Research on the Influence Mechanism of R&D Investment and Enterprise Performance Based on FEM Algorithm

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Abstract: In order to reduce the impact of external environment changes on enterprise R&D and performance since 2020, this paper selects the listed companies in Shanghai and Shenzhen A-share market from 2015 to 2019 as the research sample, uses the FEM Algorithm to empirically test the relationship between R&D investment and enterprise performance, and discusses the regulatory role of the heterogeneity of senior management team on it, and adopts the replacement variable measurement method to pass the robustness test. The research finds that R&D investment has a significant negative correlation with the current performance of enterprises and the performance of enterprises lagging behind the first phase, and a significant positive correlation with the performance of enterprises lagging behind the second phase. In the study of the influence of the heterogeneity of senior management team on the relationship between R&D investment intensity and enterprise performance, the heterogeneity of age, career background and education level is positively correlated with the two, which is not conducive to the improvement of enterprise performance. However, the gender and tenure heterogeneity of senior executives and the two have a negative regulatory effect, promoting the improvement of corporate performance.

Keywords: R&D Investment, Enterprise Performance, Heterogeneity of Senior Management Team.

1 INTRODUCTION

Innovation is the source of national sustainable development and a strong strategic support for economic growth. All developed economies in the world are guided by national strategic needs, driven by innovation, relying on high-level scientific and technological innovation, and accumulating strength to carry out original and leading scientific and technological breakthroughs. As an important implementation subject of scientific and technological innovation, enterprises should have long-term core competitiveness and R&D investment is essential. Through R&D investment, enterprises can obtain patents and technologies protected by laws such as patent rights, and their products are favored by consumers and earn excess profits. Secondly, R&D investment can promote enterprises to optimize production mode,

BDEDM 2023, January 06-08, Changsha, People's Republic of China

DOI 10.4108/eai.6-1-2023.2330369

improve efficiency and reduce production costs. Differentiated products also help enterprises to stand out in the market and gain excess market share.

Among the factors affecting the relationship between R&D input and enterprise performance, the key one is the decision-making opinions of the senior management team. Research and development investment is characterized by long investment time, high risk and uncertain returns. From the perspective of agency theory, senior executives may pay little attention to research and development investment with uncertain returns based on short-term benefits. The level of decision-making is also influenced by the differing opinions of the senior management team.

The main contributions of this paper are as follows: First, through empirical testing of the impact of R&D input on the corporate performance of Shanghai and Shenzhen A-share listed companies during 2015-2019 and the following two periods, the research gap of the relationship between R&D input and corporate performance in recent years was filled; Second, the five dimensions of the heterogeneity of the top management team are studied to measure the impact of the heterogeneity of the top management team in different dimensions on the relationship between R&D input and corporate performance, which has practical significance for the innovation implementation of listed companies.

2 THEORETICAL ANALYSIS AND RESEARCH HYPOTHESIS

2.1 R&D Investment and Enterprise Performance

The relationship between R&D investment and enterprise performance in the current period. Ben Branch (1974) analyzed 111 companies in the United States from 1950 to 1965 and found that, except for the pharmaceutical industry, R&D investment in other six industries promoted the growth of corporate profitability. Hitt, Hoskisson (1991) studied 191 companies in the United States from 1970 to 1986 and found that R&D investment negatively regulated enterprise performance among companies across 29 industries. Lantz J S, Sahut J M (2005) found through the empirical model that if the R&D investment can obtain income in the current period, its capitalization can increase financial performance, if it can obtain income in the future, the reverse is true. The relationship between R&D investment and enterprise performance is nonlinear. Alam A, et al (2020) used GMM method to study 432 companies in 12 countries, and found that safeguard measures effectively regulate the positive correlation between R&D investment and enterprise performance. Xu J, Wang X, Liu F (2021) believed that R&D investment has a positive and significant effect on performance, especially for state-owned enterprises and enterprises with R&D directors. The R&D investment will make the enterprise ahead of its peers in terms of products, production costs and market share.

