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Article

The Effect of R&D Investment of Chinese Companies on Business Innovation Performance

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Abstract: This study aims to analyse whether Chinese companies' R&D investment affects management innovation performance. Also, this dissertation defines management innovation as diversification strategies such as technology and industry diversification and analyzes the impact of these diversification strategies. In particular, this paper analyzes whether R&D investment leads to technology and industry diversification and whether technology diversification creates a mediating effect in the process of R&D investment leading to industry diversification. The analysis results can be summarized as follows: First, R&D investment showed a significant positive relationship with industry diversification. Second, R&D investment shows a significantly positive relationship with technology diversification. Third, technology and industry diversification showed a positive relationship. Fourth, this study examined the mediating role of technology diversification, and it was confirmed that technology diversification plays a mediating role in the effect of R&D investment on industry diversification. R&D investment and business innovation play a key role in the sustainable development of enterprises, and the findings of this paper have important reference value for enterprises' R&D investment decision-making. The results of this study provide the following implications that Chinese companies improve business innovation performance by increasing their R&D investment, promoting innovative R&D, and improving technology diversification and industry diversification strategies.

Keywords: R&D investment; industry diversification; technology diversification; business innovation

1. Introduction

Innovative R&D investment is an important strategic means to generate excess profits by strengthening a company's growth potential and core competitiveness and plays a key role in helping the sustainable growth of a country or region's economy [1]. In the current business environment, such as rising production costs, overheated market competition, sluggish exports, and trade disputes, innovative R&D is directly related to companies' long-term growth and ability to cope with economic crises.

Research on corporate diversification strategies, which began in the 1960s, has expanded from product diversification to market diversification (internationalization) and technology diversification [1]. Also, it is argued that diversification in importing and exporting countries, technologies, and industries continues to expand, and the claims most closely related to companies are technology diversification and business diversification (industry diversification) among them [2]. Fontana and Vezzulli [3] analyzed the relationship between technology diversification and innovation, demonstrating a positive correlation between the level of technology diversification and mid- to long-term innovation. They argued that technology-oriented companies should expand the scope of technology through various methods to gain a competitive advantage in the market in order to increase long-term growth and sustainability.

In particular, they suggested that technology diversification can be achieved through the strengthening of a company's core technology, and that companies should focus on innovative R&D investment in order to be competitive in new technology. Innovation is manifested in a variety of forms. Companies can realize technology diversification by developing and improving technology

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based on research and development. Furthermore, a company can expand its market by diversifying the business through technology diversification while generating profits and increasing its value. In response, the Chinese government implements the largest R&D investment policy among countries in the world, providing tax support to attract Chinese companies to bold R&D investment.

In April 2001, the China Securities Regulatory Commission issued the Guidelines for Industry Classification of Listed Companies, which clearly defined industry divisions and provided data integration standards for measuring diversification. AUX, originally an automobile company, acquired a finished vehicle manufacturer in Shenyang, China. Even after the acquisition, Oaks invested in research and development, entered the home appliance industry, and implemented a management diversification strategy. The impact of rational use of R&D expenditure on income tax makes companies more financially advantageous and helps them diversify their management.

The purpose of this study is to analyze how Chinese listed companies' R&D expenditures affect technology diversification and industry diversification. In particular, this study divides a company's innovation performance into technology diversification and industry diversification, analyzing a series of innovation processes in which technology diversification leads to industry diversification. To this end, this study evaluates the relationship between R&D investment size and technology diversification, the relationship between R&D investment size and industry diversification, and the mediating effect of technology diversification on the relationship between R&D investment size and industry diversification.

This study also analyzes Chinese companies because the Chinese government is promoting tax support as well as financial support for corporate R&D investment more strongly than other countries. Therefore, this study has academic and practical significance. In addition, this study reviews whether there are differences in R&D investment scale, technology diversification, and industry diversification depending on whether or not they are state-owned enterprises in China.

2. Review of Theoretical Background and Research Hypotheses

2.1. China's R&D Investment Policy

R&D investment is an important way to improve a company's technology, and the focus of R&D investment was whether a company could produce innovative results if it could strengthen its R&D activities. Corporate R&D investment means developing new products, seeking new technologies, utilizing new resources, and expanding new businesses. Enterprises must constantly improve themselves in the face of strong market competition, consolidating their competitive advantage in innovative ways. Therefore, R&D investment can be said to be an essential activity for a company's continuous innovation.

However, in some respects, a company's R&D investment can be seen as financial expenditure for product production, technology introduction, material purchase, and talent recruitment.

2.2. Technology Diversification

Early theoretical studies related to technology diversification were mainly focused on the marketing field among business management and primarily dealt with business diversification and market diversification. In contrast, research on technology diversification, which represents technology development and technological innovation, not marketing, has rarely been conducted. Furthermore, Kodama [4] argued that technology diversification means research and development activities outside of a company's product or marketing area and that it is the expansion of activities such as technology innovation and technology development into the company's main activities [5].

Yang et al. [6] presented an analysis result that technology diversification can be measured through the distribution of patents owned by companies and that this diversification directly affects the performance of companies. In other words, the number of patents serves as a sufficient proxy for technology diversification.

There are many studies on the relationship between R&D investment and technology diversification, but consistent research results cannot be presented. First, Zhou et al. [7] asserted a

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research result that there is a relationship between R&D investment and technology diversification. They presented research results that showed a positive relationship between R&D costs and technology diversification in the case of companies with organizational slack but no relationship in other cases.

