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Long-term Effects of Research and Development on Firm Performance - Taking Taiwan as the Example (2001-2017)

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Abstract

Previous researches made by scholars on R&D expenses have shown that firm performance can be better with more R&D investment. However, some scholars have expressed that R&D investment has negative effects on firm performance. Therefore, this research explored the causes of positive and negative results. The listed surviving firms (excluding financial firms) of Taiwan, a developed country, between 2001 and 2017 were taken as the research samples, and totally 15,708 samples of 924 enterprises were deleted due to incomplete data. From the research results, the benefits of R&D activities were found to have the time lag effect, which shows why scholars in the past believed that R&D investment has both positive and negative effects. Furthermore, from the research results, R&D investment in the first year has negative effects on firm performance (Tobin's Q). R&D expenses have no significant effects on firm performance in the following four years and do not appear until the fifth year, but continue until the ninth year and above.

Keywords: R&D expenses; Firm performance; Panel data

INTRODUCTION

With the development of science and technology in today's society, in the information age, consumers' demands are gradually becoming diversified, the life cycle of new products is getting shorter, and enterprises are at risk of losing their competitiveness rapidly and being eliminated by society in the case of failure to innovate products or services. Hence, enterprises engage in R&D investment with the expectations to launch new products and services. In this mode, R&D activities gradually replace real assets and become the key factor of business success. Previous researches have shown that more R&D investment activities can bring higher performance to enterprises. Bradley, Jarrell & Kim (1984); Morck et al. (1988); Titman & Wessels (1988); Crutchley & Hansen (1989); McConnell & Servaes (1990); Hermalin & Weisbach (1991); Jensen et al. (1992); Hirschey & Weygandt (1993); Klette (1996); Missaka (2015);Josheski & Sopova (2013); and Shih Yung et. al. (2017) believed that more R&D expenditures indicate high firm growth in the future.

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Previous researches suggested that R&D intensity is often used to measure both product innovations and process innovations (Kotabe et al., 2002). If a firm has an excellent product design, it can gain differentiated advantages from competitors and get more desirable pay. Similarly, if process innovations can reduce production costs, compared with competitors, the innovations can also improve a firm's product quality. Hence, the innovations are reflected in the R&D capacity, which can enable firms to achieve operational efficiency (Hitt et al., 1994). Research has also found that R&D intensity can positively regulate firm performance (Delios & Beamish, 1999; Kotabe et al., 2002; Lu & Beamish, 2004; Bae et al., 2008).

R&D expenditures must be on product innovations or technology improvement to benefit firm performance. Loof and Heshmati (2002) believed that R&D expenditures must bring actual outputs (such as patents) to positively affect performance. Lev and Zarowin (1999), and Lev and Sougiannis (1996) found that R&D investment may be related to product or technological innovations and patents that can be obtained through R&D investment to help enterprises create values. Chauvin and Hirschey (1993), and Deeds (2001) found through empirical researches that the R&D

expenditures and patent approvals of an enterprise have significantly positive effects on its market value, and that the effects can be continued for many years. Deeds (2001) found that R&D intensity, technological development capacity, and technological absorptive capacity at the final stage of R&D have positive effects on the increase of enterprise market values.

Although the literature on international enterprises generally supports the positive relationship between R&D and firm performance, some scholars have found that R&D activities are negatively related to firm performance (Chan, Martin, & Kensinger, 1990; Mank & Nystrom, 2001) and that the investment incomes of R&D activities may be quite low (Rouse & Boff, 1998). By using a total of 47,167 annual firm data in Compustat collected from 1982 to 2002, Franzen and Radhakrishnan (2009) discussed the effects of R&D expenditures on the share values of profitable and non-profitable firms, and the empirical results indicated that R&D investment is negatively related to the share prices of profitable firms, that is, R&D investment has negative effects on the value of profitable firms.

Successful R&D expenditures can also create ongoing effects for firms. Based on researches, Lev and Aboody (2001) found that the benefits produced from R&D expenditures will last for two to seven years. According to Tubbs (2007), R&D expenditures can bring abnormal returns to firms in the next five years. Gary et al. (2006) found that China's industrial R&D is positively related to the incomes on fixed assets, with the benefits outweighing the costs by three or four times. Sougiannis (1994) indicated that, when an enterprise increases NT$ 1 to R&D expenses on average, in the next seven years, the surpluses can be increased by NT$ 2 and the market value can be increased by NT$ 5. Lev and Sougiannis (1996) indicated that, when an enterprise increases NT$ 1 to R&D expenses, operation incomes of NT$ 2.328 can be produced in the future. Therefore, the increases in R&D incomes per unit can be helpful to increase market value.

