Journal of Applied Finance & Banking, vol. 3, no. 5, 2013, 107-119
ISSN: 1792-6580 (print version), 1792-6599 (online)
Scienpress Ltd, 2013

An Empirical Study on the Relationship between R&D and Financial Performance

Feng-Jui Hsu[1], Mu-Yen Chen[2,*], Yu-Cheng Chen[3] and Wei-Chieh Wang[4]

Abstract

This study investigates the relationship between R&D investment, patent filings and financial success for firms. Firms which have high degrees of R&D investment and large numbers of patents are referred to as “high innovation energy corporations”. This study investigates the financial performance of such firms among a sample of Taiwanese high-tech companies from 2000 to 2011. Findings indicate that the lag between R&D expense and benefit, and the lead periods for patents (i.e., the duration of the application process) significantly affect stock returns. Moreover, these delays and a firm’s R&D expense rate also impact net sales. In other words, firms with a high level of innovative energy have better stock returns and net sales, but such firms do not have an advantage in terms of operating income. Empirical results indicate that higher R&D expenses increase operating costs which, in turn, decreases operating income despite increased net sales.

JEL classification numbers: G14, G32.
Keywords: Innovative energy, financial performance, stock return, net sales, operating income

1 Introduction

Since the 1970s, Taiwan’s government has promoted the development of domestic high-tech industries. The combination of technology and engineering requirements in such

---

[1]National Chung Hsing University, Taiwan, Assistant Professor, No.250, Guoguang Rd., South Dist., Taichung City 40227, Taiwan (R.O.C.)
[2]National Taichung University of Science and Technology, Taiwan, Associate Professor, No.129, Sec. 3, Sanmin Rd., North Dist., Taichung City 40401, Taiwan (R.O.C.)
[3]National Chung Hsing University, Taiwan, Professor, No.250, Guoguang Rd., South Dist., Taichung City 40227, Taiwan (R.O.C.)
[4]National Chung Hsing University, Taiwan, Master, No.250, Guoguang Rd., South Dist., Taichung City 40227, Taiwan (R.O.C.)

Article Info: *Received :* July 10, 2013. *Revised :* August 7, 2013.
Published online : September 1, 2013

firms generate significant numbers of well-paying jobs, thus fueling economic development. In Taiwan, high-tech products account for more than 50% of GDP, and government policy focuses on promoting the development of intellectual property through R&D investment and patents. As defined by Galbraith (1969), intellectual property is the product of mental work. The production of intellectual property requires mastery of knowledge and organizational skills, and can give firms a competitive industrial advantage (Edvinsson, 1997). Intellectual property is a form of intangible asset, and modern companies are more dependent on such assets than before, with both firms and nations devoting significant and increasing resources to produce or procure new technologies to ensure future profitability. Firms engage in research and development to secure patent rights which can be commercialized.

This research examines the relationship between R&D results and firm operating performance. Unlike previous studies, this study not only considers R&D expenditures but also includes an analysis of the total number of patents secured. Firms can secure patents either by engaging in proprietary R&D or by purchasing existing patents from other companies. Purchasing patents provides firms a way to increase the company's intellectual property, but does little to increase the firm's R&D experience. Developing patentable technologies in-house increases the firm's core R&D capability, which may have a significant positive effect on its operating performance. Jones et al. (2001) noted a negative correlation between the proportion of externally-sourced patents or technologies and operating performance.

This study investigates the impact of R&D capability on a firm's financial performance by using historical data from Taiwanese companies from 2000 to 2011, and aims to answer the following questions: (1) how does R&D strength relate to a firm's stock price, (2) how does R&D strength relate to a firm's operating performance, and (3) does a firm's total number of patents influence firm performance? Empirical results indicate that the lag periods of R&D expenses and the lead time for patent applications significantly affect stock returns. Moreover, net sales revenue is related to the R&D expense lag, patent application lead time, and R&D expense rate (defined as the ratio of R&D expenses to total expenses). In addition, firm performance is positively correlated with the number of patents the firm owns. That is to say, firms with greater innovative strength have better stock returns and net sales, but operating income not affected. Expanding R&D expenses is found to increase operating costs, thus decreasing operating income despite a net increase in sales.

2 R&D Expenditure and Firm Performance

Research and development is an essential expenditure in high-tech industries, but there is no linear relation between R&D investment and returns. Successful R&D improves firm performance while failed efforts are treated as sunk costs. High-tech products command premium prices in the marketplace. Improving and maintaining competitiveness often requires significant investments in R&D.

