R&D Investment and Market Reactions in Non-crisis and Crisis Periods: Evidence from Taiwan

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Abstract

This study examines market reactions to firms with different level of R&D expenditure. In particular, we investigate whether R&D investment in an uncertain environment, such as during the global financial crisis of 2008, will aggravate the level of information asymmetry and increase the likelihood of undervaluation on R&D stocks. We use a sample of Taiwanese firms and classify the sample into four portfolios: no R&D, low R&D, middle R&D and high R&D firms, and estimate abnormal returns using the Fama and French three factor and Carhart four factor models. We find that the no R&D portfolio has the highest positive and significant abnormal returns in the non-crisis period (2000-2007), while the high R&D portfolio has the highest abnormal return in crisis period (2008-2011). Our multivariate analysis provides supporting evidence that high R&D firms have a greater extent of information asymmetry than no R&D firms during the crisis period, while no R&D firms bear a high risk of low growth potential in non-crisis period. Similar results are obtained either by equal-weighted or value-weighted portfolio returns. Recent studies propose that investors may misprice high-tech firms. Our results provide international evidence that investors react differently to no R&D and R&D intensive firms, and R&D investment in crisis period will aggravate information asymmetry and the extent to which investors underestimate the value of R&D stocks.

Keywords: research and development, abnormal returns, market efficiency, crisis period

1. Introduction

Although the literature shows that R&D investment can enhance a firm's competitive ability and thus have a positive influence on firm performance (Grilichies, 1984; Chauvin & Hirschey, 1993; Bae & Kim, 2003), recent studies propose that investors may underestimate the value of technology stocks (Eberhart, Maxwell, & Siddique, 2004; Hirshleifer, Hsu, & Li, 2013).

This undervaluation is mainly because R&D projects have uncertain outcomes, and investors usually have difficulties in collecting and processing R&D-related information. The complex content of R&D projects makes it hard for investors to predict their value, and this worsens the extent of information asymmetry between insiders and investors (Aboody & Lev, 2000). Moreover, Chan, Lakonishok, & Sougiannis (2001) point out that underpricing may arise because accounting rules cannot fully reflect the value of R&D projects. As a result, market imperfections and investors' psychological constraints induce sluggish short-term stock price reactions to innovative firms (Hirshleifer et al., 2013). This study examines whether R&D investment in an uncertain environment, such as the global financial crisis period of 2008, will aggravate information asymmetry and the extent to which investors underestimate the value of R&D stocks.

This study examines a sample of Taiwanese public firms. Technology firms account for a large portion of the Taiwanese Stock Exchange (TWSE) and innovation-related activities play a key role in the development of local capital markets. We first classify the sample firms into four portfolios, as no R&D, low R&D, middle R&D and high R&D firms, based on the ratio of R&D expenditures to sales. We then conduct portfolio analysis by applying the Fama and French three-factor (1993) and Carhart (1997) four-factor models and estimate abnormal returns based on both equal- and value-weighted portfolio returns. For the whole sample, we find the abnormal returns (alpha value) decrease monotonically with the ratio of R&D expenditures to sales. No R&D and low R&D portfolios have positive monthly abnormal returns of 2.66% and 1.72%, respectively, which are significantly higher than the 0.20% of high R&D portfolio, based on estimations from the Fama and French three-factor model and using equal-weighted portfolio returns. Since no R&D and low R&D firms have significant higher loadings on the book-to-market ratio (B/M) than high R&D firms, we cannot reject the possibility that the positive abnormal returns provided by no R&D firms might be explained by the risk premium.

We further investigate whether the disturbances that occur during a financial crisis may increase information asymmetry and cause greater mispricing of technology stocks. We separate the sample into non-crisis (2000-2007) and crisis period (2008-2011) subsamples, and then perform portfolio analysis. The results of non-crisis subsample are similar to those obtained for the whole sample period, in that the no R&D firms have highest and most significant abnormal returns, while high R&D firms have the lowest abnormal returns. An interesting finding is that, in the crisis period, the abnormal return increases to 1.33% in the high R&D firms, but falls to 1.39% in the no R&D firms.

Since the factor loadings on each risk factor in the high R&D firms are not significantly higher than those in the no R&D and low R&D firms during crisis period, we further perform multivariate regression to verify whether the abnormal returns for high R&D firms are related to mispricing. We draw on the model in Chan et al. (2001) by using stock return volatility as a proxy for information asymmetry. We find that high R&D firms have positive and large coefficients on stock return volatility in the crisis period, but the coefficients are about half this size and less significant in the non-crisis period. The results provide supporting evidence for our portfolio analysis, and show that the undervaluation of high R&D firms may be driven by mispricing due to aggravated information asymmetry in the crisis period.