However, can R&D investment increase profits? Schutzer (1994) indicated that R&D expenditures are not necessarily associated with better operation performance, and the research results of Scherer (1965) showed that the benefits of R&D activities have the effect of a time lag. Lev and Aboody (2001) found that the benefits generated from R&D expenditures can last for two to seven years and that the effects usually occur after two to three years. The time lag effect of R&D expenses is the concern of this research. Hence, this research takes listed firms in Taiwan as the subjects to explore the time lag effect of R&D expenses.

This research is divided into four parts. Section 1 is the introduction and includes literature related to the effects of R&D expenses on firm performance. Section 2 contains the research data and research method of this research, explanations to all research variables, and panel data analysis. Section 3 is the empirical analysis, including univariate analysis, bivariant analysis, general regression analysis, and panel data analysis. The empirical analysis results show that the R&D expenses of Taiwanese enterprises indeed have the time lag effect on firm performance and that the effect is longer than the two to three years mentioned by scholars in the past. The last section is the conclusion, which summarizes the analysis results and provides suggestions.

RESEARCH DATA AND RESEARCH METHOD

Taiwan's per capita GDP surpassed US$10,000 in 1992 to become a developed economy. In 1993, Taiwan was rated as one of the top 20 economies in the world. Therefore, this study selected data having been acquired since the 21st century. The total number of samples of this study, after deleting those of incomplete data, is 15,708 from 924 listed companies (excluding the financial sector) in Taiwan from 2001 to 2017.The R&D expense rate of the independent variation dates back to eight years, so the data are from 1993 to 2017. (source: Taiwan Stock Exchange).

The industrial types of these samples are shown in Table 1. According to Table 1, the electronics industry has the largest number of listed companies in Taiwan, which accounts for more than half (60.17%).

1.1 Research Variable

(1) Independent variable - R&D expense ratio

R&D intensity is used to measure innovations, and both product innovations and process innovations are considered helpful to improve the operation efficiency of firms. Research has also found that R&D intensity is positively related to firm performance (Bradley, Jarrell & Kim, 1984; Morck et al., 1988; Titman & Wessels, 1988; Crutchley & Hansen, 1989; McConnell & Servaes, 1990; Hermalin & Weisbach, 1991; Jensen et al., 1992; Hirschey & Weygandt, 1993; Klette, 1996; Delios & Beamish, 1999; Kotabe et al., 2002; Lu & Beamish, 2004; Bae et al., 2008; Missaka, 2015; Josheski & Sopova, 2013; Shih-Yung et. al., 2017).

Table 1. **Industrial types of samples**

Industry	Department store	Textile	Rubber	Electrical appliance
Quantity of companies	10	45	11	15
Industry	Electronics	Technologies of agricultural and forestry	Steel	Sightseeing
Quantity of companies	556	1	39	1
Industry	Transportation	Manufacturing of construction materials	Others	Chemistry
Quantity of companies	5	4	49	35
Industry	Automobile	Electrical motor	Food	Biotech
Quantity of companies	2	68	15	28
Industry	Cement	Paper making	Plastic	Oil, power and gas
Quantity of companies	2	6	23	1
Industry	Culture and creativity	Total		
Quantity of companies	8	924		

However, some scholars have found that R&D activities are negatively related to firm performance (Chan, Martin, & Kensinger, 1990; Rouse & Boff, 1998; Mank & Nystrom, 2001; Franzen & Radhakrishnan, 2009), and thus stated that the investment incomes of R&D activities may be quite low, that is, R&D investment has negative effects on the value of profitable firms.

Scherer (1965) and Lev and Aboody (2001) demonstrated that the benefits of R&D activities have the time lag effect.

