a significant impact on financial performance through research. As R&D has become the foundation for enterprises to gain a firm foothold in the fierce competition market, the correlation between R&D investment and enterprises' investment decisions, operation management and profit acquisition has gradually increased, and the relationship between R&D investment and financial performance has also received extensive attention. The existing research mainly has the following viewpoints:

(I) R&D investment is positively correlated with financial performance

Tao (2022) pointed out that when an enterprise successfully completes the R&D of new products or technologies and quickly gains an advantage in the market to the extent of monopolizing the market, the enterprise can obtain more substantial economic benefits, thereby promoting the improvement of its financial performance. Liu et al. (2022) believe that R&D activities can effectively help enterprises improve their technical level, continuously improve the production process of products and launch new products, so as to reduce product costs and gradually occupy the market to obtain excess returns. Yue & Meng (2022) analyzed 19 data-driven enterprises and found that the impact of R&D investment on financial performance of such enterprises is lagging, and it is positively correlated with the operation capacity of the second phase lag. Zheng & Chen (2021) believe that the greater the investment in R&D, the better the long-term sound development of the enterprise can be ensured, and the reform of enterprise productivity and technology can be continuously promoted to obtain higher quality products at lower cost and further improve financial performance. After analyzing 40 seed companies, Chen & He (2021) concluded that R&D

investment can promote the financial performance of enterprises lagging behind the second and third periods, and R&D investment is conducive to better development of enterprises in the future.

(II) R&D investment is negatively correlated with financial performance

Yang et al. (2023) believe that it is difficult for R&D investment to achieve results in the current period and there is great uncertainty to reach the expected level. By analyzing the data of A-share listed companies in Shanghai and Shenzhen from 2013 to 2020 in eight carbon trading pilot provinces and cities of Beijing, Shanghai, Chongqing, Tianjin, Shenzhen, Guangdong, Hubei and Fujian, it is found that R&D investment inhibits the financial performance of enterprises in the current period. Zheng et al. (2022) believe that there is an inverse impact between the scale of R&D and financial performance. Enterprises should not excessively invest in the number of R&D personnel. Excessive investment in the number of R&D personnel often leads to a significant reduction in work efficiency, with blurred responsibilities among personnel and a decline in work efficiency. Shao & Bo (2022) believe that R&D investment by manufacturing enterprises will have a reverse impact on financial performance in the short term, only high-quality internal control plays a good regulatory role. Chen et al. (2021) studied the data of environmental protection enterprises for four consecutive years and found that R&D investment would affect the financial performance of the current period and play a negative role. This is because R&D investment in the current period cannot be quickly transformed into results conducive to the development of enterprises, and more R&D expenditure will be paid in the current period, resulting in the decline of corporate profits, but it will be conducive to the development of enterprises in subsequent periods. Lin (2019) conducted a study on GEM listed companies and found that the lag effect of R&D investment would affect the financial performance of the current period and the next period, resulting in a significant decline in financial performance.

(III) R&D investment and financial performance is nonlinear relationship

Yang et al. (2010) took the high-tech listed enterprises in Taiwan's manufacturing industry as the research objects and discovered that there is a three-stage S-curve model relationship between the intensity of R&D investment and the profit level. That is, the intensity of R&D investment has a negative impact on the profit level in the first and third stages, and has a positive impact in the second stage. Dai & Cheng (2013) conducted a threshold regression analysis on China's industrial enterprises and concluded that there is a double-threshold effect of the intensity of R&D investment on the performance of enterprises, and only when the intensity of R&D investment reaches the first threshold value can it play a significant role in promoting the performance of enterprises. Liu (2022) analyzed listed enterprises in Guangdong Province and found that R&D investment has a significant triple threshold effect on financial performance in both the whole industry and private listed enterprises. The impact of R&D investment on

financial performance will vary with the different levels of R&D investment, and the overall structure will appear "S". When the intensity of R&D investment is at a higher or lower level, it will be conducive to the improvement of financial performance. Zhao et al. (2021), after studying the scientific and technological innovation enterprises, proposed that the relationship between R&D input and financial performance presents an inverted "V" shape, which has a threshold effect. At a lower R&D intensity, R&D output has the greatest elasticity, which can promote the development of financial performance. When R&D intensity exceeds a certain level, it will inhibit financial performance and will not bring higher enterprise growth.

