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Board Diversity and R&D Investment: An Evidence from China

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Abstract. Innovation plays a crucial role in the survival and development of enterprises, and the investment in research and development (R&D) projects, as the core indicator for measuring innovation investment, has attracted much attention. In recent years, in order to explore the key factors that affect corporate innovation, scholars' research perspectives have gradually focused on the level of corporate governance. This article uses empirical research methods to deeply analyze the intrinsic relationship between board diversity and research and development expenditures. The research results show that board diversity has a significant impact on R&D investment. Specifically, the negative impact of gender and age diversity is more prominent, while educational background diversity shows a clear positive driving effect. In addition, this article also found that board diversity often plays a role in inhibiting R&D investment in small-scale enterprises, while it can play a stronger promoting role in large-scale enterprises. The results of this article not only enrich the research in related fields such as upper echelons theory but also provide important references for corporate governance practice.

1 Introduction

Nowadays, innovative development has become an important goal for enterprises. Spending in R&D is a vital element to estimate the innovation of enterprises. Nevertheless, it's not easy for enterprises to make a lot of R&D investing on account of the high risk of innovation [1].

To examine the influencing factors of R&D investment and reduce high risk of advancement, scholars have gradually turned their attention to the field of corporate governance. Corporate governance has always been an important research topic internationally. Studies show that before 2000, there were few studies on corporate governance. After the financial crisis of 2008, people's attention to this issue rose explosively [2]. Today, researchers' dissection of corporate governance is more detailed. The members in board, as some necessary components of corporate governance, undertakes most of the work of making investment decisions for the enterprise. Studies have shown that the board of directors can affect strategic decisions [3]. Therefore, it is of great significance for this paper to learn about board diversity and R&D investing jointly.

This paper learns about connection between board diversity and innovation. The outcomes reveal that the diversity distinctly affects R&D investment. Among them, gender

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and age diversity have negative impacts. The diversity of educational backgrounds has a facilitating effect. There are the following contributions in this paper: Firstly, theoretically, it has enriched the research scope of the Upper Echelons Theory and the research field between corporate governance and R&D investment. Secondly, practically, it provides more abundant data support for corporate governance and points out the way for the innovative development of Chinese enterprises.

2 Literature review

2.1 Board diversity

The diversity of age, race, nationality, educational background, etc., of members in board is called board diversity. Scholars' exploration of board diversity mainly focuses on four aspects, namely corporate performance, policy changes, corporate responsibility, and governance quality [4]. Representative research related to board diversity include corporate social responsibility, corporate policies, firm performance and investment efficiency [5-7]. Fewer studies involve exploring the connection between board diversity and corporate innovation, especially R&D investment [8].

It is worth mentioning that some articles such as article from Azzam, specifically measure the influence of gender diversity only on R&D investment [9]. It means that gender diversity was often used as the sole indicator to measure board diversity in previous studies. In this case, the board diversity in the other dimensions was ignored.

The above articles attempt to explain the relationship from the perspectives of risk, resource dependence, interest divergence and effective supervision, providing a valuable reference for the research mechanism of this paper.

2.2 R&D investment

Research often regards investing in R&D as an independent variable to explore influence on other factors. Research that takes R&D expenses as the dependent variable can mainly be divided into whether internal and external factors have an impact on it [10]. External factors include patent protection, public R&D policies and so on [10,11]. Internal factors include corporate characteristic, resources and corporate governance [12].

When exploring the influencing factors from corporate governance, the existing research mainly focuses on how board structure, board power, and CEO traits make a difference on R&D investment [13,14]. There are few articles related to connection between board diversity and investing in R&D. A research gap occurs in this field. Moreover, the samples selected for most studies are from North American and European countries, while there are few related studies from other countries [2].

2.3 Board diversity and R&D investment

Even though there have been researches regarding the connection between board diversity and investing in R&D in various countries at present, the research samples and methods they chose are different. Midavaine, Dolfsma and Aalbers found that investing in R&D is distinctly influenced by board diversity [15]. However, their article only focused on the US market and was limited by the lack of board information, resulting in a relatively small research sample size. Asad, Akbar, Li and Shah focused on the UK market [16]. They calculated a board diversity index that combines seven dimensions and did not study the subdivision of board diversity.