This research comprehensively discusses the previous research results obtained by scholars and explores the long-term effects of R&D intensity on firm performance. The R&D expense ratio is used as the proxy variable of R&D intensity.

$$\text{R \& D expense ratio}_{it}(RD_{it}) = \frac{\text{R \& D expenses}_{it}}{\text{Sale revenues}_{it}} \quad t = 0,1,2,...,8 \qquad (1)$$

(2)Dependent variable -Corporate Performance (Tobin's Q)

This study adopts Tobin's Q, the most commonly used indicator to measure a company's market performance. La Porta et al. (2002) employed Tobin's Q, but failed to figure out Tobin's Q, because they could not obtain the replacement cost of company assets. As a result, they replaced Tobin's Q with Proxy Q, and the latter was adopted by Claessens et al. (2000). Proxy Q is measured as follows:

$$\text{Tobin's Q} = \frac{\text{Market value of equity} + \text{market value of debts}}{\text{Asset replacement cost}} \qquad (2)$$

$$\text{Proxy Q} = \frac{\text{Market value of equity (common stocks} + \text{special stocks)} + \text{book value of debts}}{\text{Book value of assets}} \qquad (3)$$

(3)Control variables

1.Growth rate of fixed assets (LA)

Agrawal and Knoeber (1996), Titman and Wessels (1988), and Shih-Yung Wei et. al. (2017) noted that the higher the growth rate of fixed assets is, the more opportunities for future investment and growth a company has. The growth rate of fixed assets is also an indicator of corporate performance (data source: Taiwan Stock Exchange).

$$\text{LA} = \frac{\text{(Total fixed assets of the year - Total fixed assets of the previous year)}}{\text{Total fixed assets of the previous year}} \qquad (4)$$

2.Degree of internationalization (FS)

By measuring the degree of internationalization with the ratio of foreign sales to total sales (FSTS), Kafouros et al. (2008); Hsu and Pereira (2008); Bae et al. (2008); Gaur and Kumar (2009); Filatotchev and Piesse (2009), and Brouthers et al. (2009) believed that a higher degree of internationalization has more positive effects on firm performance (Taiwan Stock Exchange Corporation).

$$\text{Degree of internationalization= ratio of foreign sales to total sales} \qquad (5)$$

3.Scale of company (SC)

Firms with a large scale can generally be regarded as having the capability to acquire a profit margin above the normal level, as compared with general firms. Therefore, such firms are able to operate in an imperfect market and acquire a higher excess profit by leveraging their monopoly or oligopoly strength. Furthermore, firms with a large scale may have access to funds with a low cost in the capital market or operate in the market with a low cost due to risk diversification.

In respect of the impact of the scale of a company on performance, it is easier for firms with a larger scale to utilize the advantage of economies of scale to result in good operating performance. Therefore, scale of company was defined as a control variable. Measurement of the scale of company includes total assets, total operating revenue, and number of employees (Kotabe et al., 2002; Lu & Beamish, 2004; Chari et al., 2007; Bae et al., 2008; Ravichandran et al., 2009). Generally, the total assets or operating cost of a firm at natural logarithms is defined as a proxy variable. Therefore, in this study, the carrying amounts of the total assets of the sample firms at natural logarithms were used as proxy variables. The data were derived from the Taiwan Economic Journal.

$$\text{Scale of company} = \log(\text{total assets}) \quad (6)$$

4.Debt-asset ratio (D/A; DA)

Myers (1977), Jensen (1986), Morck, Shleifer, and Vishny (1988), Stulz (1990), Shih-Yung Wei et al. (2017) argued that the debt-asset ratio, on the one hand, implies the information of corporate tax shields; on the other hand, according to the Pecking Order Theory, the higher the debt-asset ratio is, the lower the rate on investment is, and the smaller the corporate value will be (data source: Taiwan Stock Exchange).

$$\text{Debt-asset ratio} = \frac{\text{Book value of debt}}{\text{Book value of asset}} \quad (7)$$

5.Firm Age; AG

The firm age of this study refers to the natural firm age, and so its calculation mode is as follows:

$$\text{Firm age} = \frac{(\text{Date of data collection(supposed December 31 of that year)} - \text{Date of establishment})}{365} \quad (8)$$