Through the in-depth combing and analysis of the existing literature as mentioned above, it can be found that the current research community has achieved relatively rich and in-depth results in the study of the relationship between R&D investment and financial performance. However, there are still some inconsistent phenomena, which may be due to the significant differences in the industries, countries, and periods of the enterprises selected by scholars when conducting research. Enterprises in different industries, countries, and periods have significant differences in their development characteristics and environment, which may have an impact on the relationship between R&D investment and financial performance. Some scholars through a large number of empirical research and data analysis have found that R&D investment can have a positive promoting effect on financial performance, and can effectively enhance the profitability and market competitiveness of enterprises. Moreover, the promoting effect of R&D investment on financial performance may have a certain time lag, that is, R&D investment may not immediately show the improvement effect on financial performance in the short term, but after a period of accumulation and precipitation, its promoting effect on financial performance will gradually emerge. However, some scholars also believe that R&D investment may have an inhibitory effect on financial performance or there is a non-linear relationship between the two. This inconsistent view and research result further highlights the complexity and uncertainty of the relationship between R&D investment and financial performance. In view of the inconsistency of the existing research results, this paper takes manufacturing enterprises as the research starting point, and defines R&D investment from financial indicators and non-financial indicators respectively. At the same time, the impact of the lag period of R&D investment on financial performance is fully considered to accurately grasp the relationship between R&D investment and financial performance. Finally, this paper classifies the enterprises through the nature of property rights to study the relationship between R&D investment and financial performance in state-owned enterprises and non-state-owned enterprises.

Therefore, based on the above analysis, this paper takes A-share listed companies in China's manufacturing industry as the research object, starts from R&D investment, defines the R&D investment of enterprises with financial indicators and non-financial indicators respectively, conducts in-depth research on the complex relationship between them and financial performance, and further analyzes the relationship

between them from the perspectives of lag period and property nature. Some suggestions are provided for manufacturing enterprises to make more effective use of R&D investment to improve financial performance.

Research Hypotheses

According to the innovation theory, if an enterprise wants to gain a unique advantage in the market competition, R&D investment is the key. R&D investment is an important driving force for enterprise innovation and the core support for sustainable development. The reason why many leading enterprises in the world can maintain their leading position in the industry for a long time is precisely because they deeply understand the significance of innovation and regard R&D investment as the top priority of enterprise development. With their unique R&D capabilities, these enterprises constantly innovate and lead the development of the industry. Through continuous R&D investment, they maintain their leading position in the industry and transform R&D results into actual products and services to meet the needs of the market. In their study, Cheng & Liu Shiyu (2021) pointed out that R&D investment is a dynamic process, and its leaping change reflects the positive response of enterprises to changes in external environment, and is the result of enterprises actively perceiving external changes and making adjustments, which plays a positive role in promoting the financial performance of enterprises. For manufacturing enterprises, the importance of research and development investment is particularly prominent. As the core part of the real economy, manufacturing industry has a complex production process, a wide variety of products and fierce market competition. In this context, manufacturing enterprises must innovate if they want to gain a firm foothold in the fierce market competition, and R&D investment is an important way for enterprises to obtain new technologies and resources (Zheng & Li 2021). Through research and development investment, manufacturing enterprises can improve production processes and processes, improve production efficiency, reduce production costs, and thus produce more competitive products. At the same time, R&D investment can also help enterprises launch new products to meet the changing needs of consumers, further occupy market share and gain competitive advantage. However, the more research and development investment is not the better, and the relationship between it and the financial performance of enterprises is not simple and linear. On the one hand, moderate R&D investment can significantly promote the financial performance of enterprises. Research and development investment can lead to the improvement of production efficiency, product quality improvement, and the launch of new products, which will have a positive impact on the financial performance of enterprises. Especially when a company launches a new product, it can bring higher sales and profits, which can significantly improve the financial performance of the company. On the other hand, excessive R&D investment may inhibit the financial performance of enterprises (Zheng et al. 2023). This is because R&D investment requires sustained financial support, which is limited. When enterprises over-invest in research and development, it may crowd out investment in

other important areas, such as marketing, supply chain management, etc., thus affecting the overall operational efficiency of enterprises. In addition, research and development activities themselves have high risks and uncertainties. If the research and development project fails, the enterprise not only cannot get the expected return, but also may face huge losses. Therefore, excessive R&D investment may increase the financial risk and operational risk of enterprises, which will have a negative impact on financial performance.

Based on the above analysis, we can conclude that the impact of R&D investment on financial performance presents an inverted "U" shape. When the intensity of R&D investment is moderate, it can significantly promote the financial performance of enterprises. But when the intensity of R&D investment is too high, it will have an inhibitory effect on financial performance. Due to the lag effect of R&D investment, that is, the effect of R&D investment often needs to be shown in a period of time in the future, so this paper studies the impact of R&D investment on financial performance in the lag period. Based on the above analysis, we propose the following hypothesis:

H1: Lagged-period R&D investment will significantly affect a manufacturing company's financial performance, following an inverted "U"-shaped relationship.