Sun and Wamg [8] revealed that government subsidies and tax support for corporate R&D investment are highly likely to lead to technological innovation while attracting R&D investment. Bolli and Martin [9] analyzed Chinese high-tech companies from 2010 to 2015 and found that there was a significant positive correlation between government subsidy and R&D investment when control variables were controlled by applying a fixed effect model. which leads to technological innovation. Wang [10] also revealed that the level of technology diversification increases as the number of patent applications increases for Swiss companies. This is because it occurs in companies with a large investment in R&D, and is not statistically significant in companies with a small investment in R&D.

On the other hand, there are also studies that show that there is no relationship between R&D investment and technology diversification, or that R&D investment can adversely affect technology diversification. As a representative study, Zheng and Li [11] reports that, as a result of empirical analysis using panel data of Chinese high-tech companies, government subsidies have a negative effect on the relationship between R&D investment and technological innovation performance of state-owned enterprises. This means that R&D investment in cutting-edge technology must be made voluntarily by companies in order to develop into technology development or diversification. Furthermore, it suggests that R&D investment through government policy may be less likely to lead to technology diversification. In addition, Zheng and Li [11] & Zhao et al. [12] presented research results that the impact of corporate R&D investment on technological innovation or technology diversification may differ depending on the government support policy method. In other words, if there is direct government financial support for R&D, R&D investment leads to technology diversification, whereas if R&D investment is supported through tax support such as tax expenditure, it is less likely to lead to technology diversification. Huang and Chen [13] reported an inverted U-shaped relationship between technology diversification and R&D costs.

Du et al. [14] analyzed the relationship between technology diversification and R&D innovation through data from 134 Chinese manufacturing companies. They presented the research result that technology diversification and R&D innovation are not linearly related. Yang et al. [15] also reported that companies with low R&D investment have a negative effect on technology diversification if the core technology level (patent technology level) is low and that excessive R&D is rather less likely to lead to technology diversification. As such, previous studies have not consistently reported the relationship between R&D investment and technology diversification, indicating that there are other factors that affect the relationship between these variables.

2.3. Diversification of Industries (or Business)

Sun and Huang [16] present that corporate R&D investment suppresses industry diversification, reporting that this phenomenon is particularly prominent in state-owned enterprises. In addition, this deterrence is mainly due to government intervention, and private companies rarely experience this phenomenon. However, Zhang and Li [17] presented a research result that found that the negative relationship between innovative R&D investment and industry diversification was limited to Chinese companies. According to them, multinational companies have a rather positive relationship between the two variables because their R&D fields are selected at their discretion, and companies are free to choose industries that utilize newly developed technologies. In particular, Nelson and Winter [18] analyzed using Chinese listed company data, revealing that a lack of innovative R&D investment caused industry diversification.

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2.4. Hypotheses of Development

Companies that have secured a competitive advantage through R&D realize higher future performance and profits than other companies [19]. Companies can increase the number of patents by investing more in R&D.

In addition, as the company's technological innovation capacity to develop new technologies increases, the company can acquire the ability to enter other industries. Furthermore, based on the technological competitiveness acquired through R&D investment in various fields, companies can advance into diverse industries and prepare alternative growth strategies for future business opportunities, which suppresses the entry of potential competitors and enables the company to grow continuously [20]. Therefore, this study established the following hypotheses based on the fact that a company will pursue business diversification if it has a lot of new R&D investment activities in various fields.

(H1): *As the level of corporate R&D investment increases, industry diversification will also increase.*

Firm value can be maximized by increasing R&D expenditure in innovative business management. In this way, companies can implement a technology diversification strategy as they increase their R&D capabilities, which analyzes the relationship between the external market's competitive environment, business scope, and technology development direction, and connects each technology sector of the company. Therefore, the rational use of resources and efficient allocation of technical resources can promote corporate performance, such as increased resource efficiency and reduced production cost [21].

In addition, technology diversification can be progressed more easily by integrating resources such as encouraging R&D activities, increasing R&D investment, improving companies' technology integration capabilities, and integrating knowledge between related technology fields [22]. Moreover, it is predicted that technology diversification will develop as R&D investment increases. Therefore, this study established the following hypotheses.

(H2): *As the level of R&D investment increases, the level of technological diversification also increases.*

The industry diversification strategy expands a company's technological resource capabilities, while technology diversification promotes industry diversification [23]. Grandstrand [24] theoretically reviewed the interactive relationship between technology diversification and industry diversification of a company and argued that the higher the level of a company's industry diversification, the more diversified opportunities for R&D activities. In addition, companies' increased degree of technological diversification can provide incentives for companies to enter various related new industrial markets.

The integration of new technologies can promote business diversification and entry into new industries, so more technologies need to be developed. If an industry faces new user needs and technological opportunities, it must transform the technological foundation of its products in addition, companies develop new technologies through technology diversification, and at this time, the relationship between industries and technologies changes due to technology diversification in related industries. New technology development can motivate a company to enter a new industry field, which means that a company can achieve industry diversification [25]. This paper established the following hypotheses.

(H3): *The higher the level of technology diversification of a company, the higher the level of industry diversification.*

For companies, R&D and technology are a source of diversification and new opportunities [26]. All technology diversification companies must consider whether to implement a follow–up industry diversification strategy or to gain greater competitiveness in existing industries. Firms can gain a new competitive edge by increasing their R&D investment and strengthening innovation capabilities. Such R&D innovation requires broadening the technological base of the company. In other words, companies need to develop technology innovation activities in various technology fields [27]. Therefore, technology diversification of companies can create competitiveness in new industrial fields, such as updating existing industrial platforms, diversifying management in technology-related industries, and discovering new business opportunities. Technology diversification provides

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a basis for companies to consider two diversification strategies: technology and sector. Therefore, technology diversification is expected to mediate R&D investment and industry diversification, and the following hypotheses can be established.