Based on this, this paper proposes:

Hypothesis 1. R&D investment will promote the current performance of enterprises.

The relationship between R&D investment and enterprise performance lags behind. William (1971) took the U.S. manufacturing industry from 1957 to 1967 as the research sample, and found that R&D investment has a positive lag effect on enterprise performance, which is

reflected in the continuous growth of sales revenue and profit in the second to ninth years. Chambers (2002) found that the lagged relationship between R&D investment and enterprise performance has lasted for about ten years. This conclusion was drawn through empirical research on nearly 10000 American enterprises. Zhu Z, Huang F (2012) conducted research on listed technology-based enterprises and found that there is a positive correlation between R&D investment and enterprise performance in the next year. Li Lu and Zhang Wanting (2013) believed that R&D investment positively adjusted the current performance, and there was a lag effect of two periods, which decreased year by year. The results of R&D investment and market audience feedback are gradually realized, but how to achieve the effect remains to be verified.

Based on this, this paper proposes:

Hypothesis 2. R&D investment will promote the current performance of enterprises.

2.2 The Influence of the Heterogeneity of Senior Management Team on the Correlation Between R&D Investment and Enterprise Performance

As decision-makers of major business strategies, senior executives play a key role in R&D investment and performance of enterprises. In the background of agency theory, different senior management team characteristics play a differentiated role in the final business decisions and the realization of corporate goals.

Regulation of age heterogeneity. Zenger and Lawrence (1989) believed that the greater the age heterogeneity, the less technical communication within the project team. Richard O C, Shelor R M (2002) found that the middle and low level of age heterogeneity promoted sales growth, while the high level of age heterogeneity inhibited sales growth. Wang H, He W, Yang Y (2022) said that in innovation oriented enterprises, age heterogeneity will not affect enterprise innovation performance, and more attention should be paid to team members' abilities, personality and work adaptability. The senior management team with significant age difference is more conducive to coping with the complex internal and external environment.

Based on this, this paper proposes:

Hypothesis 3. The age heterogeneity of senior executives has a positive moderating effect on R&D investment and enterprise performance

Regulation of gender heterogeneity. Rivero, Arlene (2003) believed that female executives, compared with male executives, had keen insight and communication skills, and would make efficient decisions more quickly using existing information and resources in the face of risk decisions. Dezso (2011) empirically found that the participation of senior female executives was positively correlated with corporate performance. Ren Ting et al. (2010) believed that the increase in the proportion of female executives in the team is positively improving enterprise performance. In terms of innovation decision-making, female executives are cautious. Anderson R C, Reeb D M (2011) found that in the board of directors, gender differences help improve the company's performance and bring in different talents and perspectives.

Based on this, this paper proposes:

Hypothesis 4. The gender heterogeneity of senior executives has a positive moderating effect on R&D investment and enterprise performance.

The moderating effect of occupational background heterogeneity. Sutcliffe (1994) believes that the diversity of professional backgrounds of senior management team members will reduce the efficiency of decision-making communication, weaken the ability to identify external opportunities, and be unfavorable to making effective decisions to improve corporate performance. Simons (1999) believed that senior management teams with different career backgrounds can enrich the team's cognition, skills and handling methods, which is conducive to the making of corporate performance decisions. Ndofor H A, Sirmon D G, He X (2015) believed that occupational background heterogeneity promoted the resource-action connection, but had a negative impact on the action-performance connection.

Based on this, this paper proposes:

Hypothesis 5. The heterogeneity of senior executives' occupational background has a negative moderating effect on R&D investment and firm performance.

The moderating effect of educational level heterogeneity. Smith (1994) believed that the more differentiated the education level of the top management team, the deeper understanding of the phenomenon, is conducive to improving the quality of decision-making and corporate performance. Pinelli M, Cappa F, Franco S, et al (2020) studied the education level and educational background of the founders of 1078 start-ups and found that the heterogeneity of education level and educational background promoted the increase of the amount of enterprise financing, but the coexistence of both weakened the positive relationship. In-depth information mining and cognition requires the support of high education level.