6.Board structure

This variable is presented in three forms in this study: board size (BSIZE; BS), ratio of external directors (PE), and concurrent positions of directors (CP). Yermack (1996) and Shih-Yung et al. (2017) studied the relationship between board size and corporate performance. The empirical results of their studies show that board size and performance are negatively correlated - that is, a smaller board of directors can better supervise managers to raise the corporate value. Fich and Shivdasani (2005) found when most of the members of the board of directors are concurrent directors of three or more other companies that corporate performance will be undermined; Core, Holthausen, and Larcker (1999) and Shivdasani and Yermack (1999) proposed when members of the board of directors hold multiple positions concurrently that they cannot effectively supervise the managers. However, the empirical results of some foreign literature hold the opposite view. For example, Ferris, Jagannathan, and Pritchard (2003) found no evidence to indicate when most directors hold three or more positions that they will evade their responsibilities - that is, evading the responsibility of supervising managers. Yermack (2004) noted when most board directors hold three or more positions that they will still fulfill the responsibility of supervising managers.

Regarding a board of directors composed by external and insider directors, from the supervisory point of view, although external directors have less information to supervise managers, they can play a more independent supervisory role, because of their independent status. Internal directors who hold positions within the company will have more information to supervise managers, but their potential conflicts of interest with managers may subject them to the control of managers or make them more inclined to collaborate with managers to adopt strategies that compromise corporate interests. Fama (1980) and Baysinger and Hoskisson (1990) believed that external supervisors, who are independent inside the company and boast know-how, are hired by companies in the hope that they use their professional knowledge to improve corporate performance. Therefore, the higher the ratio of external directors in a company is, the more effective the supervision can be, and the better the corporate performance can be achieved through their professional knowledge.

$$\text{Scale of board of directors} = \text{Total seats of directors} \quad (9)$$

$$\text{Ratio of external directors} = \frac{\text{Seats of external directors}}{\text{Total seats of directors}} \quad (10)$$

The concurrent position of directors is a virtual variable. If more than half of the board of directors assume three or more positions (including their position in the sampled company), then the variable is 1 and otherwise 0.

Due to problematic data acquisition, the definition of positions is mainly those directors and managers present in the annual reports of listed companies. (11)

7.Proportion of pledged shares by directors (Pledge; PL)

This proportion is one of the commonly used indicators for corporate governance. Yeh and Lee (2001) and Shih-Yung Wei et al. (2017) argued that the higher the proportion is of pledged shares by major shareholders, the deeper their involvement in the stock market is, and the worse the corporate performance will be (data source: Taiwan Stock Exchange).

$$\text{Proportion of pledge shares by directors} = \frac{\text{Quantity of pledge by directors}}{\text{Total shares by all directors}} \quad (12)$$

The estimated impact of the control variables in this study on corporate performance is shown in Table 2.

Table 2. **Summary of definitions of variables and expected effect**

Variable	Definitions	expected	notes
Dependent variable			
Tobin's Q	$\frac{\text{Market value of equity (common stocks + special stocks) + book value of debts}}{\text{Book value of assets}}$		
Independent variable)			
R&D Expense Ratio (RD)	$R\ \&\ D\ \text{expense} / operation\ revenue$ RD(0) = R&D expense ratio in the current period RD(i) = R&D expense ratio in the first i year(s), i=1,2,...,8	?	Morck et al. (1988), Shih Yung Wei et. al.(2017)...
Control variables			
Degree of Internationalization (FS)	Foreign Sales as a percentage of Total Sales, FSTS(FSTS)	+	Bae et al. (2008); Gaur and Kumar(2009); Filatotchev and Piesse(2009); Brouthers et al. (2009)、..
Pledge Ratio (PL)	$pledge / shares\ held$	-	Yeh and Lee (2001), Shih Yung Wei et. al.(2017)
Liability Ratio (DA)	$book\ value\ of\ debts / book\ value\ of\ assets$	?	McConnell and Servaes(1995), Shih Yung Wei et. al.(2017)
Scale (SC)	$\ln(total\ assets)$	+	Shih Yung Wei et. al.(2017)
Board Size (BS)	$seats\ of\ directors$	-	Yermack (1996), Shih Yung Wei et. al.(2017)
Concurrent Post Holding (CP) (dummy variable)	$\begin{cases} 1, & half\ of\ the\ directors\ hold\ three\ or\ more\ positions \\ 0, & else \end{cases}$	?,-	Fich, Shivdasani (2005), Shih Yung Wei et. al.(2017)
Proportion of External Directors (PD)	$number\ of\ external\ directors / total\ number\ of\ directors$	+	Fama (1980)Baysinger and Hoskisson (1990), Shih Yung Wei et. al.(2017)
Growth Rate of Fixed Assets (LA)	$(Total\ fixed\ assets\ of\ the\ year - Total\ fixed\ assets\ of\ last\ year) / Total\ fixed\ assets\ of\ last\ year$	+	Agrawal, Knoeber (1996)

growth ratio of fixed assets, and pledge ratio (LA) exhibit leptokurtosis. Detailed analysis results are shown in Table 3.