(H4): *Technology diversification affects the relationship between R&D investment and industry diversification.*

3. Research Model and Measurement of Variables

3.1. Research Model

The purpose of this study is to verify the effect of Chinese listed companies' R&D expenditure on technology diversification and industry diversification. In addition, this study aims to confirm the correlation between technology diversification and industry diversification. In this study, the endogeneity problem was solved by defining the dependent variables *IND_n* and *ETECHDIV* through t+1 years.

In addition, a regression analysis was performed by inputting a company's technology diversification level and industry diversification level, a proxy for company's R&D expenditure, and other control variables that could affect management innovation of the company. Therefore, this study presented the model of regression analysis as follows:

$$IND_{n_{i,t+1}} = \alpha + \beta_1 RND_{i,t} + \beta_2 GOV_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 LEV_{i,t} + \beta_5 CFO_{i,t} + \beta_6 ROA_{i,t} + \beta_7 LARGE_{i,t} + \beta_8 FOREIGN_{i,t} + \beta \Sigma YEAR + \beta \Sigma IND + \varepsilon_{i,t}$$

Equation (1)

$$ETECHDIV_{i,t+1} = \alpha + \beta_1 RND_{i,t} + \beta_2 GOV_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 LEV_{i,t} + \beta_5 CFO_{i,t} + \beta_6 ROA_{i,t} + \beta_7 LARGE_{i,t} + \beta_8 FOREIGN_{i,t} + \beta \Sigma YEAR + \beta \Sigma IND + \varepsilon_{i,t}$$

Equation (2)

$$IND\_n_{i,t+1} = \alpha + \beta_1 ETECHDIV_{i,t} + \beta_2 GOV_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 LEV_{i,t} + \beta_5 CFO_{i,t} + \beta_6 ROA_{i,t} + \beta_7 LARGE_{i,t} + \beta_8 FOREIGN_{i,t} + \beta \Sigma YEAR + \beta \Sigma IND + \varepsilon_{i,t}$$

Equation (3)

where,

ETECHDIV: Entropy index representing the level of technology diversification in year t+1

IND_n: Measured as 1 if the number of industries that account for 10% or more of total operating sales is 3 or more, otherwise it is measured as 0

RND: [(Research and development expenses/Total sales of current period)]x100 as a company's R&D intensity

GOV: "1" for state-owned enterprises, "0" for non-state-owned enterprises

SIZE: Natural logarithm of total assets at the end of the year or company size

LEV: Total Debt/Total Assets as Debt Ratio

CFO: Cash Flow/Total Assets from Operating Activities

ROA: Net Income/Total Assets as return on assets

LARGE: Equity ratio of major shareholders

FOREIGN: Percentage of foreign ownership (Number of common shares held by f oreigners/Total number of common shares)

ΣYEAR: Industry dummy variables

ΣIND: Year dummy variables

ε: Residual

The research model sets technology diversification and industry diversification of companies as dependent variables, setting the company's R&D concentration as an independent variable. Furthermore, the research model was designed to observe the relationship between R&D investment within a company and the level of technology diversification and industry diversification by controlling other financial and accounting variables that could affect R&D expenditure. Besides, in order to verify this, this study measured the level of technology diversification as an entropy index

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based on previous studies. Furthermore, this study evaluated the level of industry diversification as a dummy variable. Also, the R&D concentration was measured by expressing the percentage of R&D expenses in total sales for the current period [28].

Referring to the research method of Kim et al. [29], this study aims to verify the mediating effect of technology diversification on the relationship between R&D expenditure and industry diversification. Step 1, this study will verify the relationship between R&D expenditure and industry diversification. Step 2, this study will conduct a regression analysis of the relationship between R&D investment and technology diversification. Step 3, this study will verify whether the relationship between R&D investment and industry diversification changes by adding a technology diversification variable. This study presents the following regression model to test the mediating effect of technology diversification.

$$IND_{n_{i,t}} = \alpha + \beta_1 RND_{i,t} + \beta_2 GOV_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 LEV_{i,t} + \beta_5 CFO_{i,t} + \beta_6 ROA_{i,t} + \beta_7 LARGE_{i,t} + \beta_8 FOREIGN_{i,t} + \beta \Sigma YEAR + \beta \Sigma IND + \varepsilon_{i,t}$$

Equation (4-1)

$$ETECHDIV_{i,t} = \alpha + \beta_1 RND_{i,t} + \beta_2 GOV_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 LEV_{i,t} + \beta_5 CFO_{i,t} + \beta_6 ROA_{i,t} + \beta_7 LARGE_{i,t} + \beta_8 FOREIGN_{i,t} + \beta \Sigma YEAR + \beta \Sigma IND + \varepsilon_{i,t}$$

Equation (4-2)

$$IND_{n_{i,t}} = \alpha + \beta_1 RND_{i,t} + \beta_2 ETECHDIV_{i,t} + \beta_3 GOV_{i,t} + \beta_4 SIZE_{i,t} + \beta_5 LEV_{i,t} + \beta_6 CFO_{i,t} + \beta_7 ROA_{i,t} + \beta_8 LARGE_{i,t} + \beta_9 FOREIGN_{i,t} + \beta \Sigma YEAR + \beta \Sigma IND + \varepsilon_{i,t}$$

Equation (4-3)

where,

ETECHDIV: Entropy index representing the level of technology diversification in year t+1

IND_n: Measured as 1 if the number of industries that account for 10% or more of total operating sales is 3 or more, otherwise it is measured as 0

RND: [(Research and development expenses/Total sales of current period)]x100 as a company's R&D intensity

GOV: "1" for state-owned enterprises, "0" for non-state-owned enterprises

SIZE: Natural logarithm of total assets at the end of the year or company size

LEV: Total Debt/Total Assets as Debt Ratio

CFO: Cash Flow/Total Assets from Operating Activities

ROA: Net Income/Total Assets as return on assets

LARGE: Equity ratio of major shareholders

FOREIGN: Percentage of foreign ownership (Number of common shares held by foreigners/Total number of common shares)

ΣYEAR: Industry dummy variables

ΣIND: Year dummy variables

ε: Residual

3.2. Measurement of Variables

This study measured the level of technology diversification, a dependent variable, based on the international patent classification criteria reported by [29]. Patent classification standards are classified according to the International Patent Classification (IPC) code, which is used internationally as a patent classification standard. The structure of International Patent Classification consists of a hierarchical structure of sections, classes, subclasses, and main groups and subgroups.