Our findings contribute to providing international evidence regarding R&D activities in two aspects. First, our results show that no R&D firms are undervalued possibly due to their low growth potential in the non-crisis period, while high R&D firms might be mispriced due to the higher level of information asymmetry in the crisis period. Prior literature proposes that investors' limited attention and psychological constraints may cause mispricing of technology stocks (Chan et al., 2001; Hirshleifer et al., 2013). Our findings provide additional evidence that investors might have different reference point to evaluate no R&D and R&D intensive firms. Second, our findings show that high R&D firms have higher level of information asymmetry and undervaluation in crisis period than in non-crisis period. Concurrent studies argue that herd behavior of investors (Kim & Wei, 1999) or firm characteristics such as cash flow, liquidity and debt ratio (Mulder, Perrelli, & Rocha, 2012) may affect the likelihood and depth of the influence of financial crisis. Our findings suggest that high R&D expenditure may aggravate the extent of information asymmetry and mispricing during crisis period.

The remainder of the paper is organized as follows. Section 2 provides the literature review. Section 3 describes the data and methodology. Section 4 reports the descriptive statistics and regression analysis for all samples and sub-samples. Section 5 summarizes the paper.

2. Market Reactions to R&D Stocks

The efficient market hypothesis suggests that investors will react immediately when they receive new information (Fama, 1970). In terms of a firm's innovative activities, this means that any benefits from R&D activities will be immediately reflected in stock price once investors are aware of the value of R&D projects. The stock price will thus incorporate the value of R&D capital, and no association is expected between R&D expenditure and future stock returns.

However, recent studies point out that investors may underestimate the value of technology stocks (Eberhart et al., 2004). Investors usually have greater difficulty in processing information about intangible assets, and the uncertain outcomes of R&D projects also make it hard for investors to predict the value of such projects (Pandit, Charles, & Zach, 2011). In addition, accounting practices do not adjust the long-term benefits of R&D activities into firms' financial statements. These characteristics of innovative activities mean that R&D firms have a higher level of information asymmetry than no R&D and low R&D firms (Aboody & Lev, 2000).

Additionally, technology firms may choose to release limited information about their R&D projects, due to the intense market competition, and thus insiders usually hold more information, and more accurate information, regarding a firm's R&D activities. R&D intensive firms are thus considered as having a greater chance of insider trading and earnings management than low R&D firms (Morck, Yeung, & Yu, 2000). As a result, it has been claimed that the difficulties with regard to pricing and information asymmetry due to these characteristics are likely to cause undervaluation of R&D stocks (Chan et al., 2001; Hirshleifer et al., 2013).

3. Methodology

The sample includes 7,499 firm-year observations listed on the Taiwan Stock Exchange (TWSE) for the years 2000 to 2011. We exclude observations from the financial services industry and those with missing variables. The financial and stock return data are derived from Taiwan Economic Journal (TEJ) data bank.

Based on Chan et al. (2001), Ciftci and Cready (2011), we use R&D expenditure divided by sales to measure a company's investment in R&D (RD/sales). We then classify the observations into four portfolios: no R&D, low R&D, middle R&D and high R&D portfolios, based on the 33rd and 67th percentiles of RD/sales. We first estimate abnormal returns from the Fama and French three-factor model (1993), as follows:

$$R_{pt} - R_{ft} = a + b\left(R_{mt} - R_{ft}\right) + s(SMB_t) + h(HML_t) + \varepsilon_{pt} \quad (1)$$

where R_{pt} is the monthly return control for size and book-to-market, based on equal- or value-weighted portfolio returns in month *t*. R_{ft} is the one-month deposit interest rate of the Bank of Taiwan. $R_{pt} - R_{ft}$ represents the excess returns on a strategy of buying the stocks in a specific R&D portfolio. R_{mt} is the TWSE value-weighted market index return. SMB_t is the difference between the average of returns of a small firm portfolio and big firm portfolio. HML_t is the difference between the simple average of returns of the high book-to-market (B/M) portfolio and low book-to-market portfolio. Firms with book-to-market equity higher than the 67th percentile and lower than 33rd percentile are classified as high and low B/M groups, respectively.

We also measure abnormal returns from the Carhart four-factor model (1997), as follows:

$$R_{pt} - R_{ft} = a + b\left(R_{mt} - R_{ft}\right) + s(SMB_t) + h(HML_t) + d(UMD_t) + \varepsilon_{pt} \quad (2)$$

where UMD_t is a momentum factor that measures the difference between the average returns of high and low prior returns portfolios. Prior returns are measured from month -12 to – 2 before month *t*.

In addition, we examine whether R&D intensity influences the extent of information asymmetry. Following Chan et al., (2001), we use the volatility of stock returns as a proxy of information asymmetry and perform multivariate regression analysis as follows:

$$\delta_{i,t+1} = \alpha + \beta_1 Low_{i,t} + \beta_2 Middle_{i,t} + \beta_3 High_{i,t} + \beta_4 ln(MV)_{i,t} + \beta_5 ln(B/M)_{i,t} + \beta_6 Age_{i,t} + \varepsilon_{i,t+1} \quad (3)$$

where $\delta_{i,t+1}$ is the standard deviation of monthly returns on the subsequent 12 months of sample firms; *Low, Middle and High* are dummy variables representing low R&D, middle R&D and high R&D firms; $ln(MV)_{i,t}$ is the market value of firms (in logarithms) in year *t*; $ln(BM)_{i,t}$ is the book-to-market of firms (in logarithmic form) in year *t*; *Age* is the number of years since the firms were first listed on the TWSE.