Therefore, there are many innovative parts to this paper. Firstly, this paper explores the relationship between the two in the Chinese market, which is of research significance. Secondly, board diversity is subdivided into gender, age and educational background diversity in this paper. Compared with exploring the influence of gender diversity in a single way and combining all diversity to explore the common influence, this paper is more detailed and richer. Thirdly, the robustness of the model in this paper is examined by using different ways to measure investing in R&D, and degree of influence of diversity under different company scales is also found out.

3 Theoretical development and research hypotheses

3.1 Theoretical development

3.1.1 Upper echelons theory

Hambrick and Mason first came up with the Upper Echelons Theory [17]. They pointed out that the cognitive basis and values of the top management act like a filter, influencing the decisions of the executive team. The cognitive basis and values are often composed of factors such as gender, experience, and age. This theory serves as the basis for this paper to explain that decisions related to enterprise strategies would be affected by directors' characteristics.

3.1.2 Resource dependency

There is mutual influence between an organization and its external environment, and the organization relies on external resources for development [18]. If an organization can control some resources or reduce its reliance on resources, it can enhance the operational efficiency of the organization. According to this theory, it can be known that if an enterprise can master certain human resources, financial resources, etc., it will be helpful to optimize its strategic decisions. The diversified nature of members in board will enable the enterprise to have more disposable resources.

3.1.3 Information decision theory

Information Decision Theory believes that information processing can help organizations reduce uncertainty and equivocality [19]. More accurate and comprehensive information enables decision-makers to make decisions that are more beneficial to the organization. The top-level information processing capacity of an enterprise often depends on the board members.

3.2 Research hypotheses

In contrast to male members in board, female directors are more risk averse [20]. Therefore, they will reduce investment when facing R&D investment projects with higher risks. The richer the gender diversity in board is, the more female members there are on the board. Consequently, hypothesis one is shown in this paper:

H1: Gender diversity of members in board distinctly negatively affects the R&D investment.

Although the disposable resources of enterprises have increased due to the diversification of the attributes of board members, the resulting differences of opinion and conflicts will also increase. Especially when there are significant age differences among the board members. Elder people take fewer risks than young people [21]. Therefore, the coordination among the board members will also become more difficult. They will reduce R&D investment. Consequently, research hypothesis two is shown in this paper:

H2: Age diversity of members in board distinctly negatively affects the R&D investment.

As per the Resource Dependency Theory and Information Decision Theory, members in board with different educational backgrounds will have more diverse resources and information, which often eliminates some of the investment risks caused by the lack of information and resources. The board of directors is more confident in the investment, thereby enriching investment in R&D. Consequently, research hypothesis three is shown in this paper:

H3: Educational background diversity of members in board distinctly positively affects the R&D investment.

4 Methodology

4.1 Sample selection and data sources

Empirical research methods are adopted to verify research hypotheses. This paper selects such samples that are A-shares listed companies from 2018 to 2023 in the Chinese market (excluding ST companies and financial companies), and the processed sample size is 15,482. The board data and financial data used in this paper are all from the CSMAR database. In this paper, Excel is used to pre-process the data, and then Stata 18 is used for regression analysis. The average variance inflation factor of all variables is 1.49, which is lower than 5. Therefore, there is no serious multicollinearity problem with the selected variable.

4.2 Model design and variable definition

According to the study from Ullah et al., this paper sets up the following models to find out the connection between board diversity and R&D investment [8]. Among them, Model (1) is used to prove H1. Models (2) and (3) are used to prove H2 and H3 respectively.

$$RDintensity_{i,t} = \beta_1 + \beta_2 gender\_d_{i,t} + \sum \beta_i control_{i,t} + year_i + industry_t + \varepsilon_{i,t} \quad (1)$$

$$RDintensity_{i,t} = \beta_1 + \beta_2 age\_d_{i,t} + \sum \beta_i control_{i,t} + year_i + industry_t + \varepsilon_{i,t} \quad (2)$$

$$RDintensity_{i,t} = \beta_1 + \beta_2 edu\_d_{i,t} + \sum \beta_i control_{i,t} + year_i + industry_t + \varepsilon_{i,t} \quad (3)$$

In model (1), (2) and (3), i represents the industry and t represents the year. The dependent variable $RDintensity_{i,t}$ is intensity of R&D investment. Core independent variables are respectively gender diversity ($gender\_d_{i,t}$), age diversity ($age\_d_{i,t}$) and educational background diversity ($edu\_d_{i,t}$) of the board of directors. year and industry are respectively the annual dummy variable and the industry dummy variable. $\varepsilon_{i,t}$ is a random error term.