When the International Patent Classification is classified into subclasses, the calculation of the diversification index can be divided into a narrow range of technical fields. Therefore, this study calculated the technology diversification index using classification criteria divided into sections and classes. This study used the technical diversification index calculated by the entropy-based method as the dependent variable. In general, previous studies largely used the Herfindahl index and the entropy index when measuring technology diversification. In particular, they mainly used the Herfindahl index as a measure of technology diversification [30]. The Herfindahl-Hirschman Index

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(HHI) is an indicator of market concentration, which is the sum of the squares of each market share (%) of all players in the market. Thus, the HHI, an index that can describe diversified industrial agglomeration, can be expressed as follows [29].

$$HHI = 1 - \Sigma P_i^2$$

The Herfindahl index, which measures concentration, can be obtained for each company variable and year variable. The level of technology diversification can be measured by subtracting that value from 1. P_i indicates the proportion of the number of patents filed for subclass i in the current year to the total number of patents filed by a specific company. On the other hand, when calculated with the Herfindahl index, the overall technology diversification index can be calculated.

However, there is a disadvantage in that it cannot be calculated and reflected by related diversification and unrelated diversification types. In order to compensate for this point, many previous studies calculated the entropy index as a technology diversification index [31,32]. The entropy index can be measured as follows.

$$ETECHDIV = \sum_{i=1}^{n} P_i Ln(\frac{1}{P_i})$$

Here, n is the technical classification based on the IPC subclass, and P_i is the proportion of the number of patents filed in subclass i in the current year to the total number of patents filed by a specific company. Also, the value of entropy has a value closer to 1 as the degree of diversification increases.

In this study, industry diversification was measured as 1 if the number of industries accounting for 10% or more of total sales was 3 or more, and otherwise, it was measured as 0. According to previous studies, there are four methods for measuring industry diversification.

1. Industry dummy: Measured as 1 if the number of industries is more than 1. Otherwise, it is measured as 0.
2. Number of businesses operated: Measured as 1 if the number of industries that account for 10% or more of total operating sales is 3 or more, otherwise it is measured as 0
3. It is calculated using the Herfindahl index in the following way [33]. When calculating the relevant diversification index within the flagship industry, the percentage of sales based on the sales of the flagship industry is calculated and used. If the value of the Herfindahl industry diversification index is high, it is interpreted that the company has undergone a lot of industry diversification.

   Herfindahl–Hirschman index = $1 - \Sigma P_i^2$
4. In the entropy index, the industry diversification index was calculated based on the sales share of individual business units classified in the sales status of the business report [34]. Also, when individual business units are grouped into intermediate categories, the related diversification index can be measured using the sales share of the business units within the group. If a company has several different business divisions, and each sales share for these companies is P_i, the industry diversification index is expressed as $\Sigma P_i Ln(\frac{1}{P_i})$.

The research model of this study set *RND* (company's R&D concentration) as an independent variable and measured the percentage of R&D expenses in total sales for the current period [27]. The control variables are *GOV* (whether state-owned or privately owned), *SIZE* (firm size), *LEV* (debt ratio), *CFO* (cash flow from operations), *ROA* (return on assets), *LARGE* (major shareholders' ownership), *FOREIGN* (share ratio of foreign investors), etc. Year dummies ($\sum YEAR$) and industry dummies ($\sum IND$) were additionally considered to control changes in the economic environment and differences in industry characteristics. Detailed measurements and definitions of control variables are reported at the bottom of Equations (1) and (2).

3.3. Sampling

This study selected corporate data from the Chinese CSMAR and WIND databases listed on the Chinese stock market from 2013 to 2020. Based on this, the final analysis sample was composed of companies that satisfied the following conditions.

1. Companies not belonging to the financial and insurance industries

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2. Companies whose fiscal year ends at the end of December
3. Companies without capital impairment
4. Companies that can provide data on R&D expenses and financial data necessary for analysis

The final analysis sample is a total of 22,714 company-years. Also, by industry, companies were distributed in the order of manufacturing (14,550 companies-year), IT companies (1795 companies-year), and wholesale and retail (1094 companies-year). Winsorizing was performed on the upper and lower 1% of all continuous variables to minimize the effect of extreme values in the data.

4. Results

4.1. Descriptive Statistics

Table 1 shows the descriptive statistics of the major variables. According to the results, the mean value of the measure of technology diversification (*ETECHDIV*) is 0.284 and the mean value of industry diversification (*IND_n*) is 0.028. The *RND*, a major variable in this study, is 0.003, with a minimum value of 0 and a maximum value of 0.069. It is confirmed that the sample companies' mean R & D cost is about 0.3% of the total sales. In addition, the Chinese state-owned company (*GOV*), a dummy variable of this study, is designated as 0 and 1, including state-owned companies in the sample.

Table 1. Descriptive statistics of variables(N=22,714).