Table 3. **Descriptive statistics**

	Obs.	Mean	Median	Max.	Min.	Std.	Sk.	K.
Tobin's Q	15708	1.090	0.870	28.140	0.000	0.797	7.083	137.857
RD(0)	15708	3.915	1.760	185.110	0.000	7.522	6.796	88.460
FS	15708	60.254	68.480	107.960	0.000	32.662	-0.487	1.865
SC	15708	15.159	14.964	21.949	9.795	1.479	0.784	3.992
AG	15708	26.264	24.675	71.718	1.101	12.484	0.558	2.907
BS	15708	9.246	9.000	29.000	0.000	2.429	0.950	10.725
PD	15708	14.880	16.667	80.000	0.000	15.051	0.456	2.114
CP	15708	0.096	0.000	1.000	0.000	0.294	2.748	8.550
DA	15708	42.161	42.375	132.890	0.900	17.286	0.169	2.793
LA	15708	6.197	-0.274	108.000	-99.917	27.816	1.491	7.775
PL	15708	7.496	0.000	100.000	0.000	16.247	2.821	11.560

2.2 Bivariant Analysis

Table 4 (correlation coefficient matrix table) shows that the correlation coefficients among independent variables are mostly low correlated, indicating that the interaction among them is not significant, and that regression analysis will not produce results different from the actual situation. Independent variables including Scale, Age, D/A ratio, and Pledge ratio are negatively correlated with the dependent variable Tobin's Q, and most of these variables are also negatively correlated with others, which nevertheless are positively correlated with Tobin's Q. However, the impact of variables on Tobin's Q still needs further quantitative analysis.

Table 4. **Matrix table of variables**

	RD (0)	FS	SC	AG	BS	PR	CP	DA	LA	PL	Tobins' Q
RD (0)	1 -----										
FS	0.062 (7.751)***	1 -----									
SC	-0.192 (-24.533)***	0.060 (7.494)***	1 -----								
AG	-0.227 (-29.24)***	-0.11 (-13.876)***	0.355 (47.575)***	1 -----							
BS	-0.072 (-9.026)***	-0.031 (-3.944)***	0.328 (43.527)***	0.197 (25.149)***	1 -----						
PR	0.086 (10.846)***	0.181 (23.103)***	-0.073 (-9.229)***	-0.165 (-20.94)***	0.015 (1.943)*	1 -----					
CP	0.030 (3.777)***	0.048 (5.98)***	0.264 (34.27)***	-0.003 (-0.35)	0.068 (8.487)***	0.042 (5.215)***	1 -----				
DA	-0.281 (-36.703)***	-0.001 (-0.133)	0.232 (29.949)***	0.095 (12.01)***	-0.008 (-0.958)	-0.039 (-4.879)***	0.022 (2.695)***	1 -----			
LA	-0.02 (-2.467)**	-0.003 (-0.352)	0.017 (2.137)**	-0.139 (-17.6)***	-0.026 (-3.284)***	0.041 (5.198)***	0.002 (0.236)	0.012 (1.477)	1 -----		
PL	-0.07 (-8.748)***	-0.047 (-5.858)***	0.252 (32.682)***	0.167 (21.241)***	0.036 (4.469)***	-0.126 (-15.933)***	0.064 (8.065)***	0.171 (21.783)***	-0.053 (-6.635)***	1 -----	
Tobin's Q	0.141 (17.803)***	0.065 (8.19)***	-0.062 (-7.763)***	-0.158 (-20.021)***	0.026 (3.321)***	0.142 (18.004)***	0.007 (0.904)	-0.23 (-29.586)***	0.133 (16.755)***	-0.091 (-11.455)***	1 -----

2.3 Regression Analysis

Prior to the panel data analysis, general regression analysis is conducted to determine the appropriate models for the sample data. In this research, the general regression analysis models are first used to analyze the R&D Expense Ratio, which is the explanatory variable and the number of delay periods, then to analyze the global control

variables, and finally to analyze the overall variable. The analysis results are shown in Table 5.