4. Empirical Results

4.1 Descriptive Statistics

Table 1 provides innovation variables and financial variables by industry, sorted by R&D expenditure to sales in descending order. The Biotechnology & Medical Care industry has highest R&D ratio of 7.84%, while Electronics, Electrical Machinery and Automobiles have R&D ratios over 2%. The high R&D industries in Taiwan are quite similar to those in the US, as defined by Brown et al. (2009). Tourism and Shipping firms have the lowest R&D ratios, at 0 % and 0.01%, respectively. The Electronics industry ranks second by R&D ratio, and it also has the largest number of observations, accounting for over half of our sample, with the lowest average firm age of 9.54 years. The statistics show that many Taiwanese manufacturing firms aggressively engage in innovative activities.

We now look at the market valuation and characteristics of firms with different levels of R&D expenditure. We take all domestic common stocks listed on the TWSE and classify the firms into four portfolios: no R&D, low R&D, middle R&D and high R&D, based on the 33rd and 67th percentiles of R&D to sales. We first compute the raw returns by averaging the monthly returns over the four groups. As shown in Table 2, the no R&D firms have the highest raw stock returns, at 20.21%, while the middle R&D firms have raw returns of 19.50%. In contrast, high R&D firms have the lowest raw returns of 12.57%.

We further provide the equal- and value-weighted excess returns of each portfolio. We follow the general approach in the literature and control for size and book-to-market effects. Table 2 shows the monthly excess returns net of the risk free rate. The risk free rate is represented by one-month deposit interest rate of the Bank of Taiwan. The excess returns based on equal-weighted portfolios are -0.20, -0.48%, -0.56% and -0.67% for no R&D, low R&D, middle R&D and high R&D firms, respectively. For the value-weighted estimations, the excess returns are -0.15%, 0.07%, -0.51% and -0.46%, respectively. These findings show that the raw and excess returns decrease as R&D expenditure increases. Chan et al. (2001), Fama and French (1992) and Lakonishok, Shleifer, & Vishny (1994) note that glamorous investments in R&D projects may raise investor concerns, and our findings show that the market might discount the value of firms engaged in a high level of R&D activities.

Table 1. Descriptive statistics by industries

Industry	Obs	RD/sale	Stock Return	ROE	ROA	Assets	Sale	MV	B/M	Firm age
Biotechnology & Medical Care	428	7.84	17.99	9.21	6.72	7,098	4,563	6,770	0.90	16.36
Electronics	3438	3.92	18.34	8.75	6.82	22,666	22,538	28,106	0.82	9.54
Electrical machinery	401	2.50	17.80	6.52	4.39	6,478	3,872	4,595	0.99	12.56
Automotive	62	2.21	23.83	10.64	7.90	37,251	39,726	31,443	1.02	18.55
Glass &Ceramic	48	1.37	15.57	3.44	3.45	14,657	5,129	13,858	1.38	18.75
Rubbers	116	1.12	24.57	10.36	7.59	12,578	5,479	14,493	0.93	23.51
Textile	505	1.01	13.38	-1.57	1.03	9,170	5,052	5,853	1.59	17.59
Others industries	406	1.01	16.33	8.29	7.05	8,688	4,620	8,071	0.88	13.85
Plastic	253	0.97	18.85	6.65	4.91	48,788	27,822	52,244	1.10	21.51
Electrical cable	160	0.57	13.96	1.02	2.39	12,693	8,777	6,395	1.59	22.48
Building materials	461	0.43	26.05	0.17	2.08	12,045	3,721	5,695	1.57	14.08
Foods	248	0.40	18.58	5.84	4.37	9,962	7,174	8,872	1.13	21.91
Papers	86	0.25	11.97	2.43	2.08	14,565	8,305	7,715	1.41	32.03
Iron and Steel	300	0.23	26.40	3.87	3.94	20,160	16,088	17,225	1.46	15.33
Cement	84	0.06	10.19	4.16	3.44	34,409	6,523	25,052	1.38	29.50
Supermarket	126	0.05	12.01	6.98	4.50	15,137	15,343	15,691	0.78	21.37
Oils	93	0.02	14.30	10.82	6.32	46,156	61,872	70,529	0.84	14.81
Shipping	190	0.01	19.81	8.57	6.79	38,651	21,927	21,440	1.01	17.47
Tourism	94	0.00	15.46	7.43	5.56	4,778	1,317	6,588	0.79	22.06

Note: This table lists summary statistics by industry sorted by RD/sales. ROE is earning divided by the book value of equity. ROA is earning divided by the book value of total assets. MV is the market value of equity. B/M is the book-to-market ratio calculated as the book value of equity divided by the market value of equity. Sales, assets and market value are presented in units of a million NTD.