Core independent variables ($gender\_d_{i,t}$, $age\_d_{i,t}$, $edu\_d_{i,t}$) in the model are the sub-dimension of board diversity, and its calculation method is based on the research of Blau [22]:

$$Blauindex = 1 - \sum_{i=1}^{n} p_i^2 \quad (4)$$

In Formula (4), p_i represents the probability of occurrence of each type. There are two types of gender, namely male and female. There are five age categories, namely age under 40, 40-49, 50-59, 60-69, and over 70. There are five types of educational qualifications, namely vocational high school diploma and below, associate's degree, bachelor's degree, master's degree, and doctoral degree and above. If probabilities of occurrence of each type are the same, the maximum values of the above three diversities are 0.5, 0.8, and 0.8, respectively.

This paper selects the following control variables: duality, return on assets, enterprise growth potential, enterprise solvency, company size, and capital density. Table 1 shows the variable definition and explanation.

Table 1. Variable definition and explanation.

Type	Variable	Symbol	Description
Dependent variable	R&D investment intensity	RDintensity	R&D expenses/Total operating income
Independent variables	Gender diversity	gender_d	D=$\mathbf{1}-\sum_{\mathbf{i=1}}^{\mathbf{n}}\mathbf{p_i^2}$, $\mathbf{p_i}$represents the probability of occurrence of each type.
	Age diversity	age_d	D=$\mathbf{1}-\sum_{\mathbf{i=1}}^{\mathbf{n}}\mathbf{p_i^2}$, $\mathbf{p_i}$represents the probability of occurrence of each type.
	Educational background diversity	edu_d	D=$\mathbf{1}-\sum_{\mathbf{i=1}}^{\mathbf{n}}\mathbf{p_i^2}$, $\mathbf{p_i}$represents the probability of occurrence of each type.
Control variables	Duality	dual	If chairman and CEO are the same person, take 1; Otherwise, take 0.
	Return on asset	ROA	Net income/total assets
	Enterprise growth potential	growth	(Total assets at year-end-Total assets at year-beginning)/Total assets at year-beginning
	Company size	size	The total assets of an enterprise are taken as the natural logarithm.
	Solvency	Lev	Total liability/total assets
	Capital density	capden	Non-current assets/total assets
	annual dummy variable	year	This paper selects samples from 2018 to 2023.
	Industry dummy variable	industry	It is classified according to the industry classification of the China Securities Regulatory Commission in 2012.

5 Result

5.1 Descriptive statistics

The descriptive statistical results of the main variables is shown in Table 2. According to the results, the maximum values of gender diversity(gender_d), age diversity(age_d) and educational background diversity(edu_d) are 0.5, 0.8 and 0.8 respectively, which are in line with the above predicted results.

Table 2. Descriptive statistics.

Variable	N	Mean	SD	Min	Max
RDintensity	15482	0.0463	0.0443	0.000147	0.247
gender_d	15482	0.241	0.163	0	0.500
age_d	15482	0.564	0.133	0	0.800
edu_d	15482	0.534	0.185	0	0.800
dual	15482	0.314	0.464	0	1
ROA	15482	0.0256	0.285	-30.69	7.446
Lev	15482	0.435	0.323	0.00978	31.467
size	15482	22.43	1.33	18.88	28.70
growth	15482	0.109	0.805	-0.961	77.70

capden	15482	0.436	0.184	0	0.978

5.2 Correlation analysis

In this paper, the correlation of core variables was tested. The results report that the diversity of educational qualifications is positively correlated, which is consistent with the H3. There is no distinct connection between age diversity and investing in R&D, and gender diversity's coefficient is positive, which might be because no control variables were added.

5.3 Regression analysis

Table 3 respectively presents the relationships among gender, age, and educational background diversity and the intensity of investing in R&D. Gender diversity's coefficient in the column (1) is -0.00346 and is distinct at 5% level. This proves H1, that is, gender diversity has a distinct inhibiting influence on R&D investment. The coefficient of age diversity in column (2) is -0.0107, which is distinct at the level of 1%. This means that the H2 can be verified. The coefficient of educational background diversity in column (3) is 0.00406 and is distinct at the 1% level. This result proves H3, that is, educational background diversity has a distinct facilitating effect on enterprises' R&D investment.

The column (4) shows the result of regressions among core variables, which indicates that board diversity (gender_d, age_d, edu_d) have a distinct influence on an enterprise's investing in R&D.