However, new technologies derived from R&D may not necessarily be translated into commercially successful products. Baker and Freeland (1975) showed that the R&D and product development processes are fraught with uncertainty leading to failure to achieve expectations. For example, newly designed products may run into unexpected manufacturing problems, or may prove to not be commercially viable. In addition, profits from new products may fail to justify the R&D expense required to develop the products, resulting R&D expenditures becoming a sunk cost. Nevertheless, Nelson (1982) indicated that accumulating R&D experience over time has a positive impact on current R&D activity. Empirical studies indicate that R&D activity can improve a firm's future performance. Edvinsson and Malone (1997) showed that intellectual property produced by R&D investment must be properly understood and appropriately managed to increase future firm performance. Lev and Sougiannis (1999) found that once an R&D expense is added to a firm's capitalization, it becomes a risk factor related to the firm's future returns and also has a positive impact on subsequent stock returns. Toivanen et al. (2002) showed that the R&D and innovation of UK firms have a positive influence on market value. Bharadwaj et al. (1999) found that investing in R&D increases firm productivity and creates conditions for quick and efficient innovation in the IT industry. Each time firms engage in innovation or R&D, they transform financial and human resources into accumulated experience, knowledge, and capability, which become the firm's main intangible assets. Madanmohan et al. (2004) showed that improvements to a firm's human resources or technology will have a positive impact on the company's overall technological capability. Finally, studies have identified a time lag effect on R&D activity, due to the time required to transform R&D inputs into practical applications. Hirschey and Weygandt (1985) showed that R&D expenditures have a deferred return of 5 to 10 years.

Patents can be regarded as the product of R&D, and R&D expenditures which fail to produce patents can be seen as a loss for the firm. Thus, some empirical studies have attempted to use the number of patents secured by a firm as a key factor in performance analysis. Lilien and Yoon (1989) showed that firms with more patents are better able to innovate and improve upon existing products. Crèpon et al. (1998) found significant correlations between R&D expenditure, firm size, market share, and technological demand. In addition, R&D which results in useful patents also has a positive impact on firm productivity, which is related to firm performance (Hall & Bagchi-Sen, 2002). Thus, the intensity of a firm's R&D activity and the number of patents the firm secures are related to overall performance (Beneito, 2006). Some empirical studies have shown that simultaneously implementing multiple technologies can result in improved management performance, and firms with more patents and patent citations exhibit better corporate governance (Ernst, 1995; Deng et al., 1999; De Carolis, 2003; Miller et al., 2007).

3 Methodology and Data

3.1 Research Hypothesis

Based on previous studies, R&D expenditures are related to firm performance and patents can be regarded as the output of R&D. However, patents can also be obtained through acquisition, alliance, or merger. The sample selection for this study first considers R&D expenditures and uses the R&D expense rate to control for the size effect. In our analysis, we regard firms with high R&D expense rates as being active in terms of R&D, and firms holding higher numbers of patents are classified as having strong R&D capacity. The research hypotheses investigated here are listed as follows:

H1：Firms with high R&D expenditures and high numbers of patents enjoy improved financial returns.

H2a：R&D expenditures and patent holdings have a significant impact on a firm’s net sales.

H2b：High R&D expenditures and high numbers of patents significantly improve firm operating income.

3.2 Data

A sample of high-tech firms was selected from the Taiwan Economic Journal (TEJ) from 2000 to 2011, with detailed patent data obtained from the Taiwan Intellectual Property Office. Firms were selected from a variety of industries, including telecommunications, information technology, consumer electronics, semiconductors, precision optical machinery, the automated chemical industry, chemicals and pharmaceuticals, and solar energy utilities. In these industries, not all R&D investments result in products, and the delay between investment and mass production varies significantly among the industries. Three industries with particularly long lag time to commercialize R&D investments were thus removed from consideration.

Sample selection was conducted in two stages. First, we chose firms in the highest quartile for R&D expense rate in each industry. From these, we then selected firms in the highest quartile for patent ownership in each industry.

Table 1 summarizes the 588 samples obtained from 2000 to 2011 from industries including semiconductor manufacturing (136 samples), display panel manufacturers (65 samples), computer and computer peripheral manufacturers (219 samples), telecommunications and information technology firms (85 samples), and other electronics manufacturers (83 samples).