A total of three regression equations can be generated from Table 5, respectively the explanatory variable regression equation, the control variable regression equation, and the global variable regression equation. The explanatory variable regression equation is listed below.

Tobin's Q = 0.9873-0.0039RD(0)+0.0027RD(1)+0.0017RD(2)+0.0019RD(3)+0.0068RD(4)+0.0042RD(5)+0.0049RD(6)+0.0081RD(7)+0.0032RD(8)
(0.0072) *** (3.8831) *** (3.3465) (-12.3776) (5.3512) (12.7908) *** (-0.7649) *** (7.2597) *** (-25.0663) *** (15.2214) ***

Based on the preliminary analysis, this research found that R&D investment has significantly negative effects on firm performance (-0.0039) in the current period, has no significant effects on firm performance in the next three years, and starts to have significant effects on firm performance at the fourth year (0.0068, 0.0042, 0.0049, 0.0081 & 0.0032). R&D expenses affect the firm performance for at least five years.

The control variables have significant effects on all conditions (except the situation of directors taking additional positions); therefore, degree of internationalization, scale, board size, proportion of external directors, and growth rate of fixed assets have significantly positive effects on firm performance, while firm age, liability ratio, and pledge ratio have significantly negative effects.

The results of the global regression are the same as those of the significantly positive and negative effects separately obtained for the explanatory variable and control variables in this research, which will not be repeated.

2.4 Panel Data Analysis

The samples in this research are panel data. Hence, the effects on the time series of the sample data and cross-sectional data are required to be determined. In this research, pooled regression models are used for determination, and the results related to this analysis are shown in Table 6.

Table 6 shows that, among the three equations, the R-squared values (0.0548, 0.1613, and 0.1732) in the pooled regression models of the explanatory variable regression equation are lower than those in the general regression models, but the R-squared values in the other two kinds of models are higher than those in the general regression models (0.1018 and 0.1295), and the sum of the squared values (7913.1550 and 7764.8060) in the pooled regression models of the control variable regression equation and the global variable regression equation are lower than those in general regression models. Such results indicate that the control variable regression equation and the global variable regression equation of the research samples are suitable for panel data analysis. The explanatory variable regression equation can be simply explained by the general regression models

Table 5. **General Regression Models**

Variable	Coefficient、Std. Error and significance		
RD (0)	-0.0039		-0.0073
	(0.0015) ***		(0.0014) ***
RD (1)	0.0027		0.0025
	(0.0015)		(0.0015)
RD (2)	0.0017		0.0008
	(0.0012)		(0.0012)
RD (3)	0.0019		0.0006
	(0.0011)		(0.0010)
RD (4)	0.0068		0.0056
	(0.0010) ***		(0.0010) ***
RD (5)	0.0042		0.0033
	(0.0010) ***		(0.0009) ***
RD (6)	0.0049		0.0040
	(0.0010) ***		(0.0009) ***
RD (7)	0.0081		0.0072
	(0.0010) ***		(0.0009) ***
RD (8)	0.0032		0.0023
	(0.0009) ***		(0.0008) ***
FS		0.0008	0.0007
		(0.0002) ***	(0.0002) ***
SC		0.0139	0.0180
		(0.0050) ***	(0.0049) ***
AG		-0.0074	-0.0054
		(0.0005) ***	(0.0005) ***
BS		0.0139	0.0106
		(0.0027) ***	(0.0026) ***
PR		0.0054	0.0048
		(0.0004) ***	(0.0004) ***
CP		-0.0077	-0.0385
		(0.0214)	(0.0212) *
DA		-0.0100	-0.0087
		(0.0004) ***	(0.0004) ***
LA		0.0033	0.0034
		(0.0002) ***	(0.0002) ***
PL		-0.0011	-0.0013
		(0.0004) ***	(0.0004) ***
C	0.9873	1.2281	1.0448
	(0.0072) ***	(0.0669) ***	(0.0677) ***
R-	0.0595	0.1018	0.1295
SSE	9382.5590	8960.9850	8684.7750