The outbreak of the novel coronavirus has brought a huge impact on the global economy, and has also brought unprecedented challenges to China's manufacturing enterprises. In order to control the spread of the epidemic, the Chinese government took measures to completely shut down and delay the resumption of work at the early stage of the epidemic, resulting in the suspension of the production lines of a large number of manufacturing enterprises, and production activities were seriously affected. At the same time, the epidemic has had a severe impact on the global supply chain, and China's manufacturing industry, as part of the global industrial chain, has also been affected by supply chain disruptions. Due to the obstruction of production and transportation links, the supply of raw materials and parts is unstable, which further restricts the normal operation of manufacturing enterprises (He *et al.*, 2020; Zhao *et al.*, 2020). When the COVID-19 pandemic swept in, it brought tremendous impacts and severe challenges to manufacturing enterprises. Under such circumstances, many manufacturing enterprises actively and initiatively adjusted their production strategies and significantly increased their investment in automated production equipment and intelligent manufacturing technologies. After the introduction of advanced automation technology, manufacturing enterprises can more effectively reduce the intensity of manpower in the production process, while reducing the gathering of employees, thereby minimizing the risk of the spread of the epidemic to the greatest extent. Moreover, the benefits brought by this hardware equipment upgrade are not only the improvement of production efficiency, but also the further enhancement of the enterprise's ability to resist risks. In addition, while upgrading hardware equipment, manufacturing enterprises have also further increased their investment in innovation and research and development. Enterprises actively invest a large amount of research and development funds, dedicated

to developing more innovative production processes and technologies, striving to further improve production efficiency, optimize product quality, and minimize the dependence on human resources as much as possible. Through continuous research and development investment, manufacturing enterprises have the ability to develop more intelligent and automated production lines, making the originally labor-intensive production process become more efficient and stable. This not only significantly reduces labor costs, but also greatly improves the stability and reliability of the production line, enabling enterprises to maintain a leading position in the fierce market competition all the time. However, it is worth noting that the outbreak of the COVID-19 pandemic has further exacerbated the inverted "U"-shaped trend between the research and development investment and financial performance of manufacturing enterprises. On the one hand, moderate research and development investment can help manufacturing enterprises better cope with various challenges brought by the epidemic, improve production efficiency, product quality, and market competitiveness, thereby alleviating the negative impact of the epidemic on financial performance to a certain extent. On the other hand, excessive research and development investment may bring greater financial risks and operational risks to manufacturing enterprises. Under the impact of the COVID-19 pandemic, the capital chains of many manufacturing enterprises have become extremely tense. If excessive research and development is still invested at this time, it may further increase the financial pressure of the enterprise, and even lead to the enterprise falling into a difficult situation. In addition, the COVID-19 pandemic has also increased the uncertainty and risks of research and development activities. Due to the impact of the epidemic, many research and development projects may face a series of problems such as shortage of personnel and interruption of the supply chain, resulting in blocked or even failed research and development progress. This situation not only fails to bring the expected returns to enterprises, but also is very likely to bring huge losses to enterprises. Therefore, under the background of the COVID-19 pandemic, while manufacturing enterprises increase their research and development investment, they must more carefully evaluate the risks and benefits of research and development projects to avoid the occurrence of adverse consequences caused by excessive investment.

H2: The impact of the COVID-19 pandemic has strengthened the inverted "U"-shaped relationship between lagged-period R&D investment and financial performance.

Research Design

(1) Sample Selection and Data Sources

This study selects manufacturing companies listed in mainland China (A-shares) as the research sample. Data from 2015 to 2023 were filtered according to the following criteria: (1) Exclusion of financial and insurance companies; (2) Exclusion of ST and *ST listed companies; (3) Exclusion of companies with incomplete data; (4) Exclusion of delisted companies; (5) Trimming samples with continuous variables falling between 0 %-1 % and 99 %-100 %. We selected a total of 19,031 valid samples. Data for

relevant variables were sourced from the CSMAR database, and statistical analyses were primarily conducted with Excel 2019 and Stata 16.

(II) Variable Definition

1. Dependent Variable: The dependent variable is financial performance. This research adopted Return on Assets (ROA), an indicator of how profitable a company is relative to its assets, to evaluate financial performance. ROA measures the efficiency of both debt and equity assets. ROA is calculated by dividing a firm's net income by the average of its total assets.

2. Independent Variables: Independent variables include Research and Development Investment (Rd) and Research and Development Manpower (Rdman). This research assesses R&D investment through both financial and non-financial indicators. The financial indicator is the ratio of R&D expenditure to operating income (Rd), while the non-financial indicator is the ratio of R&D personnel to total

employees (Rdman). As the study focuses on the lagged impact of R&D investment on financial performance, (LRd) and (LRdman) are used to represent the lagged one-period R&D investment.