3.3 Methodology

Our analysis of R&D activity and operating performance of our selected sample proceeds in three regression equations.

Table 1: Sample Statistics Description

Industry	Semico-nductor		Panels		Computers		Telecommunications & IT		Other electronics		Total sample	
Year	n	%	n	%	n	%	n	%	n	%	n	%
2000	9	1.53	4	0.68	12	2.04	3	0.51	5	0.85	33	5.61
2001	11	1.87	5	0.85	13	2.21	3	0.51	5	0.85	37	6.29
2002	11	1.87	5	0.85	16	2.72	5	0.85	6	1.02	43	7.31
2003	11	1.87	5	0.85	18	3.06	7	1.19	6	1.02	47	7.99
2004	11	1.87	5	0.85	19	3.23	8	1.36	7	1.19	50	8.50
2005	11	1.87	5	0.85	19	3.23	8	1.36	7	1.19	50	8.50
2006	12	2.04	6	1.02	20	3.40	8	1.36	7	1.19	53	9.01

2007	12	2.04	6	1.02	20	3.40	8	1.36	8	1.36	54	9.18
2008	12	2.04	6	1.02	20	3.40	8	1.36	8	1.36	54	9.18
2009	12	2.04	6	1.02	20	3.40	9	1.53	8	1.36	55	9.35
2010	12	2.04	6	1.02	21	3.57	9	1.53	8	1.36	56	9.52
2011	12	2.04	6	1.02	21	3.57	9	1.53	8	1.36	56	9.52
N	136	23.13	65	11.05	219	37.24	85	14.46	83	14.12	588	100

Note: 1. Sample period is from 2000 to 2011.
2. % denotes the percentage of the whole sample represented by each industry.
3. N and n respectively denote the number of the whole sample and number of firms in each industry.

$$Return_{i,t} = \alpha_0 + \alpha_1 Rdexp_{i,t} + \alpha_2 Rdratio_{i,t} + \alpha_3 Patent_{i,t} + \alpha_4 Size_{i,t} + \alpha_5 It_t + \alpha_6 IPI_t + \alpha_7 UMEP_t + \alpha_8 DY\_CP_{i,t} + \alpha_9 DY\_C_{i,t} + \alpha_{10} DY\_E_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$Netsale_{i,t} = \beta_0 + \beta_1 Rdexp_{i,t} + \beta_2 Rdratio_{i,t} + \beta_3 Patent_{i,t} + \beta_4 Size_{i,t} + \beta_5 It_t + \beta_6 IPI_t + \beta_7 UMEP_t + \beta_8 DY\_CP_{i,t} + \beta_9 DY\_C_{i,t} + \beta_{10} DY\_E_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$Oprt_{i,t} = \gamma_0 + \gamma_1 Rdexp_{i,t} + \gamma_2 Rdratio_{i,t} + \gamma_3 Patent_{i,t} + \gamma_4 Size_{i,t} + \gamma_5 It_t + \gamma_6 IPI_t + \gamma_7 UMEP_t + \gamma_8 DY\_CP_{i,t} + \gamma_9 DY\_C_{i,t} + \gamma_{10} DY\_E_{i,t} + \varepsilon_{i,t} \quad (3)$$

where $Return_{i,t}$ (Vendatraman & Ramanujam, 1986), $Netsale_{i,t}$, and $Oprt_{i,t}$ are respectively the return, net sales and operating income of firm i in year t. There are two types of independent variables. The first is firm characteristics including $Rdexp_{i,t}$, $Rdratio_{i,t}$, $Patent_{i,t}$, and $Size_{i,t}$, (Kim & Sorensen, 1986) respectively denoting R&D expenditure, R&D expense ratio, number of patents, and firm size. The second is microeconomic variables, including It_t (Cutler et al., 1989), IPI_t (Berger & Ofek, 1995), and $UMEP_t$, respectively denoting the market interest rate, the industrial production index, and the unemployment rate. All industries were divided into four groups using three dummy variables, $DY\_CP_{i,t}$, $DY\_C_{i,t}$, and $DY\_E_{i,t}$, respectively denoting the computers and computer peripherals, telecommunications and IT, and other electronics; all others are included in the panel or semiconductor industries.