Table 3. OLS regressions.

	(1)	**(2)**	**(3)**	**(4)**
	RDintensity	**RDintensity**	**RDintensity**	**RDintensity**
gender_d	-0.00346**			-0.00303*
	(0.00172)			(0.00172)
age_d		-0.0107***		-0.0108***
		(0.00217)		(0.00218)
edu_d			0.00406***	0.00447***
			(0.00132)	(0.00132)
Control	Yes	Yes	Yes	Yes
Constant	0.0870***	0.0918***	0.0821***	0.0901***
	(0.00807)	(0.00808)	(0.00794)	(0.00819)
industry	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes
r2	0.421	0.421	0.421	0.422
r2_a	0.417	0.418	0.417	0.419
N	15482	15482	15482	15482

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.4 Robustness check

The results of the robustness check are presents in Table 4. This paper replaces the calculation method of R&D investment. Referring to Song, Kang and Zhou's article, the calculation method of R&D expenses divided by total assets can be used to measure R&D investment [23]. According to Table 4, the results of gender and age diversity are distinct and the symbols of coefficient are the same as those of the regression results in Table 3. Although the result of educational background is not prominent, the symbol is the same as that mentioned above. This result proves that the model set in this paper is basically robust.

Table 4. Robustness check.

	(1)	(2)	(3)	(4)
	RD2	**RD2**	**RD2**	**RD2**
gender_d	-0.00330***			-0.00302***
	(0.000818)			(0.000817)
age_d		-0.00605***		-0.00587***
		(0.00102)		(0.00103)
edu_d			0.000544	0.000796
			(0.000629)	(0.000630)
Control	Yes	Yes	Yes	Yes
Constant	0.0351***	0.0371***	0.0330***	0.0380***
	(0.00259)	(0.00261)	(0.00257)	(0.00268)
industry	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes
r2	0.380	0.381	0.379	0.381
r2_a	0.376	0.377	0.375	0.377
N	15482	15482	15482	15482

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, ***$p < 0.01$

5.5 Heterogeneity test

Table 5 reports the results of heterogeneity test. This paper distinguishes large-scale enterprises (greater than the median) from small-scale enterprises based on the median of the total assets. It can be seen from columns (1) to (4) that in small enterprises, gender and age diversity make a more obvious inhibitory effect on dependent variable. In large enterprises, the promoting effect of educational background diversity is more obvious, which can be seen from columns (5) and (6). This might be because large-scale enterprises have stronger risk resistance capabilities and are less restricted by funds. So they would invest more in R&D projects. The above research outcomes are consistent with Muhammad, Migliori and Consorti's article [24].

Table 5. Heterrogeneity test.

	(1)	(2)	(3)	(4)	(5)	(6)
	RDintensity		**RDintensity**		**RDintensity**	
	Large-scale	**Small-scale**	**Large-scale**	**Small-scale**	**Large-scale**	**Small-scale**
gender_d	-0.00214	-0.00475*				
	(0.00223)	(0.00266)				
age_d			-0.00878***	-0.0119***		
			(0.00274)	(0.00345)		
edu_d					0.00506***	0.00256
					(0.00157)	(0.00226)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.0540***	0.0559***	0.0589***	0.0595***	0.0488***	0.0526***
	(0.00968)	(0.0174)	(0.00974)	(0.0174)	(0.00966)	(0.0173)
r2	0.451	0.399	0.452	0.400	0.451	0.399

r2_a	0.445	0.393	0.445	0.394	0.445	0.393
N	7870	7612	7870	7612	7870	7612

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6 Conclusion

R&D is particularly vital for the innovation of an enterprise. The characteristics of the board of directors will have an impact on the investment decisions of an enterprise. This paper explores the connection between board diversity and R&D investment, which finds that the influence of board diversity on R&D investment is significant. This proves that the human capital of an enterprise will be an important factor influencing the strategic decisions of the enterprise. Further research shows that gender and age diversity negatively affect R&D investment, while educational background diversity positively affect with R&D investment. This is different from some previous studies and also provides new ideas for future study in this field. In addition, this paper also selected listed companies in the non-financial industry in China as research samples, which is different from previous studies focusing on the markets of European and American countries.

For shareholders, this study can help them identify which characteristics of directors are more worthy of attention. For top management and supervisor, this study suggests that they need to focus more on-board diversity. Future study can examine the diversity of more board characteristics and explore the connection between board diversity and more different decisions.

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