3. Moderating Variable: To examine the influence of R&D investment on financial performance under the impact of the COVID-19 pandemic, the study introduces a pandemic dummy variable, Covid. This variable is set as 1 after the outbreak of the pandemic in 2019 and 0 otherwise. Additionally, an interaction term, Covid×DTCG, is created to analyze the interaction between R&D investment and the pandemic.

4. Control Variables: Control variables in the study include the firm size (Size), the leverage ratio (Lev), the growth rate of revenue (Growth), the ownership concentration (Top1), the total asset turnover (Liqu), board size (Board), executive team size (Team), company listing age (Market), and year fixed effects (Year).

Table 1

Definitions and Explanations of Variables

Variable Name	Symbol	Definition
Dependent Variable	Financial Performance	<i>Roa</i>
		Net Profit / Average Total Assets, where Average Total Assets = (Total Assets at the End of the Year)
Independent Variables	Research and Development Investment	<i>LRd</i>
		Lagged One-Period Research and Development Expenditure / Operating Income
		<i>LRdman</i>
		Lagged One-Period R&D Personnel Number / Total Employee Number
Moderating Variable	COVID	<i>Covid</i>
		Assigned value of 1 after 2019, 0 otherwise
	Firm Size	<i>Size</i>
		Natural Logarithm of the Total Assets at the End of the Period
	Leverage Ratio	<i>Lev</i>
		Total Liabilities at the End of the Period / Total Assets
	Revenue Growth Rate	<i>Growth</i>
		Revenue Growth Amount / Total Revenue from the Previous Year
Control Variables	Ownership Concentration	<i>Top1</i>
		Percentage of Ownership by the Largest Shareholder
	Total Asset Turnover	<i>Liqu</i>
		Revenue / Average Total Assets
	Board Size	<i>Board</i>
		Natural Logarithm of the Number of Board Members
	Executive Team Size	<i>Team</i>
		Natural Logarithm of the Number of Executive Team Members
	Company Listing Age	<i>Market</i>
		Year of Company Listing
Other Variable	Property Rights	<i>Quality</i>
		Dummy Variable for Year
		Assigned value of 1 if the company is state-owned, 0 otherwise

(III) Model Design

To test the inverted “U”-shaped relationship between lagged R&D investment and current financial performance (H1), Model 1 is built as follows:

$$Roa_{i,t} = \alpha_0 + \alpha_1 Rd_{i,t-1} / Rdman_{i,t-1} + \alpha_2 Rd_{i,t-1}^2 / Rdman_{i,t-1}^2 + \alpha_3 Controls + \varepsilon_{i,t}$$

To examine how the COVID-19 pandemic affected the “U”-shaped relationship of lagged R&D investment and the financial performance (H2), Model 2 is formulated:

$$Roa_{i,t} = \alpha_0 + \alpha_1 Rd_{i,t-1} + \alpha_2 Rd_{i,t-1}^2 + \alpha_3 Covid_{i,t-1} + \alpha_4 Covid_{i,t} \times Rd_{i,t-1} + \alpha_5 Covid_{i,t} \times Rd_{i,t-1}^2 + \alpha_6 Controls + \varepsilon_{i,t}$$

Empirical Analysis

(I) Descriptive Statistics

Table 2 presents the descriptive statistics of the primary variables. According to the table, the financial performance

(Roa) ranges from a minimum of -0.162 to a maximum of 0.239, with a standard deviation of 0.062. This indicates that the financial performance of China's listed manufacturing companies vary a lot, even though the majority of those companies are profitable. R&D investment (Rd) ranges from a minimum of 0.001 to a maximum of 0.262, with a median value of 0.044. Meanwhile, R&D personnel ratio

(Rdman) spans from a minimum of 0.009 to a maximum of 0.592, with a median value of 0.136. These figures illustrate the discernible differences in R&D investment among manufacturing companies. The average value of property rights (Quality) at 0.173 suggests that the majority of the listed manufacturing companies are non-state owned.