4 Empirical Results

4.1 Sample Characteristics

Table 2 summarizes statistical data for the whole sample. The mean, minimum, and maximum returns were respectively 18%, -86%, and 403% with a 73% standard deviation for the return variable. This high standard deviation indicates a high degree of volatility in stock returns. In addition, the mean, minimum and maximum net sales were 17.17, 11.43, and 21.74, respectively, with a median of 17.31. The proximity of the mean and median for the net sales variable indicates that the sample distribution is relatively centralized. The mean, minimum, and maximum operating income were 9.78, -17.96, and 18.86, respectively. The means for R&D expenditures, R&D expense ratio, number of patents, size, market interest rate, industrial production index, and unemployment were 12.38, 0.05%, 4.22, 17.21, 4.22%, 6.15%, and 4.46%, respectively.

To determine the relationship between the intensity of R&D activity and firm performance, multiple comparison analysis tests were used to identify differences among the various groups. Significant differences are found for Netsale, Oprt, Rdexp, Rdratio, Patent, and Size variables, but not for Return. Table 3 shows the empirical results. In the R&D expenditure variable, there is no significance between the semiconductor industry and the panel industry, while these two industries have the highest R&D expenditure of all industries represented in the sample. In the R&D expense rate variable, significant differences are only found in the computer and computer peripheral industry and the semiconductor industry. In terms of patent variables, the semiconductor and panel industries had the highest number of patents in the sample, but the difference not significant. The semiconductor and panel industries were also largest in terms of firm size. According to Table 3, the only difference between the semiconductor and panel industries was found in terms of operating income; thus these two industries are grouped together for subsequent analysis.

Table 2: Sample Characteristics

Variables	Mean	Min.	Q1	Median	Q3	Max.	Std Dev.	N
Return (%)	0.18	-0.86	-0.27	0.01	0.40	4.03	0.73	518
Netsale (ln)	17.17	11.43	16.38	17.31	18.23	21.74	1.70	573
Oprt (ln)	9.78	-17.96	11.96	13.95	15.37	18.86	10.68	573
Rdexp (ln)	12.38	0.00	11.76	12.73	13.61	15.93	2.32	573
Rdratio (%)	0.05	0.00	0.01	0.01	0.02	4.97	0.35	573
Patent (n)	4.22	0.00	3.53	4.39	5.27	8.40	1.45	573
Size (ln)	17.21	11.78	16.24	17.32	18.43	21.15	1.68	573
It (%)	4.22	2.56	2.88	3.85	4.21	7.38	1.62	573
IPI (%)	6.15	-32.04	-8.06	7.47	18.71	47.76	19.57	573
UMEP (%)	4.46	3.27	3.86	4.58	5.03	5.74	0.67	573
DY_CP (D_1)	0.38	0.00	0.00	0.00	1.00	1.00	0.49	573
DY_C (D_2)	0.15	0.00	0.00	0.00	0.00	1.00	0.36	573
DY_E (D_3)	0.14	0.00	0.00	0.00	0.00	1.00	0.35	573

Note: 1. Min, Q1, Q3, Max, and Std Dev. respectively denote minimum, first quartile, third quartile, maximum, and standard deviation.

2. Return, Rdratio, It, IPI, and UMEP are in %.

3. Netsale, Oprt, Rdexp, and Size are in logarithm form.

4. Return, Netsale, Oprt, Rdexp, Rdratio, Patent, Size, It, IPI, UMEP, DY_CP, DY_C, and DY_E respectively denote stock return, net sales, operating income, R&D expenditures, R&D expenseratio, number of patents, firm size, market interest rate, industrial production index, unemployment rate, computer industry dummy, telecommunications and IT industry dummy, and other electronics industry dummy.

Table 3: Multiple Comparison Analysis in All Groups

Panel A: Variable is Netsale		Panel B: Variable is Oprt		Panel C: Variable is Rdexp	
Post hoc tests	Diff.	Post hoc tests	Diff.	Post hoc tests	Diff.
Comm.-Comp.	-0.7456***	Comm.-Comp.	-2.1095	Comm.-Comp.	-0.5334
Comm.-Panel.	-1.4975***	Comm.-Panel.	9.1456***	Comm.-Panel.	-1.2920***
Comm.-Other.	-0.1341	Comm.-Other.	2.4505	Comm.-Other.	0.9749***
Comm.-Semi.	-0.8971***	Comm.-Semi.	2.3878	Comm.-Semi.	-1.7066***
Comp.-Panel.	-0.7519***	Comp.-Panel.	11.2551***	Comp.-Panel.	-0.7585
Comp.-Other.	0.6115***	Comp.-Other.	4.5599***	Comp.-Other.	1.5083***
Comp.-Semi.	-0.1515	Comp.-Semi.	4.4972***	Comp.-Semi.	-1.1732***
Panel.-Other.	1.3634***	Panel.-Other.	-6.6952***	Panel.-Other.	2.2668***
Panel.-Semi.	0.6004	Panel.-Semi.	-6.7579***	Panel.-Semi.	-0.4147
Other.-Semi.	-0.763***	Other.-Semi.	-0.0627	Other.-Semi.	-2.6815***