Variable	Mean	SD	p50	Min	Max
ETECHDIV	0.284	0.341	0	0	0.925
IND_n	0.028	0.164	0	0	1
RND	0.003	0.011	0	0	0.069
GOV	0.351	0.477	0	0	1
SIZE	22.18	1.302	22	19.830	26.210
LEV	0.414	0.204	0.403	0.056	0.894
CFO	0.050	0.068	0.049	-0.148	0.248
ROA	0.039	0.062	0.039	-0.262	0.202
LARGE	0.344	0.149	0.322	0.087	0.749
FOREIGN	0.011	0.057	0	0	0.421

* The definition of variable is as follows. *ETECHDIV*: Entropy index representing the level of technological diversification. *IND_n*: Measured as 1 if the number of industries that account for 10% or more of total operating sales is 3 or more, otherwise it is measured as 0. *RND*: [(Research and development expenses/Total sales of current period)]x100 as a company's R&D intensity. *GOV*: "1" for state-owned enterprises, "0" for non-state-owned enterprise. *SIZE*: Natural logarithm of total assets at the end of the year or company size. *LEV*: Total Debt/Total Assets as Debt Ratio. *CFO*: Cash Flow/Total Assets from Operating Activities. *ROA*: Net Income/Total Assets as return on assets. *LARGE*: Equity ratio of major shareholders. *FOREIGN*: Percentage of foreign ownership (Number of common shares held by foreigners/Total number of common shares)

4.2. Correlation Analysis between Variables

Table 2 shows the results of Pearson's correlation analysis between major variables. RND concentration (*RND*) is confirmed as 0.069 and 0.042 for technology diversification (*ETECHDIV*) and industry diversification (*IND_n*), respectively, which are statistically significant at the 10% level. This means that the higher the R&D cost investment, the higher the level of technology diversification and industry diversification of the company. Industry diversification (*IND_n*) shows a positive correlation with technology diversification (*ETECHDIV*), which is not statistically significant.

Also, among the control variables, company size (*SIZE*) shows a correlation of 0.062 and 0.052 for technology diversification (*ETECHDIV*) and industry diversification (*IND_n*), respectively, which is statistically significant at the 10% level. Thus, it can be interpreted that the larger the company size,

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the higher the level of diversification of the company. Among corporate financial variables, the debt ratio (*LEV*) does not reveal any correlation with industry diversification.

There is a statistically significant negative correlation at the 10% level between diversification of cash flow from operations (*CFO*) and return on assets (*ROA*). On the other hand, there is a negative correlation between the corporate governance variables "*LARGE* and *FOREIGN*" and the dependent variable industry diversification (*IND_n*), which is not statistically significant.

Table 2. Correlation analysis.

VARIABLES	*ETECHDIV*	*IND_n*	*RND*	*GOV*	*SIZE*	*LEV*	*CFO*	*ROA*	*LARGE*
IND_n	0.011								
RND	0.069*	0.042*							
GOV	-0.053*	0.049*	-0.047*						
SIZE	0.062*	0.052*	-0.006	0.346*					
LEV	-0.035*	0.005	-0.076*	0.274*	0.519*				
CFO	0.047*	-0.020*	-0.050*	-0.057*	0.034*	-0.179*			
ROA	0.097*	-0.018*	-0.049*	-0.124*	-0.044*	-0.362*	0.393*		
LARGE	0.001	-0.010	-0.118*	0.201*	0.179*	0.051*	0.116*	0.145*	
FOREIGN	0.022*	-0.011	-0.019*	-0.101*	-0.073*	-0.101*	0.068*	0.107*	0.070*

Note 1) ***p<0.01, **p<0.05, *p<0.1. Note 2) The definition of the variable is the same as the note in Table 1.

4.3. Results of Regression Analysis

Table 3 presents the results of the regression analysis conducted using Equation (1) to verify Hypothesis 1 in this study. Research and development concentration (*RND*) is confirmed to have a positive effect on industry diversification (*IND_n*) at a statistical significance level of 5%. Therefore, Hypothesis 1 was accepted. This means that the concentration of R&D is strong in various fields, and the level of diversification of industries will increase if the company advances into various sectors based on its technological competitiveness. In addition, the control variable, Chinese state-owned enterprises (*GOV*), shows a correlation of 0.773, which is statistically significant (p<0.01). This means that Chinese state-owned enterprises have a relatively high degree of business diversification.

The correlation between business size (*SIZE*) and industry diversification (*IND_n*) is 0.476, which is statistically significant (p<0.01). This means that the larger the company size, the higher the diversification level. In addition, the result is consistent with previous studies that the higher the debt ratio, the lower the level of business diversification. Cash flow from operations (*CFO*) and return on assets (*ROA*) were found to be statistically insignificant coefficients for industry diversification. Major shareholders' equity ratio (*LARGE*) shows a significant negative correlation with industry diversification, which is statistically significant (P<0.05). This means that the higher the major shareholder equity ratio (*LARGE*), the lower the level of diversification.

Table 3. Results of regression analysis of RND and industry diversification.