Based on this, this paper proposes:

Hypothesis 6. The heterogeneity of executive education level has a positive moderating effect on R&D investment and firm performance.

The moderating role of tenure heterogeneity. Dutton (1987) believed that senior management teams with different terms of office have a comprehensive perspective on information collection and interpretation, which is more conducive for enterprises to make reasonable and optimized decisions. Boeker (1997) believed that senior management teams with large tenure differences have more opportunities to adopt different management styles and innovative strategic plans. Wang H, He W, Yang Y (2022) should try to maintain the same tenure of senior management team and extend the tenure, which is conducive to communication and exchange, and improve the efficiency and efficiency of decision-making. The length of managers' tenure affects their familiarity with the operation of enterprise management mode and employees.

Based on this, this paper proposes:

Hypothesis 7. The heterogeneity of executive tenure has a negative moderating effect on R&D investment and firm performance.

3 RESEARCH DESIGN

3.1 Sample Selection and Data Source

According to the existing research, the research samples in this paper are from the relevant data of Shanghai and Shenzhen A-share listed companies from 2015 to 2019, excluding PT, ST, *ST companies, financial companies and companies with abnormal data. The sample data is mainly from the CSMAR database, and the missing value is manually collected from the enterprise annual report. Data processing was mainly completed by stata16, and was processed by 1% horizontal indentation.

3.2 Variable Definition

Explained variable: firm performance. Based on the existing research literature, as well as the availability and quantification of data, return on assets (ROA) is used as a variable to measure corporate performance. Return on Assets (ROA) is the ratio of a company's net profit to the average amount of assets, which can be obtained by the average of the ending balance of assets.

Explanatory variable: R&D input Rd. In the past, a quantifiable measure of R&D investment was divided by total assets, operating profit, net profit, etc. In this paper, the ratio of R&D investment to operating revenue is adopted to measure the degree of R&D investment, which is studied by Zhang Zhaoguo et al. (2014). In order to study the impact of R&D input on enterprise benefits in the current period and lag period, the data of R&D input in the current period, lag phase I and lag phase II are taken in this paper.

Moderating variable: Heterogeneity of top management team. This paper measures the heterogeneity of senior management team from five dimensions: age Hage, sex Hsex, education level Hdegree, career background Hbackgroud and tenure Hterm. Age Hage and tenure heterogeneity Hterm are continuous variables, measured by the ratio of standard deviation to mean. Gender Hsex, education level Hdegree and career background Hbackgroud were measured by Hersman coefficient $H=1-\sum_{i=1}^{n} p_i^2$,where Pi is the percentage of Class i members in the team, n is the number of types, and the larger the value of H, the higher the degree of heterogeneity.

Control variables: referring to Li Xianjun (2018) et al. and Wang Xi (2020) et al. , this paper introduces the control variables of enterprise growth, asset liability ratio, enterprise size Lnassets and enterprise age Age. See Table 1 for variable settings.

Table1 Variable Definition

Type	Name	Symbol	Definition
Explained variable	Enterprise performance	Roa	Net profit/Total average assets
Explanatory variable	R&D	Rd	R&d expenditure/Operating income
Adjustment variable	Heterogeneity of age	Hage	Standard deviation of age/Mean of age
	Gender heterogeneity	Hsex	$H=1-\sum_{i=1}^{n} p_i^2$

	Heterogeneity of occupational background	Hbackground	$H=1-\sum_{i=1}^{n} p_i^2$
	Heterogeneity of education level	Hdegree	$H=1-\sum_{i=1}^{n} p_i^2$
	Heterogeneity of tenure	Hterm	Term standard deviation/ Term average
Control variables	Enterprise growth	Growth	(Total operating revenue Amount of the current year - Total operating revenue Amount of the previous year)/(Total operating revenue of the previous year)
	Asset-liability ratio	Ratio	Total liabilities/ Total assets
	Size of Enterprise	Lnassets	Log of total assets
	Age of enterprise	Age	The number of years since the company first went public