Table 2

Descriptive Statistics of Key Variables

Variable Name	Observations	Mean	Standard Deviation	Minimum	Median	Maximum
Roa	19031	0.053	0.062	-0.162	0.050	0.239
Roe	19031	0.079	0.105	-0.388	0.080	0.363
Rd	19031	0.055	0.044	0.001	0.043	0.262
Rdman	19031	0.161	0.105	0.009	0.136	0.592
Size	19031	22.047	1.156	20.000	21.878	25.696
Lev	19031	0.365	0.178	0.056	0.354	0.773
Growth	19031	0.147	0.299	-0.446	0.104	1.544
Top1	19031	0.329	0.140	0.088	0.308	0.712

(II) Correlation Analysis

Table 3 presents the correlation analysis of the primary variables in this study. The quadratic term of lagged R&D investment (L.Rd2) is negatively correlated with the financial performance. This supports hypothesis 1. Most other

variables in Table 2 have passed the significance test at the 1% confidence level, with their respective correlation coefficients falling within the expected range. This suggests that the primary variables lack substantial multicollinearity. Therefore, these variables are suitable for regression analysis.

Table 3

Correlation Analysis of Key Variables

Variable Name	Roa	L.Rd	L.Rd2	Size	Lev	Growth	Top1
Roa	1.000						
L.Rd	-0.035***	1.000					
L.Rd2	-0.045***	0.930***	1.000				
Size	-0.047***	-0.172***	-0.109***	1.000			
Lev	-0.387***	-0.195***	-0.155***	0.503***	1.000		
Growth	0.320***	0.074***	0.067***	0.058***	0.078***	1.000	
Top1	0.173***	-0.119***	-0.098***	0.041***	-0.052***	-0.005	1.000

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

(III) Analysis of Regression Results

1. The Influence of Lagged R&D Investment on Financial Performance

As shown in Table 4, both lagged R&D expenditure (LRd) and lagged R&D personnel (LRdman) demonstrate significant positive effects at the 1 % significance level. Their respective quadratic terms (LRd2 and LRdman2) exhibit significant negative effects at the same level. These findings confirm the presence of an inverse "U"-shaped relationship between lagged R&D investment and financial performance.

To validate this inverse "U"-shaped relationship, the study follows a three-step method outlined by Lind and Mehlum (2010). Their research confirms such a relationship should satisfy three key criteria: first, the quadratic coefficient of the explanatory variable should be significantly negative and align with theoretical expectations. Second, the curve should display steep slopes at both ends of the explanatory variable's data-positive at the minimum sample value and negative at the maximum. Third, the curve's extremum point should lie in the observed

range of data points. This study adopts Lind and Mehlum's test command to validate the results.

First, verification was conducted on lagged R&D expenditure (LRd). The data reveals a critical point of 0.0835, which is within the LRd range (0.0013-0.2624). The curve shows a positive slope on the left (0.2294) and a negative slope on the right (-0.4992). Both are significant at the 1% level. This confirms the validity of the inverse "U"-shaped hypothesis. Furthermore, the study divides the data around the critical point ($LRd < 0.0835$ and $LRd > 0.0835$) to carry out additional regression analysis on financial performance (Roa) and lagged R&D expenditure (LRd). Related information is shown in column 2 and column 3 of Table 5. According to the results, when $LRd < 0.0835$, lagged R&D expenditure (LRd) will significantly enhance companies' financial performance at the 1 % level, suggesting a positive impact. Conversely, when $LRd > 0.0835$, lagged R&D expenditure (LRd) will significantly inhibit financial performance at the 1 % level, indicating a negative impact.

Second, verification was performed on lagged R&D personnel (LRdman). The data identifies a critical point of

0.2418, which is within the LRdman range (0.0095-0.5920). The curve shows a positive slope on the left (0.0623) and a negative slope on the right (-0.0939). Both are significant at the 1 % level. Similarly, the study divides the data around the critical point (LRdman < 0.2418 and LRdman > 0.2418) to conduct further regression analysis on financial performance (Roa) and lagged R&D personnel (LRdman). Related information is shown in column 5 and column 6 of Table 5. According to the results, when LRdman < 0.2418, lagged R&D personnel (LRdman) will significantly

enhance companies' financial performance at the 1 % level, indicating a positive impact. Conversely, when LRdman > 0.2418, lagged R&D personnel (LRdman) will significantly inhibit companies' financial performance at the 1 % level, suggesting a negative impact.

In summary, lagged R&D investment significantly influences the financial performance of companies, demonstrating a nonlinear inverse “U”-shaped relationship between the two variables. Hypothesis 2 is supported.