Panel D: Variable is Rdratio		Panel E: Variable is Patent		Panel F: Variable is Size	
Post hoc tests	Diff.	Post hoc tests	Diff.	Post hoc tests	Diff.
Comm.-Comp.	-0.1068	Comm.-Comp.	-0.5095***	Comm.-Comp.	-0.0737
Comm.-Panel.	0.0093	Comm.-Panel.	-1.1609***	Comm.-Panel.	-1.8310***
Comm.-Other.	0.0072	Comm.-Other.	-0.7615***	Comm.-Other.	-0.1398
Comm.-Semi.	0.0002	Comm.-Semi.	-1.5023***	Comm.-Semi.	-1.4511***
Comp.-Panel.	0.1160	Comp.-Panel.	-0.6514***	Comp.-Panel.	-1.7573***
Comp.-Other.	0.1141	Comp.-Other.	-0.252	Comp.-Other.	-0.0661
Comp.-Semi.	0.1070***	Comp.-Semi.	-0.9928***	Comp.-Semi.	-1.7573***
Panel.-Other.	-0.0019	Panel.-Other.	0.3994	Panel.-Other.	1.6912***
Panel.-Semi.	-0.0090	Panel.-Semi.	-0.3414	Panel.-Semi.	0.3799
Other.-Semi.	-0.0070	Other.-Semi.	-0.7408***	Other.-Semi.	-1.3113***

Note: 1. *** denotes significance at 1%.

2. Semi., Panel., Comp., Comm., and Other respectively denote the semiconductor industry, panel industry, computer and computer-peripheral industries, telecommunications & IT industries, and other electronics industry.

3. Diff. denotes the difference between two groups.

Table 4 presents the variable coefficient correlation matrix. In terms of endogenous parameters, return and operating income have lower coefficients and are not significantly different from R&D expenditure, R&D expense ratio, and number of patents. However, the coefficients between net sales and R&D expenditure, R&D expense ratio, and number of patents is respectively 0.502, 0.167, and 0.611, which are all positive and significant. This result supports hypothesis H2a: “R&D expenditures and patent holdings have a significant impact on a firm’s net sales”. In terms of external parameters, the sample exhibits higher R&D intensity, and the number of patents is positive and significant with R&D expenditures. Furthermore, firm size has positive correlations of 0.475 and 0.583 respectively with R&D expenditure and number of patents, and has a negative correlation of -0.28 with R&D expense ratio. This demonstrates that large-scale firms have relatively greater economic capacity to engage in continuous R&D, thus allowing them to accumulate more R&D experience and intellectual property. Judge et al.(1985) noted that multicollinearity may occur between two variables if one coefficient exceeds 0.8. However, all coefficients in Table 4 are below 0.8.

Table 4: Variable Coefficient Correlation

	Return	Netsale	Oprt	Rdexp	Rdratio	Patent	Size	It	IPI	UMEP	DY_CP	DY_C	DY_E
Return	1												
Netsale	0.00445	1											
Oprt	0.155***	0.235***	1										
Rdexp	-0.0606	0.502***	0.0548	1									
Rdratio	0.0209	0.167***	0.0472	0.0993*	1								
Patent	-0.0835	0.611***	-0.00598	0.381***	0.0643	1							
Size	-0.0352	0.800***	0.0818	0.475***	-0.280***	0.583***	1						
It	-0.0533	-0.0336	0.0614	-0.00332	-0.0642	-0.220***	0.0129	1					
IPI	0.492***	-0.00815	0.0133	-0.0338	0.00269	0.0228	0.0146	-0.319***	1				
UMEP	0.264***	-0.0405	-0.104*	-0.0114	0.00346	-0.0927*	0.0147	0.107*	0.292***	1			
DY_CP	-0.0316	0.0722	-0.0926*	0.266***	-0.0594	0.292***	0.283***	0.0345	0.00315	0.0135	1		
DY_C	0.00389	-0.162***	0.0449	-0.106*	-0.0447	-0.238***	-0.143**	-0.0533	-0.00246	-0.0296	-0.230***	1	
DY_E	0.00540	-0.124**	-0.0492	-0.284***	-0.0528	-0.0138	-0.105*	0.00608	-0.00232	0.0155	-0.228***	-0.171***	1

Note:1. *, **, and *** denote the significance at 10%, 5%, and 1%, respectively.