For firm characteristics, high R&D firms have an average R&D ratio of 8.95% and an average number of patents of about 12.83, with both figures significantly larger than those seen for the no R&D and low R&D firms. High R&D firms have a stock turnover of 2.04 and a return volatility of 13.18% that is significantly higher than seen with low R&D firms, indicating that investors tend to trade high R&D firms more frequently. High R&D firms also seem to be more profitable, with a larger market value (MV) and higher growth potential (inverse of B/M) than no R&D and low R&D firms. However, low R&D firms have greater average sales and assets than no R&D firms. This is because some traditional industries, such as Cement, Oils and Shipping, have very low R&D expenditures but a large amount of sales and assets, as shown in Table 1.

4.2 Market Reactions to R&D Stocks - All Time Period

It is possible that any excess returns on R&D stocks reflect risk differentials or are due to investor mispricing. We thus examine whether the excess portfolio returns is captured by risk factors by applying the Fama and French three-factor and Carhart (1997) four-factor models. Panel A and panel B in Table 3 show the regression results based on equal- and value-weighted portfolio returns, respectively.

Table 2. Return and characteristics of R&D portfolios

	No R&D	Low R&D	Middle R&D	High R&D	T test stat. (High-No)	T test stat. (High-Low)
Observations	1,993	1,835	1,836	1,835		
Raw return%	20.21	18.44	19.50	12.57	-3.03***	-2.25**
Excess return%						
equal-weight	-0.20	-0.48	-0.56	-0.67	-0.41	-0.18
value-weight	-0.15	-0.07	-0.51	-0.46	-0.30	-0.52
R&D/Sales %	0.00	0.34	1.96	8.95	13.37***	-11.32***
Patent	0.72	5.83	5.44	12.83	10.67***	3.12***
Turnover	1.45	1.47	1.93	2.04	15.62***	15.05***
Return	13.13	11.84	12.37	13.18	0.21	5.73***
MV (in mil.)	11,772	28,151	20,287	28,907	5.31***	0.17
ROE (%)	4.35	5.39	7.11	6.48	2.26**	1.19
ROA (%)	4.15	4.49	5.34	6.28	6.04***	5.06***
B/M	1.21	1.21	0.98	0.78	-13.44***	-13.29***
Age	16.89	17.41	13.38	10.49	-22.13***	-22.75***
Sales (in mil.)	9,099	30,012	19,027	10,244	1.24	-5.44**
Assets (in mil.)	14,738	27,273	21,636	17,963	2.10**	-3.61**

Note: The ***, ** and * indicate statistical significance at the 1%, 5% and 10% level.

Panel A in Table 3 shows that high R&D firms have the largest and most significant factor loadings on (R_{mt}-R_{ft}) and *SMB,* at 1.29 and 0.97, respectively. On the other hand, high R&D firms have negative factor loading on *HML*, but no R&D and low R&D firms have positive and significant factor loadings of 0.34 and 0.08 on *HML*, respectively. We further conduct difference tests and find that the coefficients of three factors in high R&D firms are significantly different than those in no and low R&D firms (p value>0.05 on High-No and on High-Low in Table 3). These statistics suggest that high R&D firms tend to be smaller and have higher market risk. In contrast, no and low R&D firms bear more risk of a lower growth potential.

Panel A of Table 3 further demonstrates that the abnormal return (alphas) obtained from the factor models are positive and decrease monotonically as the R&D expenditure increases. The no R&D portfolio has the highest and significant monthly abnormal returns of 2.66% and 2.67%, as estimated by the three-factor and four-factor models, respectively. The low R&D portfolio has the second highest abnormal returns of 1.72% and 1.74% by three and four factor models, respectively, and both these results are significant at 0.01 level. The middle R&D portfolio has abnormal returns of 0.37% and 0.45%. In contrast, the high R&D portfolio has the lowest abnormal returns of 0.20% and 1.29% in both factor models. Panel B and Figure 1 presents the abnormal returns based on the value-weighted portfolio returns, and shows similar findings to Panel A. The results of the difference tests show that high R&D firms have significantly lower alphas than the no and low R&D portfolios in both equal- and value-weighted estimations.

However, the findings in Table 3, contrast to those obtained in Western economies, show that high R&D firms are undervalued much more than no R&D firms (Hirshleifer, et al., 2013; Chan et al., 2001). We provide two possible explanations for this. First, it might be the case that no or low R&D investment implies that the firm's managers are pessimistic about the company's future prospects. As shown in Table 2, no and low R&D firms have lower growth rates than high R&D firms. Investors may thus systematically discount the stocks of no and low R&D firms due to lower expectations about the firms' future prospects. These pessimistic attitudes may also be reflected in the lower stock trading frequency (turnover) for the no and low R&D quantiles, as reported in Table 2. The positive and significant factor loadings on HML also indicate that investors require a risk premium on no R&D firms, as shown in Table 3. Second, as shown in Table 2, high R&D firms have a higher aggregate average market value of 28,907 million and higher stock turnover of 2.04 than the no R&D firms (MV 11,772, stock turnover 1.45) and low R&D firms (MV 28,151, stock turnover 1.47), with a significant difference at the 1% level. It suggests that the high R&D stocks may have higher exposure and obtain more attention in stock market than no and low R&D stocks. Therefore, the no and low R&D stocks are likely to be undervalued, either due to the risk of a lower growth potential or investors' limited attention.