Table 4

The Influence of Lagged R&D Investment on Financial Performance

	(1) R&D expenditure	(2) LRd<0.0835	(3) LRd>0.0835	(4) R&D personnel	(5) LRdman<0.2418	(6) LRdman>0.2418
L.Rd	0.233*** (0.027)	0.141*** (0.024)	-0.125*** (0.022)			
L.Rd2	-1.395*** (0.116)					
L.Rdman				0.065*** (0.011)	0.030*** (0.008)	-0.043*** (0.011)
L.Rdman2				-0.134*** (0.021)		
Control	Yes	Yes	Yes	Yes	Yes	Yes
_cons	-2.507*** (0.138)	-2.536*** (0.143)	-1.696*** (0.454)	-2.519*** (0.138)	-2.365*** (0.145)	-3.743*** (0.441)
N	15990	13661	2329	15990	13542	2448
adj. R2	0.408	0.397	0.514	0.403	0.398	0.441

Note: Standard errors in parentheses
** p < 0.1, ** p < 0.05, *** p < 0.01 (The same below)*

2. The Moderating Effect of COVID-19 Pandemic

As depicted in Table 5, the quadratic term of lagged R&D expenditure (LRd2) and the interaction term between COVID-19 and the quadratic term of lagged R&D expenditure (Covid*LRd2) are both significantly negative

at the 1% level. Similarly, the interaction term between COVID-19 and the quadratic term of lagged R&D personnel (Covid*LRdman2) are also significantly negative at the 1% level. The COVID-19 pandemic affects the inverse “U”-shaped relationship between lagged R&D investment and financial performance, supporting Hypothesis 2.

Table 5

Impact of COVID-19 Pandemic on the Relationship between R&D Investment and Financial Performance

	(1) R&D expenditure	(2) R&D personnel
LRd	0.158*** (0.042)	
LRd2	-0.912*** (0.198)	
LRdman		0.001 (0.018)
LRdman2		0.004 (0.035)
Covid	-0.015*** (0.002)	-0.021*** (0.003)
Covid*LRd	0.112** (0.051)	
Covid*LRd2	-0.696*** (0.239)	
Covid*LRdman		0.102*** (0.022)
Covid*LRdman2		-0.213*** (0.044)
Control	Yes	Yes
_cons	-2.509*** (0.137)	-2.523*** (0.138)
N	15990	15990
adj. R2	0.409	0.404

Heterogeneity Analysis

Under the existing property rights system arrangement in China, state-owned property rights and non-state-owned property rights indeed have different impacts on the attitude of enterprise management towards R&D investment. Generally speaking, state-owned enterprises usually have more abundant financial strength, which makes them theoretically more capable of conducting large-scale R&D investment in the hope of creating more benefits for the enterprise. However, in practice, the management of state-owned enterprises may be affected by many factors, such as pursuing short-term performance and job promotion, and choosing some projects with a net present value less than zero for investment, which may lead to excessive investment and disorderly R&D and other adverse consequences. For non-state-owned enterprises, their funds are relatively limited, and the financed funds are also less, making their decision-making on R&D investment more cautious. As shown in Tables 7 and 8, the R&D investment of non-state-owned enterprises, whether current or lagged by one period, shows a significant inverted "U" relationship with financial performance, but for state-owned enterprises, this situation is not obvious, and further in-depth research is needed. In China's economic system, property rights nature, as one of the key factors affecting enterprise behavior patterns, its impact on enterprise R&D investment cannot be ignored. State-owned enterprises and non-state-owned enterprises have obvious differences in property rights ownership, resource acquisition, incentive mechanism, and risk assumption, which lead to different tendencies and effects in their R&D investment decisions. This not only has an important impact on the technological innovation ability and market competitiveness of enterprises, but also deeply reflects the shaping role of China's property rights system on the micro behavior of enterprises. State-owned enterprises, as the pillar force of the national economy, usually enjoy more advantages in terms of financial support and policy preferences. In theory, these advantages should be able to provide sufficient guarantee for their R&D investment and promote the technological progress and industrial upgrading of enterprises. But reality is often more complicated than theory. When the management of state-owned enterprises is faced with the pressure of performance assessment and job promotion, they may be more inclined to choose those R&D projects that can show results in the short term, even if the long-term benefits of these projects are not obvious, and even their net present value may be less than zero. This kind of "short-sighted" behavior may not