3.3 Model Setting

(1) The impact of R&D investment on firm performance. In order to study the impact of R&D input on enterprise performance in the current period and its lag time, three regression models of R&D input on enterprise performance in the current period, one lag time and two lag time were established.

$$Roa_{it}=r+\alpha_1 Rd_{i,t}+\alpha_2 Growth_{i,t}+\alpha_3 Ratio_{i,t}+\alpha_4 Lnassets_{i,t}+\alpha_5 Age_{i,t}+\varepsilon_{i,t} \quad (1)$$

$$Roa_{it}=r+\alpha_1 Rd_{i,t-1}+\alpha_2 Growth_{i,t}+\alpha_3 Ratio_{i,t}+\alpha_4 Ln\ assets_{i,t}+\alpha_5 Age_{i,t}+\varepsilon_{i,t} \quad (2)$$

$$Roa_{it}=r+\alpha_1 Rd_{i,t-2}+\alpha_2 Growth_{i,t}+\alpha_3 Ratio_{i,t}+\alpha_4 Ln\ assets_{i,t}+\alpha_5 Age_{i,t}+\varepsilon_{i,t} \quad (3)$$

(2)The moderating influence of the heterogeneity of top management team on R&D investment and firm performance. On the basis of model (1), the interaction term between the heterogeneity of the top executive team and R&D investment is added to determine whether the heterogeneity of the top executive team has a moderating effect on the corporate performance of R&D investment and the degree of influence.

$$Roa_{it}=r+\alpha_1 Hage*Rd_{i,t}+\alpha_2 Rd_{i,t}+\alpha_3 Growth_{i,t}+\alpha_4 Ratio_{i,t}+\alpha_5 Lnassets_{i,t}+\alpha_6 Age_{i,t}+\varepsilon_{i,t} \quad (4)$$

$$Roa_{it}=r+\alpha_1 Hsex*Rd_{i,t}+\alpha_2 Rd_{i,t}+\alpha_3 Growth_{i,t}+\alpha_4 Ratio_{i,t}+\alpha_5 Lnassets_{i,t}+\alpha_6 Age_{i,t}+\varepsilon_{i,t} \quad (5)$$

$$Roa_{it}=r+\alpha_1 Hbackground*Rd_{i,t}+\alpha_2 Rd_{i,t}+\alpha_3 Growth_{i,t}+\alpha_4 Ratio_{i,t}+\alpha_5 Lnassets_{i,t}+\alpha_6 Age_{i,t}+\varepsilon_{i,t} \quad (6)$$

$$Roa_{it}=r+\alpha_1 Hdegree*Rd_{i,t}+\alpha_2 Rd_{i,t}+\alpha_3 Growth_{i,t}+\alpha_4 Ratio_{i,t}+\alpha_5 Lnassets_{i,t}+\alpha_6 Age_{i,t}+\varepsilon_{i,t} \quad (7)$$

$$Roa_{it}=r+\alpha_1 Hterm*Rd_{i,t}+\alpha_2 Rd_{i,t}+\alpha_3 Growth_{i,t}+\alpha_4 Ratio_{i,t}+\alpha_5 Lnassets_{i,t}+\alpha_6 Age_{i,t}+\varepsilon_{i,t} \quad (8)$$

4 RESULTS AND DISCUSSION

4.1 Descriptive Statistics and Correlation Analysis

The descriptive statistical characteristics of variables in this paper are shown in the Table2. From the descriptive statistics of 13172 observations, we can see that: (1) The corporate performance of listed companies varies greatly, the maximum is 0.199, the minimum is -0.351, and the average is 0.038. Most of the corporate performance is positive. (2) The average R&D investment intensity of A-share listed companies in the past five years has reached 4.719%, which is close to the internationally competitive R&D investment standard of 5%, indicating that Chinese listed companies attach importance to R&D to build their own core competitiveness, and building innovation brings commercial moats. (3) The average of the heterogeneity of education level and occupational background of the senior management team is 0.23 and 0.21, respectively, indicating that the education level and occupational background of the senior management team are quite different. Besides, this study conducts Pearson test on each variable. From Table 3, it can be seen that the correlation coefficient between R&D investment and enterprise performance variable is -0.038, which is negative significant at the level of 1%. This means that the increase of R&D investment will lead to the decrease of enterprise performance in the current period. The assumption H1 is preliminarily rejected. Next, we made a collinearity diagnosis for all variables. From Table 4, we can see that the variance expansion factor is less than 10, and there is no high correlation between the variables. On this basis, Hausman test was conducted, and each model rejected the original hypothesis, and the regression analysis method selected the FEM Algorithm.