Table 3. Fama & French and Carhart model regression results-All time periods

	Fama and French (1993)					Carhart (1997)					
R&D portfolios	Intercept	RM-RF	SMB	HML	Adj.R^2	Intercept	RM-RF	SMB	HML	UMD	Adj. R^2
Panel A: Equal-weight											
No R&D	2.6615	1.0411	0.4413	0.3446	0.87	2.6673	1.0414	0.4402	0.3455	0.0068	0.87
	(8.64)***	(27.42)***	(3.48)***	(5.26)*		(8.36)*	(27.17)	(3.44)***	(5.18)***	(0.07)	
Low	1.7156	1.0817	0.5405	0.0836	0.90	1.7449	1.0846	0.5305	0.0913	0.0642	0.90
	(6.42)***	(33.57)***	(5.02)***	(1.50)		(6.74)***	(33.42)	(4.89)***	(1.62)**	(0.83)	
Middle	0.3721	0.9738	0.0820	-0.1755	0.90	0.4505	0.9817	0.0554	-0.1550	0.1718	0.91
	(1.60)	(34.63)**	(0.87)	(-3.61)		(1.95)*	(35.40)	(-0.60)	(-3.21)***	(2.59)**	
High	0.2044	1.2929	0.9719	-0.5634	0.85	0.2177	1.2941	0.9687	-0.5601	0.0231	0.85
	(0.53)	(28.42)***	(6.43)***	(-7.11)***		(0.56)	(28.12)	(6.34)***	(-6.92)***	(0.21)	
Test: High-No	-2.4571	0.2518***	0.530	-0.9080		-2.4466	0.2527*	0.5285***	-0.9056***	0.0163	
Test: High-Low	-1.5112	0.2112***	0.431	-0.6470		-1.5279	0.2095*	0.4382**	-0.6514***	-0.0411	
Panel B: Value-weight											
No R&D	2.1726	0.8465	-0.1452	0.4067	082	2.1989	0.8491	-0.1541	0.4136	0.0576	0.82
	(6.95)*	(22.46)***	(-1.15)	(6.25)***		(6.96)***	(22.35)	(1.21)	(6.26)***	(0.64)	
Low	1.7957	0.9196	-0.1800	0.1863	087	1.7930	0.9194	-0.1790	0.1856	-0.0059	0.87
	(6.80)***	(28.86)***	(-1.69)*	(3.39)***		(6.70)***	(28.57)***	(-1.67)*	(3.32)***	(-0.08)	
Middle	0.3721	0.9738	0.0820	-0.1755	090	0.4505	0.9817	0.0554	-0.1550	0.1718	0.91
	(1.60)	(34.63)	(0.87)	(-3.61)***		(1.95)*	(35.40)	(-0.60)	(-3.21)***	(2.59)**	
High	0.2503	1.1086	0.0752	-0.3011	088	0.1360	1.0980	0.1064	-0.3285	-0.1980	0.88
	(0.80)	(29.97)	(0.61)	(-4.67)		(0.43)	(29.86)***	(0.87)	(-5.08)***	(-2.25)**	
Test: High-No	-1.9223***	0.2621	0.220	-0.7078		-2.0629**	0.2489*	0.260	-0.7421**	-0.255	
Test: High-Low	-1.5454***	-0.8110***	0.255	-1.0874		-1.6570**	0.1786*	0.285	-0.5141**	-0.192	

Note: t statistics is in parentheses. The ***, ** and * indicate statistical significance at the 1%, 5% and 10% level.

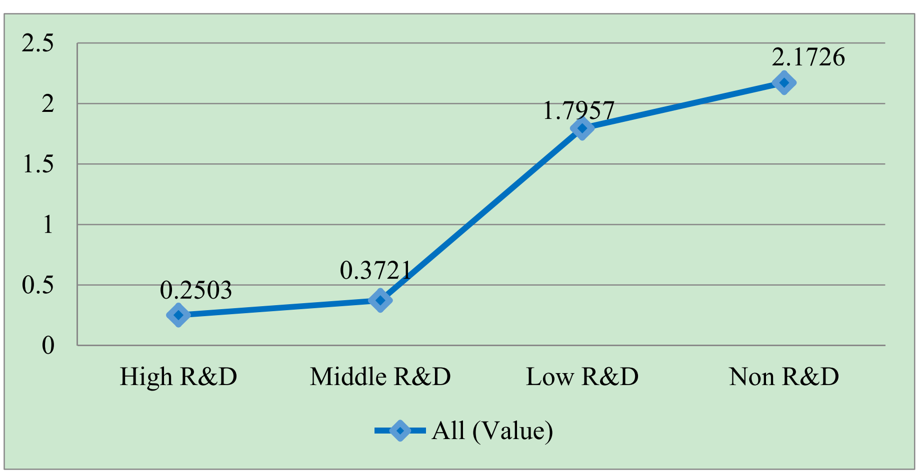

Figure 1. Abnormal returns of R&D portfolios (2000-2011)