only lead to the waste of resources, but also may trigger a series of problems such as excessive investment and disorderly R&D, seriously hindering the sustainable development of enterprises. In addition, the complex principal-agent relationship within state-owned enterprises also makes the information asymmetry problem between the owner and the operator more prominent, further intensifying the irrationality of R&D investment decision-making. In contrast, non-state-owned enterprises show more caution and rationality in R&D investment. Due to the relatively limited source of funds and the lack of the convenience of direct government support, when non-state-owned enterprises decide whether to conduct R&D investment, they often need to go through more rigorous market analysis and risk assessment. They are more inclined to choose those R&D projects with clear market prospects, high rate of return and controllable risks to achieve the optimal allocation of resources and the maximization of benefits. As shown in Tables 7 and 8, there is a significant inverted "U" relationship between the R&D investment of non-state-owned enterprises and financial performance, that is, in the initial stage of R&D investment, as the investment increases, the financial performance of the enterprise will significantly improve; but when the R&D investment exceeds a certain critical point, continuing to increase the investment will instead lead to a decline in financial performance. This discovery not only verifies the market sensitivity and cost-benefit awareness of non-state-owned enterprises in R&D investment, but also provides very valuable inspiration for other enterprises. By in-depth analysis of the differences in R&D investment of enterprises under these two property rights natures, we can find that the root cause mainly lies in the different incentive mechanisms and risk assumption capabilities caused by the property rights system. Due to the ambiguous property rights ownership of state-owned enterprises, driven by the pursuit of personal career and short-term political achievements, the management often ignores the long-term benefits of R&D investment and the sustainable development of enterprises; while non-state-owned enterprises, due to clear property rights and interests directly related to themselves, the management will pay more attention to the economic benefits and long-term returns of the project when making decisions, thus forming a more rational and stable R&D investment strategy. This further highlights the important impact of the property rights system on the behavior of enterprise R&D investment, and also provides an important reference basis for us to deeply understand and optimize the decision-making of enterprise R&D investment.

Table 6

Heterogeneity Test Results of Lagged R&D Investment on Financial Performance

	(1) state-owned	(2) non-state-owned	(1) state-owned	(2) non-state-owned
LRd	0.020 (0.055)	0.290*** (0.030)		
LRd2	-0.261 (0.268)	-1.605*** (0.129)		
LRdman			0.018 (0.023)	0.086*** (0.013)
LRdman2			-0.046 (0.049)	-0.164*** (0.024)

	(1) state-owned	(2) non-state-owned	(1) state-owned	(2) non-state-owned
Control	Yes	Yes	Yes	Yes
_cons	-1.908*** (0.251)	-2.622*** (0.188)	-1.871*** (0.250)	-2.634*** (0.189)
N	2840	13150	2840	13150
adj. R2	0.352	0.427	0.351	0.421

Robustness Check

To enhance the precision of this study, we replaced Return on Assets (ROA) with Return on Equity (ROE). The explanatory and control variables were kept constant. Subsequently, a regression analysis on the relationship between R&D investment and financial performance was conducted. The results were consistent with those earlier in

this paper. As shown in Table 7, both lagged R&D expenditure (LRd) and lagged R&D personnel (LRdman) demonstrate significant positive effects at the 1 % significance level. Their respective quadratic terms (LRd2 and LRdman2) exhibit significant negative effects at the same level. These findings confirm the presence of an inverse “U”-shaped relationship between lagged R&D investment and financial performance.

Table 7

Robustness Check

	(1) Roe	(2) Roe
L.Rd	0.370*** (0.05)	
L.Rd2	-2.241*** (0.21)	
L.Rdman		0.134*** (0.02)
L.Rdman2		-0.264*** (0.04)
Control	Yes	Yes
_cons	-4.436*** (0.25)	-4.438*** (0.25)
N	15990	15990
Adj. R2	0.34	0.34

Conclusions and Recommendations

(I) Conclusions

This study examines the relationship between R&D investment and financial performance in A-share listed manufacturing companies from 2015 to 2022. It uses both financial and non-financial indicators to define R&D investment. By investigating the impact of current and lagged R&D investment on financial performance and categorizing sample companies based on property rights nature, this study explores the role of R&D investment in company development. The conclusions are as follows: (1) Lagged R&D investment significantly affects financial performance. The relationship between the two follows an inverse “U”-shape. (2) Due to the COVID-19 pandemic, the relationship between R&D investment and financial performance in manufacturing companies becomes more pronounced. (3) The inverse “U”-shaped relationship between R&D investment and financial performance is more evident in non-state-owned companies compared to SOEs.

(II) Suggestions

After conducting an in-depth analysis of the importance, current situation, challenges, and optimization strategies of R & D investment in manufacturing enterprises, this paper puts forward the following series of comprehensive and specific suggestions, aiming to provide strong guidance and

support for manufacturing enterprises, and help them build a more scientific and reasonable R & D investment system to further enhance the innovation ability of enterprises. Through these measures, manufacturing enterprises can gain an advantage in the fierce market competition, achieve leapfrog development, and ultimately achieve the goal of sustainable development.