Fixed effect models and random effect models exist in panel data analysis, and the Hausman Test, proposed by Hausman (1978), can be used to

determine which kind of model is more efficient for the data. The analysis results of this research are shown in Table 7

Table 6. **Pooled Regression Models**

Variable	Coefficient、Std. Error and significance level					
RD (0)	-0.0005				-0.0030	
	(0.0011)				(0.0011)	***
RD (1)	0.0016				0.0011	
	(0.0011)				(0.0012)	
RD (2)	0.0022				0.0014	
	(0.0010)	**			(0.0011)	
RD (3)	0.0013				0.0007	
	(0.0009)				(0.0009)	
RD (4)	0.0070				0.0060	
	(0.0009)	***			(0.0009)	***
RD (5)	0.0046				0.0035	
	(0.0009)	***			(0.0009)	***
RD (6)	0.0023				0.0020	
	(0.0008)	***			(0.0009)	**
RD (7)	0.0042				0.0038	
	(0.0008)	***			(0.0008)	***
RD (8)	0.0024				0.0022	
	(0.0008)	***			(0.0008)	***
FS			0.0005		0.0003	
			(0.0001)	***	(0.0001)	***
SC			0.0150		0.0166	
			(0.0022)	***	(0.0022)	***
AG			-0.0049		-0.0035	
			(0.0002)	***	(0.0002)	***
BS			0.0077		0.0054	
			(0.0011)	***	(0.0011)	***
PR			0.0032		0.0028	
			(0.0002)	***	(0.0002)	***
CP			-0.0154		-0.0323	
			(0.0092)	*	(0.0091)	***
DA			-0.0065		-0.0055	
			(0.0002)	***	(0.0002)	***
LA			0.0017		0.0018	
			(0.0001)	***	(0.0001)	***
PL			-0.0007		-0.0008	
			(0.0001)	***	(0.0001)	***
C	0.8735		0.9891		0.8756	
	(0.0031)	***	(0.0297)	***	(0.0301)	***
R-squared	0.0548		0.1613		0.1732	
SSE	8252.4850		7913.1550		7764.8060	

From Table 7, the results of the Hausman Test show that the fixed effect models are the most efficient in this research. The fixed effect models (the global variable regression equation) of the final analysis results generated in this research are as shown below:

Tobin's Q =1.0750-0.0063RD(0)+0.0014RD(1)+0.0008RD(2)+0.0011RD(3)+0.0053RD(4)+0.0032RD(5)+0.0044RD(6)+0.0070RD(7)+0.0019RD(8)
(0.0684) (0.0014) (0.0014) (0.0012) (0.0010) (0.0010) (0.0009) (0.0009) (0.0009) (0.0008)
*** *** *** *** *** *** ** **

+0.0006FS+0.0160SC-0.0057AG+0.0113BS+0.0046PR-0.0372CP-0.0086DA+0.0036LA-0.0011PL
(0.0002) (0.0049) (0.0006) (0.0026) (0.0004) (0.0208) (0.0004) (0.0002) (0.0004)
*** *** *** *** *** * *** *** ***

Table 7. **Panel Data Models**

Variabl	FEM	REM	FEM	REM
RD (0)			-0.0063	-0.0102
			(0.001 **	(0.001 **
RD (1)			0.0014	0.0002
			(0.001	(0.001
RD (2)			0.0008	-0.0009
			(0.001	(0.001
RD (3)			0.0011	-0.0008
			(0.001	(0.000
RD (4)			0.0053	0.0041
			(0.001 **	(0.000 **
RD (5)			0.0032	0.0024
			(0.000 **	(0.000 **
RD(6)			0.0044	0.0030
			(0.000 **	(0.000 **
RD (7)			0.0070	0.0063
			(0.000 **	(0.000 **
RD (8)			0.0019	0.0012
			(0.000 **	(0.000
FS	0.0007	0.0005	0.0006	0.0003
	(0.000 **	(0.000 *	(0.000 **	(0.000
SC	0.0109	-0.0265	0.0160	-0.0300
	(0.004 **	(0.008 **	(0.004 **	(0.008 **
AG	-0.0084	-0.0043	-0.0057	-0.0041
	(0.000 **	(0.000 **	(0.000 **	(0.000 **
BS	0.0144	0.0284	0.0113	0.0245
	(0.002 **	(0.003 **	(0.002 **	(0.003 **
PR	0.0046	0.0047	0.0046	0.0044
	(0.000 **	(0.000 **	(0.000 **	(0.000 **
CP	-0.0086	0.0122	-0.0372	0.0070
	(0.021	(0.023	(0.020 *	(0.023
DA	-0.0099	-0.0070	-0.0086	-0.0073
	(0.000 **	(0.000 **	(0.000 **	(0.000 **
LA	0.0036	0.0025	0.0036	0.0025
	(0.000 **	(0.000 **	(0.000 **	(0.000 **
PL	-0.0009	-0.0018	-0.0011	-0.0018
	(0.000 **	(0.000 **	(0.000 **	(0.000 **
C	1.3054	1.5324	1.0750	1.6306
	(0.067 **	(0.112 **	(0.068 **	(0.111 **
Hausman Test	143.8926		293.6886	
	9.0000		18.0000	
	***		***	