IND_n(t+1)	Coef.	t-value	St.Err
_cons	-17.185***	-7.52	2.287
RND	14.956**	2.43	6.156
GOV	0.773***	2.97	0.261
SIZE	0.476***	4.66	0.102
LEV	-1.288**	-2.15	0.599
CFO	-1.624	-1.31	1.24
ROA	-1.168	-0.85	1.369
LARGE	-1.704**	-2.29	0.744
FOREIGN	1.797	1.24	1.448
∑*YEAR*		Included	
∑*IND*		Included	

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Log likelihood	-1,603.957
LR chi²	1,415.890
Prob > chi²	0.000

Note 1) ***p<0.01,Note 1) ***p<0.01,**p<0.05, *p<0.1. Note 2) The definition of variable is as follows. *IND_n:* Measured as 1 if the number of industries that account for 10% or more of total operating sales is 3 or more, otherwise it is measured as 0. *RND*: [(Research and development expenses/Total sales of current period)]x100 as a company's R&D intensity. *GOV*: "1" for state-owned enterprises, "0" for non-state-owned enterprises. *SIZE*: Natural logarithm of total assets at the end of the year or company size. *LEV*: Total Debt/Total Assets as Debt Ratio. *CFO*: Cash Flow/Total Assets from Operating Activities. *ROA*: Net Income/Total Assets as return on assets. *LARGE*: Equity ratio of major shareholders. *FOREIGN*: Percentage of foreign ownership (Number of common shares held by foreigners/Total number of common shares). ∑*IND*: Industry dummy variables. ∑*YEAR*: Year dummy variables

Table 4 shows the results of regression analysis that verified Hypothesis 2 using Equation (2). The correlation between *RND* and technology diversification (*ETECHDIV*) is 1.053, which was statistically significant (p<0.05). This means that the stronger the R&D concentration, the higher the level of technology diversification. This shows the result supporting research hypothesis 2. In other words, as R&D investment costs increase or resources such as a company's technology integration capability and knowledge between related technology fields are integrated and improved, the level of technology diversification can be increased. In addition, the Chinese state-owned enterprise (*GOV*), a control variable, is -0.057, which is statistically significant (p<0.05). This means that the level of enterprise technology diversification is relatively low for Chinese state-owned enterprises. The correlation between company size (*SIZE*) and technology diversification (*ETECHDIV*) is 0.059, which is statistically significant (p<0.01). This means that the larger the company size, the higher the level of technology diversification. The major shareholder ownership ratio (*LARGE*) has a positive effect on technology diversification, which is statistically significant (p<0.05). This means that the stakes of major shareholders can increase the level of technology diversification by controlling the ownership structure of managers.

Table 4. Regression analysis results of RND and technology diversification.

ETECHDIV(t+1)	**Coef.**	**t-value**	**St.Err**
_cons	-1.355***	-1.355	-1.35
RND	1.053**	2.24	0.471
GOV	-0.057**	-2.42	0.023
SIZE	0.029***	3.84	0.008
LEV	0.077*	1.96	0.039
CFO	0.029	0.41	0.071
ROA	0.084	1.11	0.076
LARGE	0.122**	2.27	0.054
FOREIGN	0.025	0.28	0.089
∑*YEAR*	Included		
∑*IND*	Included		
Log likelihood	-9,505.807		
LR chi²	7,373.380		
Prob > chi²	0.000		

Note 1) ***p<0.01, **p<0.05, *p<0.1. Note 2) The definition of variable is as follows. *ETECHDIV*: Entropy index representing the level of technology diversification in year t+1. *RND*: [(Research and development expenses/Total sales of current period)]x100 as a company's R&D intensity. Note 3) The definition of other variables are the same as the note in Table 3.

In order to examine the relationship between technology diversification and industry diversification, this study conducts a regression analysis as shown in Equation (3), with business

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diversification as the dependent variable and technology diversification as the independent variable. Table 5 presents the results of analyzing the relationship between technology diversification and industry diversification through regression analysis. The correlation between technology diversification (*ETECHDIV*) and industry diversification (*IND_n*) is 0.276, which is statistically significant (p<0.05). This result supports Hypothesis 3 that the level of industry diversification increases as the level of technology diversification increases. In other words, there is an interaction between technology diversification and industry diversification, and the higher the level of business diversification, the more opportunities for R&D activities. On the other hand, the greater the degree of a company's technological diversification, the more motivated it is to enter relevant emerging markets. In addition, there is a positive relationship between control variables such as state-owned enterprises (*GOV*), business size (*SIZE*), and industry diversification. This can be interpreted as the degree of diversification of the industry as Chinese state-owned enterprises and the larger the size of the enterprises. The results of the remaining control variables are similar to those in Table 4.

Table 5. Results of regression analysis of technology diversification and industry diversification.

IND_n(t+1)	**Coef.**	**t-value**	**St.Err**
_cons	-11.139***	-12.69	0.877
ETECHDIV	0.276**	2.12	0.13
GOV	0.424***	4.51	0.094
SIZE	0.363***	9.1	0.039
LEV	-1.079***	-3.92	0.275
CFO	-2.458***	-3.38	0.727
ROA	-1.406*	-1.88	0.748
LARGE	-0.791***	-2.62	0.302
FOREIGN	-0.023	-0.03	0.893
∑*YEAR*	Included		
∑*IND*	Included		
Log likelihood	-1,594.056		
LR chi^2	1,402.840		
Prob > chi^2	0.000		

Note 1) ***p<0.01, **p<0.05, *p<0.1. Note 2) The definition of variable is as follows. *IND_n:* Measured as 1 if the number of industries that account for 10% or more of total operating sales is 3 or more, otherwise it is measured as 0. *ETECHDIV*: Entropy index representing the level of technology diversification in year t. Note 3) The definition of other variables are the same as the note in Table 4.

Table 6 suggests that technology diversification can mediate the relationship between R&D investment and industry diversification. In this study, three-step mediated regression is performed according to the method of Wen and Ye [28] to identify whether technology diversification plays a mediating role.

An analysis is conducted to test the mediating effect of technology diversification (*ETECHDIV*) in the relationship between RND concentration (*RND*) and industry diversification (*IND_n*). According to the results, the correlation between *RND* and *ETECHDIV* in the first stage is 1.135, which is statistically significant (p<0.01). This means that *RND* is having a positive effect on *ETECHDIV*. Also, the correlation between *RND* and *IND_n* in stage 2 is 10.10, which is statistically significant (p<0.01). This means that *RND* has a positive effect on *IND_n*.