2. Return, Netsale, Oprt, Rdexp, Rdratio, Patent, Size, It, IPI, UMEP, DY_CP, DY_C, and DY_E respectively denote stock return, net sales, operating income, R&D expenditure, R&D expense ratio, number of patents, firm size, market interest rate, industrial production index, unemployment rate, computer and computer-peripheral industry dummy, telecommunications and IT industry dummy, and other electronics industry dummy.

4.2 Empirical Results and Discussion

This study focuses on determining whether a firm's R&D activities benefit its performance in terms of returns, net sales, and operational performance. Table 5 shows the regression analysis results based on three models. In model 1, the coefficient of the regression result for return is insignificant with R&D expenditure, R&D expense ratio, and number of patents, which is contrary to expectations. There are two possible explanations for this. First, high R&D intensity firms normally invest relatively large amounts of resources in R&D activities. Thus, R&D expenditure, R&D expense ratio, and even the number of patents won't influence investor expectations for the firm's stock price performance. Second, investors are unable to predict the commercial benefits of a firm's emerging patents. Therefore, the number of patents a firm secures does not affect stock price or stock return. In model 2, net sales are positively and significant with R&D expenditure, R&D expense ratio, and number of patents, and thus supports hypothesis H2a. Furthermore, net sales are correlated with firm size, industry characteristics, and economic conditions. In model 3, operating income is positive and significant with R&D expense ratio, which supports H2b. R&D entails significant capital outlays which will have a critical impact on year-end operating income given a relatively high R&D expense ratio.

Empirically, R&D inputs are shown to provide deferred benefits. The deferral duration may be affected by the time-lag between R&D investment and the production of a desired outcome, or the time-lag in applying R&D outputs to products or services. In other words, the input of R&D expenditures might take some years to have an impact on firm performance. To capture the time-lag effect on R&D activity, two variables were added to our regression analysis: time-lag for two periods of R&D expenditures (Rdexp(+2)) and lead time for one year prior to the patent announcement (i.e., Patent(-1)). Given the short lifecycle of high-tech products, firms seek to commercialize R&D outputs as quickly as possible. Thus innovations may be applied to products before the patents are secured, producing leading results. According to Lin (2007), R&D expenditures continue to have a positive influence on earnings after two time-lag periods. Table 6 presents the time-lag regression analysis.

Table 5: Regression Analysis

	Model 1(Y=Return)		Model 2(Y=Netsale)		Model 3(Y=Oprt)	
Variable	Estimate Coefficient	t-value	Estimate Coefficient	t-value	Estimate Coefficient	t-value
Rdexp	-0.009	-0.63	0.028	2.03**	0.085	0.38
Rdratio	0.076	0.89	1.946	22.81***	2.692	1.97**
Patent	-0.034	-1.22	0.118	4.62***	-0.307	-0.75
Size	0.015	0.60	0.943	40.12***	1.539	4.08***
It	0.035	1.54	0.010	0.56	0.732	2.45**
IPI	0.017	11.55***	-0.000	-0.22	0.045	1.93*
UMEP	0.115	2.45***	-0.093	-2.29**	-2.245	-3.44***
DY_CP	0.056	0.79	1.002	14.82***	8.270	7.62***
DY_C	0.038	0.42	0.611	6.91***	6.851	4.63***
DY_E	0.041	0.44	0.563	6.33***	4.098	2.87***
Constant	-0.627	-1.55	-0.191	-0.49	-14.659	-2.33
$\bar{R}^2$	0.265		0.866		0.122	

Note: 1. *, **, and *** respectively denote the significance at 10%, 5%, and 1%.

2. Return, Netsale, Oprt, Rdexp, Rdratio, Patent, Size, It, IPI, UMEP, DY_CP, DY_C, and DY_E respectively denote stock return, net sales, operating income, R&D expenditure, R&D expense ratio, number of patents, firm size, market interest rate, industrial production index, unemployment rate, computer and computer-peripheral industry dummy, telecommunications and IT industry dummy, and the other electronics industry dummy.