4.3 Market Reactions in Non-crisis and Crisis Periods

Barberies and Shleifer (2003) propose that investors commonly misprice stocks. Similarly, Chan et al. (2001) and Hirshleifer, et al. (2013) note that R&D stocks are likely to be underpriced by investors. We further separate the sample into non-crisis (2000-2007) and crisis (2008-2011) periods to examine whether the global financial crisis that occurred in the latter period influences the market reaction to R&D firms, either due to increased risk or aggravated mispricing. We begin with comparing the returns and firm characteristics of each portfolio in the non-crisis and crisis periods.

Panel A in Table 4 shows R&D and stock trading activities. For the non-crisis period, no R&D firms have the highest raw returns of 21.53% and excess returns -0.52% and -0.50%, as estimated based on equal- and value-weighted portfolio returns. The raw and excess returns decrease as R&D expenditure increases. For the crisis period, the raw returns of the no R&D firms decrease to 18.24%, but all three RD portfolios have higher raw returns than those in the non-crisis period. The results of the difference tests show that low and middle R&D firms have higher raw returns in the crisis period, but the difference in excess returns between the two periods is not significant. With regard to stock trading, firms with more R&D have a higher turnover in both crisis and non-crisis periods, indicating Taiwanese investors' preference for trading technology stocks. The stock turnover and return volatility (δ) of each portfolio in the crisis period are significantly lower than those in the non-crisis period, indicating less stock trading during crisis period.

Panel B in Table 4 compares firm characteristics in the crisis and non-crisis periods. The results show that in the crisis period the no R&D firms have significantly higher market value (MV), profitability (ROE and ROA) and greater future prospects (lower B/M) than in the non-crisis period. In contrast, middle and high R&D firms have lower market value, profitability and future prospects.

Table 4. Return and characteristics of R&D portfolios-Crisis and Non-crisis period

	No R&D			Low R&D			Middle R&D			High R&D		
	Non-Crisis	Crisis	t stat.	Non-Crisis	Crisis	t stat.	Non-Crisis	Crisis	t stat.	Non-Crisis	Crisis	t stat.
Panel A: Return and turnover												
Stock return (%)	21.53	18.24	-0.97	15.54	22.86	2.00***	14.46	27.17	3.27***	10.49	15.73	1.36
Excess return (%)												
Equal-weight	-0.52	0.38	0.55	-0.92	0.33	0.81	-0.94	0.14	0.63	-1.01	-0.10	0.50
Value weight	-0.50	0.48	0.72	-0.01	0.23	0.18	-0.90	0.18	0.78	-1.03	0.57	0.99
Turnover	1.50	1.34	-3.32***	1.53	1.35	-3.50***	2.02	1.78	-4.35***	2.16	1.90	-4.87***
Return volatility (δ)	15.09	10.21	-12.99	12.79	10.40	-6.87***	13.17	11.16	-7.02***	13.87	12.14	-5.39***
Panel B: Characteristics												
No. of firms	1193	800		932	613		1235	813		932	613	
RD/Sales (%)	0.00	0.00	n/a	0.31	0.39	7.22***	1.77	2.24	13.82***	6.95	11.98	3.25***
MV (in mil.)	10,756	13,290	1.68*	22,231	37,154	2.70**	21,050	19,128	0.71	30,291	26,804	0.48
ROE (%)	2.51	7.32	4.41***	4.77	6.34	1.99**	7.85	6.00	-2.53**	8.29	3.73	-2.74***
ROA (%)	3.51	5.19	4.14***	4.35	4.70	0.96	5.85	4.56	-3.18***	7.65	4.19	-5.64***
B/M	1.37	0.98	-7.42***	1.27	1.12	-2.74**	0.94	1.03	2.72***	0.73	0.86	-4.44***
Age	15.78	18.55	6.36***	16.16	19.30	4.39***	12.13	15.27	8.31***	9.27	12.33	-8.74***
Sales (in mil.)	8,845	9,507	0.71	19,259	46,361	3.72***	17,611	21,179	1.40	10044	10,296	0.16
Assets (in mil.)	14,595	14,978	0.25	21,228	36,464	3.50***	20,553	23,281	1.06	18397	17,302	-0.71

Panels A and B in Table 5 provide the regression results for the equal- and value-weighted portfolios. Panel A in Table 5 shows that in the non-crisis period (2000-2007) the no R&D firms have the highest abnormal returns of 2.95% and 2.99% based on the Fama and French three-factor and Carhart four-factor models, respectively. The abnormal returns decrease as R&D expenditure increases. High R&D firms have the lowest abnormal returns of

0.34% and 0.33% based on both factor models. The results of difference tests on the coefficients of risk factors show that high R&D firms bear higher risk on market and size, but no and low R&D firms take higher risk on low growth potential (p-value<0.01 and <0.05 on High-No and on High-low). The findings in the non-crisis period are similar to those for the whole sample. As such, the results for the whole sample (Table 3) may be mainly explained by the conditions that occurred in the non-crisis period. The regression results in the non-crisis period based on value-weighted portfolio returns are similar to those based on equal-weighted returns.