Table 2 Descriptive statistics of the variables

variable	N	mean	p50	sd	min	max
Roa	13172	0.0380	0.0410	0.0710	-0.351	0.199
Rd	13172	4.719	3.690	4.496	0.0300	25.37
Hage	13172	0.129	0.124	0.0520	0.0300	0.277
Hsex	13172	0.220	0.200	0.136	0.0560	1
Hbackground	13172	0.210	0.195	0.0940	0.0650	0.595
Hdegree	13172	0.230	0.176	0.208	0	1
Hterm	13172	0.595	0.590	0.316	0	1.430
Growth	13172	0.178	0.116	0.377	-0.511	2.330
Ratio	13172	0.400	0.385	0.197	0.0600	0.912
lnassets	13172	22.15	21.98	1.268	19.96	26.18
Age	13172	8.926	7	7.341	-1	25

Table 3 Correlation Matrix

variable	Roa	Rd	Hage	Hsex	Hdegree	Hterm	Growth	Ratio	lnassets	Age
Roa	1.000									
Rd	-0.038***	1.000								
Hage	-0.013	0.049*	1.000							

		**								
Hsex	-0.048**	-0.007	0.075**	1.000						
Hbackground	-0.029**	0.006	0.025**	0.569**						
Hdegree	-0.032**	-0.060**	0.007	0.263**	1.000					
Hterm	-0.121**	-0.080**	0.013	0.008	0.094***	1.000				
Growth	0.003	-0.010	0.000	-0.007	-0.007	0.044***	1.000			
Ratio	-0.409**	-0.189**	-0.106**	-0.037**	0.035***	0.172***	0.024***	1.000		
lnassets	-0.013	-0.236**	-0.226**	-0.135**	0.031***	0.279***	0.043***	0.410***	1.000	
Age	-0.109**	-0.190**	-0.178**	0.041**	0.152***	0.419***	0.025***	0.296***	0.459***	1.000

Table 4 Collinearity diagnosis results

Variable	VIF	1/VIF
lnassets	1.540	0.647
Hsex	1.540	0.650
Age	1.520	0.657
Hbackground	1.520	0.660
Hterm	1.250	0.800
Ratio	1.240	0.809
Hdegree	1.120	0.894
Hage	1.080	0.925
Rd	1.080	0.925
Growth	1	0.997
Mean	VIF	1.290

4.2 Regression Analysis

(1) Influence of R&D investment on enterprise performance

From the regression results in Table 5, the regression coefficient of R&D investment on the current and lagging corporate performance is -0.001, which is significant at the level of 1%, indicating that R&D investment has hindered the improvement of corporate financial performance in the current and lagging corporate performance, so we refuse to assume Hypothesis1. However, the enterprise performance coefficient of R&D investment and lag phase II is 0.003, which is significant at the level of 1%, which means that R&D input-output

efficiency is positively promoting the enterprise performance of lag phase II. Based on the regression results of lag phase I and lag phase II, the relationship between R&D investment and enterprise performance is lagging behind. Hypothesis 2 is verified. Analyze the reasons. The benefits brought by the R&D investment in the current period and the first phase lag behind failed to make up for the costs paid. The second phase lag behind turns into positive benefits, indicating that the R&D investment can bring positive benefits. This is different from most research results such as Liang Laixin, Zhang Huanfeng (2005), Ren Haiyun (2009), and Zhang Jian (2014) . It may be due to the differences in the years of sample data research, as well as different research industries and sectors. Combining the descriptive statistics above, it also verifies that China's listed companies pay more attention to R&D investment, increasing from the international pass line of 2% to 4.821%.