In Table 6, for model 1, return is positive and significant with two-period time-lag R&D expenditure and one-period patent time-lead; however, the relationship between return and number of patents is negative and significant. The lifecycles of technology products are notoriously short, as is the cycle of patent-driven enhanced corporate performance. The benefits of patent protection begin with the application process but end after the patent expires. Even if the firm no longer benefits from the patent, it still incurs the expense of maintain it, which negatively impacts the firm’s return. Nevertheless, we find indirect evidence to support hypothesis 1. Returns are actually influenced by R&D expenditures and the number of patents the firm holds, but this effect can’t be observed in the current period due to the complicated patent application process and uncertainty of R&D outcomes.

Table 6: Regression Analysis with time-lag effect

	Model 1(Y=Return)		Model 2(Y=Netsale)		Model 3(Y=Oprt)	
Variable	Estimate Coefficient	t-value	Estimate Coefficient	t-value	Estimate Coefficient	t-value
Rdexp	0.210	1.17	-0.012	-0.78	-0.037	-0.13
Rdexp(+2)	1.428	2.79***	0.169	3.92***	0.608	0.76
Rdratio	-0.940	-0.71	1.952	17.59***	3.310	1.60
Patent	-1.661	-2.66***	-0.001	-0.03	-0.842	-0.86
Patent(-1)	1.962	3.03***	0.124	2.27**	0.039	0.04
Size	-0.355	-0.87	0.904	26.41***	1.644	2.58**
It	-0.171	-0.54	0.001	0.02	0.565	1.13
IPI	0.014	0.85	-0.002	-1.14	0.018	0.67
UMEP	-1.249	-2.41**	-0.106	-2.43**	-2.361	-2.91***
DY_CP	2.576	3.14***	1.041	15.1***	8.504	6.63***
DY_C	6.305	5.69***	0.647	6.94***	5.753	3.32***
DY_E	2.604	2.36**	0.662	7.12***	3.906	2.26**
Constant	-8.222	-1.65*	-1.084	-2.59**	-18.583	-2.38**
$\bar{R}^2$	0.218		0.900		0.127	

Note: 1. *, **, and *** respectively denote the significance at 10%, 5%, and 1%.

2. Return, Netsale, Oprt, Rdexp, Rdratio, Patent, Size, It, IPI, UMEP, DY_CP, DY_C, and DY_E respectively denote stock return, net sales, operating income, R&D expenditure, R&D expense ratio, number of patents, firm size, market interest rate, industrial production index, unemployment rate, computer and computer-peripheral industry dummy, telecommunications and IT industry dummy, and other electronics industry dummy.

3. Rdexp(+2) and Patent(-1) respectively denote time-lag for two periods of R&D expenditure and lead time of one year prior to the patent announcement.

5 Conclusions

Taiwan’s economic miracle was built on its domestic high-tech industry, but this industry is subject to fast changes and a high degree of uncertainty. Firms must constantly upgrade their technology to maintain their competitiveness, making effective R&D activity a crucial key success factor. This study regards high R&D expenditures and patents as a proxy measure for successful R&D. Such firms are referred to as having high R&D intensity. Analysis of performance indicators for Taiwanese high-tech companies over a ten-year period indicates a positive and significant relationship between financial returns, two-period time-lag R&D expenditures, and a one-period patent lead time. Furthermore,

net sales are positively significant with R&D expenditure, R&D expense ratio, and number of patents, while lagged R&D expenditure is also positive and significant with net sales. Operating income is positive and significant with R&D expense ratio, but the lagged variables are insignificant with operating income. That is to say, high-tech industry firms with high R&D intensity will have better stock returns and net sales, but worse operating income. Firms with high R&D intensity may have increased operating expenses and reduced operating income. Though R&D activity increases net sales, increased operating costs finally result in reduced operating income. In addition, the contribution of R&D activity to operating income may not materialize for quite some time.
According our empirical results, high R&D intensity firms may enjoy abnormal stock price returns, but there is no impact on operating income. This implies that more time is needed for R&D inputs to contribute to operating income, or that such inputs have no impact on operating income at all. However, managers may be influenced by investor misapprehension that R&D investment can provide quick benefits to financial results, and thus continue to expand R&D investments in a bid to raise their firm's stock price.