For the crisis period, Panel A shows that the no R&D firms still have abnormal returns of 1.38% and 1.37%, as estimated by the three and four factor models, respectively. However, the alphas are smaller than those in the non-crisis period (2.95% and 2.99% for the no R&D firms). In contrast, in the crisis period the alphas in high R&D firms increase to 1.33% (equal-weighted in Panel A) and 1.66% (value-weighted in Panel B) with significance levels of 10% and 5%, respectively. Firms in the top R&D quantile have higher abnormal returns than those in middle and low R&D quantiles (1.33% vs. 1.23% and 0.99%, based on the three-factor model; 1.34% vs. 1.23% and 1.00%, based the on four-factor model in Panel A). The results of the difference tests show that the abnormal returns of high R&D firms are not significantly different to those of the no R&D firms, although they are significantly higher than those of the low R&D firms at a 5% significance level during the crisis period.

Overall, as shown in Figure 2, no R&D firms have the highest abnormal returns in the non-crisis period, while high R&D firms have positive and significant abnormal returns in the crisis period. The findings suggest that investors might undervalue high R&D firms much more in the crisis period than in non-crisis period. Our findings for high R&D firms during the crisis period are quite similar to those in Xu and Zhang (2004), which finds significant expected returns for R&D stocks in the post-bubble period (1993-2000).

We then consider why the investors react differently in non-crisis and crisis periods. We first check whether risk factors explains investor reactions. In the non-crisis period, the spreads of abnormal returns between the high and no R&D firms are 2.61% (2.95%-0.34%) and 2.66% (2.99%-0.33%) in the three-factor model and four-factor model, respectively, with a significance level of 1%. The factor loadings on (R_{mt}-R_{ft}) and SMB increase as R&D increases, while the loadings on HML decrease. In particular, the difference in the coefficients on HML is larger than the differences on (R_{mt}-R_{ft}) and SMB. These findings indicate that the no and low R&D firms are likely to have higher risk due to low growth potential. Turning to the crisis period, high R&D firms do not have the highest beta and most of their risk factor loadings are not significantly different than those of low and no R&D firms, as shown in the last two columns in Panel A and Panel B. These findings suggest that the high abnormal returns of high R&D firms during the crisis period cannot be simply attributed to systematic risk.

4.4 Innovation Activities and Stock Return Volatility

A question that arises based on the results presented above is why investors undervalue high R&D firms in the crisis period rather than in the non-crisis period? As mentioned by Hirshlefier et al., (2013), limited information and psychological constraints may cause investors to underprice high R&D firms. Since companies usually incur higher sales and earnings variations during crisis (Cormier et al., 2013), R&D investment may increase both information asymmetry and mispricing for R&D intensive firms. We thus examine whether the level of R&D investment increases the degree of information asymmetry during the global crisis period. Based on the model of Chan et al. (2001), we use the volatility of stock returns as the proxy of information asymmetry, and perform a cross-sectional regression for the whole sample period (year 2000-2011), non-crisis period (2000-2007) and crisis period (2008-2011), respectively.

Table 6 shows the multivariate regression results on stock return volatility. The first three columns list the overall influence of R&D expenditure on return volatility. We find that the coefficients of RD/sale are all positive and significant at the 1% level for the whole, non-crisis and crisis periods, indicating that the higher R&D intensity firms have higher the level of stock return volatility. We then use the no R&D firms as a benchmark and set up the dummy variables for low, middle and high R&D portfolios as independent variables to compare how different levels of R&D investment influence stock return volatility. The findings show that high R&D firms have the largest coefficient in each time period. We also find that the coefficients of the high and middle R&D firms in the crisis period are almost double those in the non-crisis period (coefficients of high/middle R&D are 1.32/0.75 for the crisis period and 0.52/0.37 for the non-crisis period). In particular, the coefficient of high R&D firms in the crisis period is the largest, at 1.32 and significant at 1%. These findings suggest that the extent of information asymmetry increases in this context, as R&D expenditure and investment may cause higher level of information asymmetry in the crisis period than the non-crisis period.