Based on the fixed effect models of the global variable regression equation, this research finds that R&D investment has significantly negative effects on firm performance (-0.0063) in the current period and has no significant effects on firm performance in the next three years, but starts to have significant effects on firm performance at the fourth year (0.0053, 0.0032, 0.0044, 0.0070 & 0.0019). R&D expenses affect the firm's performance for at least five years, but the significance reduces in the ninth year (namely, the eighth year after R&D investment).

In this research, all the control variables have significant or insignificant effects on firm performance. The degree of internationalization (0.0006), scale (0.0160), board size (0.0113), proportion of external directors (0.0046), and growth rate of fixed assets (0.0036) have significantly positive effects on firm performance, while firm age (-0.0057), directors taking additional positions (-0.0372), liability ratio (-0.0086), and pledge ratio (-0.0011) have significantly negative effects. The effects of the above control variables on firm performance are roughly the same as those in previous researches made by scholars.

CONCLUSION

As indicated in the relevant literature, R&D intensity has deferred effects, which is to say that the effects of R&D investment can be deferred and shown at a later stage after a period of time. In addition, R&D investment must reach a certain threshold to produce benefits and positively contribute to firm performance, otherwise it may be a waste.

The research results show that R&D investment indeed has deferred effects. Through the discussion on the facts happening during the period after Taiwan became a developed country (1993-2017), R&D investment has negative effects on firm performance in the current year and has no significant effects on firm performance in the next two to four years. It becomes effective after the fifth years and lasts for four years. That is to say, R&D investment has significant effects from the fifth year to the ninth year, but the significance is reduced in the ninth year. The results clearly show that the effects of R&D investment can be deferred and shown at a later stage after a period of time. Moreover, R&D investment must reach a certain threshold to positively contribute to firm performance, otherwise it may be a waste. In particular, R&D investment has economies of scale. A single instance of R&D cannot produce new products and technologies, and it will take more time to get the results.

Additionally, the effects of the control variables on firm performance, such as degree of internationalization, firm scale, firm age, board size, proportion of external directors and supervisors, directors and supervisors taking additional positions, liability ratio, growth rate of fixed assets, and pledged share ratio of directors and supervisors, are analyzed. The research results are roughly consistent with those of the previous researches made by scholars; that is, degree of

internationalization, firm scale, board size, proportion of external directors and supervisors, and growth rate of fixed assets have positive effects, while liability ratio and pledged share ratio of directors and supervisors have negative effects.

The results for firm age and the situation of directors and supervisors taking additional positions (a negative relationship) are different with those of the previous researches made by scholars. The analysis shows that the enterprises of Taiwan are not as old as those of other countries (the oldest firm is only 71 years and the median age is only 24 years) and the Tobin's Q of many listed firms (older firms) approaches zero, which results in negative effects of firm age on firm performance.

Generally, there are positive and negative statements about the effects of directors and supervisors taking additional positions on firm performance. The effects will be positive if the enterprises offering additional positions cooperate with the firms but will cause sluggishness to the business and have negative effects if there is no correlation. The effects may be positive or negative due to the relationship between both. The research results show significantly negative effects, representing that, for Taiwanese enterprises, the situation of directors and supervisors taking additional positions has negative effects which are far greater than the positive effects.

This research focuses on listed surviving firms (excluding financial firms) of Taiwan between 2001 and 2017. If categorical data are further analyzed for industry analysis and listing analysis, new results may be produced.

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