References

[1] N. Baker and J. Freeland, Recent advances in R&D benefit measurement and project selection methods, *Management science*, 21(2), (1975), 1164-1175.
[2] P. Beneito, The innovative performance of in-house and contracted R&D in terms of patents and utility models, *Research Policy*, 35(4), (2006), 502-517.
[3] P. G. Berger and E. Ofek, Diversification's effect on firm value, *Journal of financial economics*, 37(1), (1995), 39-65.
[4] A. S. Bharadwaj, S. G. Bharadwaj and B. R. Konsynski, Information technology effects on firm performance as measured by tobin's q, *Management science*, 45(7), (1999), 1008-1024.
[5] D. M. Cutler, J. M. Poterba and L. H. Summers, What moves stock prices, *The Journal of Portfolio Management*, 15(3), (1989), 4-12.
[6] B. Crèpon, E. Duguet and J. Mairessec, Research, innovation and productivity: An econometric analysis at the firm level, *Economics of Innovation and new Technology*, 7(2), (1998), 115-158.
[7] D. M. De Carolis, Competencies and imitability in the pharmaceutical industry: An analysis of their relationship with firm performance, *Journal of management*, 29(1), (2003), 27-50.
[8] Z. Deng, B. Lev and F. Narin, Science and technology as predictors of stock performance, *Financial Analysts Journal*, 55(3), (1999), 20-32.
[9] L. Edvinsson, Developing intellectual capital at skandia, *Long range planning*, 30(3), (1997), 366-373.
[10] L. Edvinsson and M. S. Malone, Intellectual capital: Realizing your company's true value by finding its hidden brainpower, *Collins*, March, (1997), 26-28.
[11] H. Ernst, Patenting strategies in the german mechanical engineering industry and their relationship to company performance, *Technovation*, 15(4), (1995), 225-240.
[12] J. K. Galbraith, *How to control the military*, New American Library, 1969.
[13] L. A. Hall and S. Bagchi-Sen, A study of R&D, innovation, and business performance in the canadian biotechnology industry, *Technovation*, 22(4), (2002),

231-244.
[14] M. Hirschey and J. J. Weygandt, Amortization policy for advertising and research and development expenditures, *Journal of Accounting Research*, 23(1), (1985), 326-335.
[15] G. K. Jones, A. Lanctot JR and H. J. Teegen, Determinants and performance impacts of external technology acquisition, *Journal of Business venturing*, 16(3), (2001), 255-283.
[16] G. G. Judge, W. E. Griffiths, R. C. Hill, H. L.¨utkepohl and T. C. Lee, *The Theory and Practice of Econometrics*, Second edition, Wiley, New York, 1985.
[17] W. S. Kim and E. H. Sorensen, Evidence on the impact of the agency costs of debt on corporate debt policy, *Journal of Financial and quantitative analysis*, 21(2), (1986), 131-144.
[18] B. Lev and T. Sougiannis, Penetrating the book-to-market black box: The R&D effect, *Journal of Business Finance & Accounting*, 26(3), (1999), 419-449.
[19] G. L. Lilien and E. Yoon, Determinants of new industrial product performance: A strategic re-examination of the empirical literature, *Engineering Management*, IEEE Transactions on, 36(1), (1989), 3-10.
[20] M. L. Lin, The Impacts of Research and Development on Operation Performance and Equity Valuation, *Journal of Tainan University of Technology*, 23(1), (2007), 115-133.
[21] T. R. Madanmohan, U. Kumar and V. Kumar, Import-led technological capability: A comparative analysis of indian and indonesian manufacturing firms, *Technovation*, 24(12), (2004), 979-993.
[22] D. J. Miller, M. J. Fern and L. B. Cardinal, The use of knowledge for technological innovation within diversified firms, *Academy of Management Journal*, 50(2), (2007), 307-325.
[23] R. R. Nelson, The role of knowledge in R&D efficiency, *The Quarterly Journal of Economics*, 97(3), (1982), 453-470.
[24] O. Toivanen, P. Stoneman and D. Bosworth, Innovation and the market value of uk firms, 1989–1995*, *Oxford Bulletin of Economics and Statistics*, 64(1), (2002), 39-61.
[25] N. Venkatraman and V. Ramanujam, Measurement of business performance in strategy research: A comparison of approaches, *Academy of management review*, 11(4), (1986), 801-814.