Table 5 Regression Results of the Current and Lagging Effects of R&D Investment on Enterprise Performance

Variable	Model (1)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)
Rd	-0.001***	-0.007***	-0.005***	-0.006***	-0.005***	0.000
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
Growth	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ratio	-0.351***	-0.346***	-0.351***	-0.350***	-0.350***	-0.350***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Lnassets	0.061***	0.057***	0.061***	0.060***	0.060***	0.061***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Age	-0.011***	-0.010***	-0.010***	-0.010***	-0.010***	-0.010***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Hage*Rd		0.019***				
		(0.006)				
Hsex*Rd			-0.039***			
			(0.013)			
Hbackground*Rd				0.007***		
				(0.001)		
Hdegree*Rd					0.005***	
					(0.001)	
Hterm*Rd						-0.005***
						(0.001)
_cons	-1.072***	-0.960***	-1.048***	-1.031***	-1.036***	-1.070***
	(0.085)	(0.085)	(0.085)	(0.085)	(0.085)	(0.085)
N	13191.000	13172.000	13186.000	13186.000	13186.000	13188.000

r2	0.192	0.192	0.196	0.198	0.197	0.197
r2_a	-0.068	-0.068	-0.063	-0.061	-0.062	-0.062

Note: *, * * and * * * respectively represent 10%, 5% and 1% significance, and t value is in brackets.

(2) The moderating effect of TMT heterogeneity on R&D investment on firm performance

In order to study the impact of the heterogeneity of the senior management team on R&D investment and enterprise performance, this paper sets cross terms Hage * Rd, Hsex * Rd, Hbackground * Rd, Hdegree * Rd and Hterm * Rd to test the moderating effects of the heterogeneity of senior management age, gender, professional background, education level and tenure. The regression results are shown in Table 6. All interaction items are significant, which means that the heterogeneity of the senior management team has a moderating effect. The Hage * Rd coefficient of the interaction term of senior executives' age heterogeneity is 0.019, which is significant at the level of 1%, indicating that senior executives' age heterogeneity will strengthen (weaken) the negative (positive) relationship between R&D investment and enterprise performance, and there is a positive moderating effect. H3 is verified. It can be seen from the regression coefficient that the interaction cross term Hsex * Rd of senior executives' gender heterogeneity negatively regulates the relationship between the two, assuming that H4 refuses to verify. The heterogeneous interaction term Hbackground * Rd of senior executives' professional background and the heterogeneous interaction term Hdegree * Rd of senior executives' education level are positive significant at the level of 1%, indicating that these two will strengthen (weaken) the negative (positive) relationship between R&D investment and enterprise performance, and have a positive regulatory effect. Therefore, we refuse to assume H5, and assume H6 is verified. The heterogeneity interaction term Hterm * Rd of senior executives' tenure is negative significant, which means that the greater the diversity of senior executives' tenure, the less the effect of R&D investment on corporate performance will be. Hterm * Rd has negative regulation effect, and H7 is assumed to be verified.

Table 6 The moderating effect of the heterogeneity of senior management team on the correlation between R&D investment and enterprise performance

Variable	Model (1)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)
Rd	-0.001***	-0.007***	-0.005***	-0.006***	-0.005***	0.000
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
Growth	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ratio	-0.351***	-0.346***	-0.351***	-0.350***	-0.350***	-0.350***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Lnassets	0.061***	0.057***	0.061***	0.060***	0.060***	0.061***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Age	-0.011***	-0.010***	-0.010***	-0.010***	-0.010***	-0.010***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Hage*Rd		0.019***				
		(0.006)				
Hsex*Rd			-0.039***			
			(0.013)			
Hbackground *Rd				0.007***		