In step 3, the correlations of *RND* and *ETECHDIV* with *IND_n* are 9.930 (p<0.01) and 0.256 (p<0.05), respectively, which are statistically significant. In order to verify the mediating effect of technology diversification (*ETECHDIV*), the standardized beta value shown in step 3 should be smaller than the standardized beta value in step 2. According to the analysis results, the standardized beta value between *IND_n* and *RND* in the second stage is 10.10 (p<0.01), and the standardized beta value between *IND_n* and *RND* in the third stage is 9.39 (p<0.01). It is confirmed that the standardized beta value shown in step 2 is greater than that in step 3. Thus, this study shows that technology

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diversification plays a mediating role in the effect of R&D investment on industry diversification. In this study, the results of Sobel Test and the Goodman Test are statistically significant at the 10% and 5% levels, respectively, so hypothesis 4 is verified to be supported. In other words, as R&D investment increases, the technology of new products expands, and the level of technology diversification also increases. In addition, increasing investment in new technologies by companies in new fields not only helps them adapt to different industries and external environments, but also helps to promote the level of business diversification of companies in the end.

Table 6. Analysis of mediating effects of technological diversification.

VARIABLES	Stage 1	Stage 2	Stage 3
	ETECHDIV	*IND_n*	*IND_n*
Constant	-1.015***(-21.95)	-11.22***(-12.97)	-10.98***(-12.47)
RND	1.135***(5.38)	10.10***(3.30)	9.390***(3.05)
ETECHDIV			0.256**(1.96)
GOV	-0.003(-0.63)	0.439***(4.70)	0.426***(4.54)
SIZE	0.044***(20.70)	0.363***(9.21)	0.354***(8.81)
LEV	0.019(1.39)	-1.045***(-3.82)	-1.015***(-3.67)
CFO	-0.043(-1.22)	-2.302***(-3.20)	-2.345***(-3.21)
ROA	0.408***(10.08)	-1.22(-1.63)	-1.308*(-1.73)
LARGE	0.022(1.43)	-0.657**(-2.18)	-0.717**(-2.37)
FOREIGN	0.004(0.11)	-0.063(-0.07)	0.0162(0.02)
∑YEAR		Included	
∑IND		Included	
Observations	22,427	22,040	21,901
Sobel Test		0.008*	
Goodman Test		0.008**	
Indirect_effect_a*b		0.008*	
Direct_effect_c'		0.407***	
Total_effect_c		0.415***	
Proportion of mediating effect		0.019	

Note 1) ***p<0.01, **p<0.05, *p<0.1. Note 2) The definition of variable is as follows. *ETECHDIV*: Entropy index representing the level of technology diversification in year t. *IND_n*: Measured as 1 if the number of industries that account for 10% or more of total operating sales is 3 or more, otherwise it is measured as 0. Note 3) The definition of other variables are the same as the note in Table 4.

4.4. Additional Analysis

This analysis additionally analyzes whether R&D investment affects corporate management innovation in the current, next, and next term. In Table 7, according to the year lag of business diversification (*IND_n*), *RND* shows statistically significant coefficients of 14.956 (p<0.05), 16.426 (p<0.05), and 13.025 (p<0.10), respectively. This supports Hypothesis 1 that the concentration of R&D is strong in various business and that the level of business diversification increases when entering various business areas based on technological competitiveness. And *RND* means that it not only affects the next business diversification (*IND_n*), but also has a continuous influence on the year after two years and the business diversification after three years (*IND_n*). In addition, as a control variable, whether state-owned enterprises (*GOV*) was statistically significant for business diversification (*IND_n*) in the next year, 2 years, and 3 years, respectively, 0.773(p<0.01), 0.671(p<0.05), 0.578(p <0.05).This means that the level of future business diversification (*IND_n*) as well as the relatively high level of business diversification (*IND_n*) for state-owned enterprises is relatively high.

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Table 7. Regression analysis results of RND and business diversification (t+1, t+2, t+3).

VARIABLES	*IND_n(t+1)*		*IND_n(t+2)*		*IND_n(t+3)*	
	Coef.	t-value	Coef.	t-value	Coef.	t-value
_cons	-17.185***	-7.52	-16.664***	-6.90	-15.622***	-5.88
RND	14.956**	2.43	16.426**	2.35	13.025*	1.62
GOV	0.773***	2.97	0.671**	2.48	0.578**	1.97
SIZE	0.476***	4.66	0.430***	3.92	0.390***	3.25
LEV	-1.288**	-2.15	-1.971***	-2.97	-0.815	-1.11
CFO	-1.624	-1.31	-1.669	-1.20	-2.569*	-1.62
ROA	-1.168	-0.85	-0.484	-0.30	2.804	1.26
LARGE	-1.704**	-2.29	-1.001	-1.27	-0.999	-1.17
FOREIGN	1.797	1.24	-0.402	-0.22	-3.533	-1.43
∑*YEAR*	Included		Included		Included	
∑*IND*	Included		Included		Included	
Log likelihood	-1603.957		-1349.269		-1091.951	
LR chi2	1415.890		1189.740		908.650	
Prob>chi2	0.000		0.000		0.000	

Note 1) ***p<0.01, **p<0.05, *p<0.1. Note 2) The definition of variable is the same as Table 4.