First, clarify the strategic orientation of R&D investment. Manufacturing enterprises should deeply understand that R&D investment is the key to enterprise transformation and upgrading and enhance core competitiveness. Therefore, enterprises should be combined with their own development strategy, industry trends and market demand, clear research and development investment in the key areas and direction. This requires the senior leaders of the enterprise to have a long-term strategic vision, incorporate R&D investment into the overall development plan of the enterprise, and ensure the continuity and stability of R&D investment. At the same time, establish a cross-departmental R&D team to promote the deep integration of technology and market, ensure that R&D projects can closely match market demand, and improve the conversion rate of R&D results. Secondly, we should strengthen the fine management of R&D investment. The benefit of R&D investment depends not only on the scale of investment, but also on the efficiency of investment. Therefore, manufacturing enterprises should establish a sound R&D

investment management mechanism, including budget control, performance evaluation, risk management and so on. In terms of budget control, enterprises should reasonably allocate research and development funds according to the actual situation of research and development projects to ensure the effective use of funds. In terms of performance evaluation, establish a scientific evaluation system for R&D projects, regularly evaluate the progress, results and benefits of R&D projects, and timely adjust R&D strategies. In terms of risk management, enterprises should identify and evaluate potential risks in the research and development process, and formulate countermeasures to reduce the possibility of research and development failure. In addition, actively seek industry-university-research cooperation. Industry-university-research cooperation is an important way to enhance the innovation ability of enterprises. Manufacturing enterprises should actively cooperate with universities and scientific research institutions, jointly develop new technologies and new processes, and promote the industrialization of scientific research results. Through industry-university-research cooperation, enterprises can make full use of external innovation resources, shorten the research and development cycle, reduce research and development costs, and improve research and development efficiency. At the same time, industry-university-research cooperation also helps enterprises to cultivate high-quality R&D talents and improve the overall innovation ability of enterprises. In terms of the control of R&D investment intensity, enterprises should reasonably set the level of R&D investment based on their own financial situation and market environment. The increase of R&D investment intensity can indeed improve the innovation ability of enterprises, but too high R&D investment may also lead to greater financial risks. Therefore, enterprises should balance risks and benefits to avoid the waste of resources caused by excessive investment. In the decision-making process of R&D investment intensity, enterprises should fully consider market changes, competitor dynamics and their own financial status, and formulate reasonable R&D investment strategies. In addition, protection of intellectual property rights will be strengthened. Intellectual property protection is an important guarantee for enterprises to invest in research and development. Manufacturing enterprises should establish a sound intellectual property protection system and strengthen the application and management of intellectual property rights such as patents and trademarks. At the same time, enterprises should strengthen the protection of intellectual property rights, crack down on infringements, and protect the legitimate rights and interests of enterprises and research and development results. By strengthening the protection of intellectual property rights, enterprises can stimulate the innovation enthusiasm of R&D personnel and promote the continuous innovation of

enterprises. Finally, create a good innovation culture. Innovation culture is the cornerstone of enterprise innovation ability. Manufacturing enterprises should create an open, inclusive and innovative cultural atmosphere to stimulate the enthusiasm of employees for innovation. By holding innovation competitions and setting up innovation funds, employees are encouraged to actively participate in innovation activities and improve the overall innovation ability of enterprises. At the same time, enterprises should strengthen the innovation training of employees to enhance their innovation awareness and innovation ability.

Meanwhile, in optimizing the decision-making of enterprise R&D investment and enhancing the technological innovation ability of enterprises, we need to conduct in-depth discussions and improvements at the institutional level. Firstly, it is necessary to further improve the property rights system and clearly and explicitly define the ownership of property rights, which is a crucial fundamental work. By clarifying the ownership of property rights, it can provide a stable development environment for enterprises and stimulate their innovation motivation. On this basis, it is also necessary to strengthen the incentive mechanism and risk constraint mechanism to promote fair competition and coordinated development among enterprises of different property rights. For state-owned enterprises, it is very necessary to establish a more scientific and reasonable performance evaluation system. This system should guide the management to pay more attention to the long-term development and technological innovation of the enterprise, rather than just short-term performance. At the same time, it is necessary to strengthen internal supervision and risk control to strictly prevent the occurrence of problems such as excessive investment and random R&D, and ensure the rational use of enterprise resources. In addition, the R&D capacity and technical level of enterprises can be improved by strengthening cooperation with scientific research institutions. For non-state-owned enterprises, further deepening market-oriented reform is the key. It is necessary to further expand financing channels and reduce financing costs to provide more financial support and policy guarantees for the R&D investment of non-state-owned enterprises. At the same time, it is necessary to encourage non-state-owned enterprises to strengthen their own innovation capacity building and enhance the core competitiveness of enterprises. The government can create a more favorable development environment for non-state-owned enterprises by formulating relevant policies to promote the rapid development and technological innovation of non-state-owned enterprises. In short, through various efforts, we can jointly promote the increase of enterprise R&D investment and the improvement of technological innovation ability, and lay a solid foundation for the sustainable development of the economy.

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