				(0.001)		
Hdegree*Rd					0.005***	
					(0.001)	
Hterm*Rd						-0.005***
						(0.001)
_cons	-1.072***	-0.960***	-1.048***	-1.031***	-1.036***	-1.070***
	(0.085)	(0.085)	(0.085)	(0.085)	(0.085)	(0.085)
N	13191.000	13172.000	13186.000	13186.000	13186.000	13188.000
r2	0.192	0.192	0.196	0.198	0.197	0.197
r2_a	-0.068	-0.068	-0.063	-0.061	-0.062	-0.062

4.3 Robustness Test

In order to avoid the contingency of the above regression results, this paper uses Eps earnings per share to replace the enterprise performance Roa variable to verify the impact of R&D investment on enterprise performance, and the moderating effect of the heterogeneity of senior management team on both. It can be seen from Table 7 that after replacing earnings per share to measure enterprise performance, the conclusion that R&D investment lags behind one and two periods of enterprise performance in the current period is still valid.Therefore, the negative significant impact of R&D investment on enterprise performance is still valid, and the regulatory effects of the heterogeneity of senior management team are consistent, indicating that the study passed the robustness test.

Table 7 Robustness test results of the relationship between R&D investment and enterprise performance

Variable	Model (1)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)
Rd	-0.007***	-0.036***	-0.026***	-0.032***	-0.024***	-0.002
	(0.002)	(0.005)	(0.003)	(0.003)	(0.003)	(0.002)
Growth	0.001**	0.001**	0.001**	0.001**	0.001**	0.001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ratio	-0.917***	-0.932***	-0.912***	-0.909***	-0.909***	-0.914***
	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
Lnassets	0.371***	0.368***	0.369***	0.367***	0.366***	0.368***
	(0.021)	(0.021)	(0.020)	(0.020)	(0.020)	(0.020)
Age	-0.047***	-0.045***	-0.044***	-0.044***	-0.045***	-0.044***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Hage*Rd		0.096***				
		(0.030)				
Hsex*Rd			0.027***			
			(0.004)			
Hbackground*Rd				0.035***		
				(0.004)		
Hdegree*Rd					0.024***	
					(0.004)	
Hterm*Rd						-0.020***
						(0.003)

_cons	-6.989***	-6.818***	-6.841***	-6.783***	-6.793***	-6.962***
	(0.435)	(0.437)	(0.434)	(0.434)	(0.434)	(0.434)
N	13027.000	13009.000	13023.000	13023.000	13023.000	13025.000
r2	0.086	0.093	0.092	0.094	0.092	0.090
r2_a	-0.209	-0.200	-0.201	-0.199	-0.201	-0.204

5 CONCLUSIONS

First of all, the R&D investment of enterprises is significantly negatively correlated with the enterprise performance of the current period and the first lag period, and significantly positively correlated with the enterprise performance of the second lag period. R&D investment weakens the enterprise performance in the current period and the following year, but it will significantly improve the enterprise performance in the following two years, which is different from the conclusions of most scholars. The reasons are: first, the research expenditure in the early stage of R&D is included in the current profit and loss. Although there are tax incentives for R&D, it still has a negative impact on the current performance [29]; Second, the technology acquired by R&D investment and the intangible assets transformed need time to pave the way, which has a negative impact on the performance of enterprises lagging behind Phase I, but ultimately has a positive effect on the performance of enterprises lagging behind Phase II.

Secondly, the heterogeneity of senior management team has a moderating effect on the relationship between R&D investment intensity and enterprise performance. The heterogeneity of senior executives' age, professional background and education level is positively related to the two, which is not conducive to the improvement of enterprise performance. The gender and tenure heterogeneity of senior executives and the two are negative moderating effects, promoting enterprise performance. The enterprise can adjust the characteristics of the senior management team in a timely manner according to the current relationship between R&D investment and enterprise performance, in order to optimize enterprise performance.

Funding Statement: This research is supported by the basic research promotion project for young and middle-aged teachers in Guangxi's colleges and universities, "Research and Development Investment, Heterogeneity of Senior Management Teams and the Impact Mechanism of Enterprise Performance and Empirical Research" (2022KY1570)

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