Table 8 shows the results of additional analysis on whether R&D investment affects corporate technology diversification this year, next year, and two years later. Statistically significant coefficients of 1.053 (p<0.05), 11.431 (p<0.01), and 0.077 (p<0.10) between research and development concentration (*RND*) and technology diversification (*ETECHDIV*) according to the year difference of technology diversification (*ETECHDIV*), respectively indicates. This supports hypothesis 2 that the level of technology diversification can increase as R&D investment increases and resources such as a company's technology integration capability and knowledge between related technology fields are integrated and improved. And it shows that RND not only affects next-generation technology diversification (*ETECHDIV*), but also continues to affect technology diversification this year, next year, and beyond.

Table 8. Regression analysis results of RND and technology diversification (t+1, t+2, t+3).

VARIABLES	*ETECHDIV(t+1)*		*ETECHDIV(t+2)*		*ETECHDIV(t+3)*	
	Coef.	t-value	Coef.	t-value	Coef.	t-value
_cons	-1.355***	-1.355	-1.724***	-1.226	-2.066***	-10.30
RND	1.053**	2.24	1.431***	2.59	0.077***	0.14
GOV	-0.057**	-2.42	-0.046**	-1.90	-0.013***	-0.51
SIZE	0.029***	3.84	0.027***	3.07	0.056***	6.50
LEV	0.077*	1.96	0.162***	3.59	-0.085**	-1.88
CFO	0.029	0.41	0.156**	1.97	-0.175**	-2.11
ROA	0.084	1.11	0.059	0.75	0.632***	6.02
LARGE	0.122**	2.27	0.078	1.28	0.042	0.71
FOREIGN	0.025	0.28	-0.086	0.74	0.014	0.14
∑*YEAR*	Included		Included		Included	
∑*IND*	Included		Included		Included	
Log likelihood	-9505.807		-7815.511		-8910.362	
LR chi2	7373.380		5834.700		4627.560	
Prob>chi2	0.000		0.000		0.000	

Note 1) ***p<0.01, **p<0.05, *p<0.1. Note 2) The definition of variable is the same as Table 5.

Table 9 shows the results of additional analysis on whether technology diversification affects corporate business diversification this year, next year, and two years later. Technology diversification

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(*ETECHDIV*) according to the year difference of business diversification (*IND_n*) show statistically significant coefficients of 0.276 (p<0.05), 0.055 (p<0.01), and 0.248 (p<0.10), respectively. This supports research Hypothesis 3 that the higher the level of technology diversification, the higher the level of industry diversification. In addition, it presents that technology diversification (*ETECHDIV*) not only affects next year's business diversification (*IND_n*), but also continues to affect business diversification (*IND_n*) in the next and subsequent years.

Table 9. Regression analysis results of technology diversification and business diversification(t+1, t+2, t+3).

VARIABLES	*IND_n(t+1)*		*IND_n(t+2)*		*IND_n(t+3)*	
	Coef.	t-value	Coef.	t-value	Coef.	t-value
_cons	-11.139***	-12.69	-16.912***	-6.88	-18.337***	-5.60
ETECHDIV	0.276**	2.12	0.055***	0.19	0.248*	0.65
GOV	0.424***	4.51	0.630**	2.32	0.656*	1.77
SIZE	0.363***	9.1	0.432***	3.89	0.405***	2.72
LEV	-1.079***	-3.92	-2.007***	-3.03	-0.727	-0.86
CFO	-2.458***	-3.38	-1.669	-1.19	-2.602	-1.46
ROA	-1.406*	-1.88	-0.673	-0.42	3.239	1.32
LARGE	-0.791***	-2.62	-1.204	-1.52	-1.289	-1.23
FOREIGN	-0.023	-0.03	-0.459	-0.25	-5.177	-1.74
∑*YEAR*	Included		Included		Included	
∑*IND*	Included		Included		Included	
Log likelihood	-1594.056		-1343.126		-1086.539	
LR chi2	1402.840		1184.550		907.730	
Prob>chi2	0.000		0.000		0.000	

Note 1) ***p<0.01, **p<0.05, *p<0.1. Note 2) The definition of variable is the same as Table 6.

5. Conclusions

This study analyzed whether the company's technology diversification and industry diversification changes significantly as the company's R&D investment increases, targeting Chinese listed companies. In addition, this paper empirically verified whether R&D investment promotes technology diversification and has a mediating effect that affects industry diversification. In this study, R&D concentration was measured by expressing the percentage of R&D expenditure in total sales for the current period, the level of technology diversification was calculated as an entropy index, and the level of industry diversification was measured as a dummy variable. The results of this analysis can be summarized as follows.

First, as a result of analyzing the relationship between R&D investment cost and industry diversification, R&D investment showed a significant positive relationship with industry diversification. This means that the level of industry diversification can increase as corporate R&D investment increases. In other words, the concentration of R&D is intense in various fields, and the level of diversification of industries is increasing by advancing into various business areas based on technological competitiveness.

Second, technology diversification intensified as the company's R&D cost increased. Furthermore, it is confirmed that R&D investment has a significant positive relationship with technology diversification. In other words, the integration of resources such as technology integration capabilities and knowledge between related technology fields, as well as corporate R&D investment costs, can increase the level of technology diversification.

Third, technology diversification showed a positive influence on the expansion of industry diversification. In other words, there was an interaction relationship between technology diversification and industry diversification, and the higher the company's industry diversification level, the more diverse R&D activity opportunities appeared. This is interpreted as the higher the

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degree of technology diversification of a company, the more motivated it is to enter relevant emerging markets.

Fourth, it was confirmed that technology diversification plays a mediating role in the effect of R&D investment on business diversification. As companies increase their R&D investment, the technology of new products expands, and the level of technology diversification also rises. In addition, enterprises' greater investment in new technologies in new fields not only contributes to adapting to different industries and external environments but also helps to promote the level of business diversification of enterprises in the end.

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