Table 5. Fama & French and Carhart model regression results-Crisis and non-crisis period

	Fama and French (1993)					Fama and French (1993)					
Panel A: Equal-weight	Intercept	RM-RF	SMB	HML	Adj.R^2	Intercept	RM-RF	SMB	HML	UMD	Adj. R^2
Non-crisis period											
No R&D	2.9497 (7.64)***	1.0745 (22.66)***	0.5804 (3.82)**	0.3286 (4.45)***	0.88	2.9920 (7.59)***	1.0796 (22.32)**	0.5685 (3.69)**	0.3369 (4.46)***	0.0595 (0.59)	0.88
Low	1.7834 (5.02)***	1.0669 (24.45)***	0.6109 (4.37)***	0.0736 (1.09)	0.88	1.8104 (4.99)***	1.0701 (24.02)**	0.6034 (4.25)***	0.0791 (1.14)	0.0375 (0.40)	0.87
Middle	0.7372 (1.71)*	1.1891 (22.47)***	1.1378 (6.70)***	-0.4957 (-6.01)***	0.85	0.7652 (1.74)*	1.1925 (22.06)**	1.1299 (6.57)***	0.4902 (-5.81)***	0.0394 (0.35)	0.84
High	0.3408 (0.74)	1.2728 (22.88)***	1.2104 (6.87)***	-0.7009 (-8.10)***	0.86	0.3274 (0.68)	1.2712 (22.19)**	1.2133 (6.78)***	-0.7033 (-7.89)***	-0.0147 (-0.12)	0.86
Test: High-No	-2.6089**	0.1983**	0.6300**	-1.0295**		-2.6646***	0.1916**	0.6448**	-1.0402***	-0.0742	
Test: High-Low	-1.4426**	0.2059***	0.5995***	1.0295***		-1.4830***	0.2011**	0.6099**	-1.0402***	-0.0742***	
Crisis period											
No-R&D	1.3873 (2.18)**	1.0490 (16.09)***	0.2345 (1.05)	0.0537 (0.31)	0.88	1.3663 (2.15)***	1.0534 (16.23)**	0.2386 (1.07)	0.0314 (0.18)	-0.2720 (-1.25)	0.88
Low	0.9857 (2.14)**	1.1516 (24.48)***	0.4523 (2.81)**	-0.1174 (-0.92)	0.94	0.9957 (2.15)**	1.1497 (24.31)**	0.4504 (2.79)**	-0.1067 (-0.83)	0.1299 (0.82)	0.94
Middle	1.2334 (2.13)**	1.2576 (21.27)***	0.4721 (2.33)**	-0.0034 (-0.02)	0.92	1.2312 (2.11)**	1.2582 (21.03)**	0.4727 (2.31)**	-0.0064 (-0.04)	-0.0364 (-0.18)	0.92
High	1.3343 (1.77)*	1.2421 (16.08)***	0.3650 (1.38)	0.1256 (0.60)	0.88	1.3394 (1.75)*	1.2411 (15.88)**	0.3640 (1.36)	0.1310 (0.62)	0.0662 (0.25)	0.87
Test High-No	-0.0530	0.1931	0.1305	0.0719		-0.0269	0.1877	0.1254	0.0996	0.1404	
Test High-Low	0.3486*	0.0905	-0.0873	0.2430		0.3437*	0.0914	-0.0864	0.2377	-0.0637	

Note: The ***, ** and * indicate statistical significance at the 1%, 5% and 10% level.

Panel B: Value-weight	Intercept	RM-RF	SMB	HML	Adj.R^2	Intercept	RM-RF	SMB	HML	UMD	Adj.R^2
Non-crisis period											
No R&D	2.2068 (6.03)***	0.8300 (18.45)***	-0.1784 (-1.24)	0.4554 (6.50)***	0.83	2.2812 (6.13)***	0.8389 (18.37)***	-0.1993 (-1.37)	0.4702 (6.59)***	0.1048 (1.10)	0.83
Low	2.0892 (6.15)***	0.8925 (21.39)***	-0.1983 (-1.48)	0.2267 (3.49)**	0.85	2.0563 (5.93)***	0.8885 (20.86)***	-0.1890 (-1.39)	0.2202 (3.31)**	-0.0464 (-0.52)	0.85
Middle	0.3014 (1.02)	0.9508 (26.31)***	0.0867 (0.75)	-0.1904 (-3.38)**	0.89	0.4539 (1.58)	0.9692 (24.47)***	0.0437 (0.39)	-0.1601 (-2.91)**	0.2149 (2.91)**	0.90
High	0.1991 (0.55)	1.1757 (27.13)***	0.1633 (1.19)	-0.3518 (-5.22)***	0.90	0.0366 (0.10)	1.1573 (26.51)***	0.1988 (1.46)	-0.3813 (-5.61)***	-0.1785 (-1.96)**	0.91
Test: High-No	-2.0077***	0.3457***	0.3417*	-0.1036***		-2.2446***	0.3184***	0.3981*	-0.8515***	-0.2833*	
Test: High-Low	-0.3486***	0.2832***	0.3616*	-0.5785***		-2.0197***	0.2688***	0.3878*	-0.6015***	-0.1321	
Crisis period											
No R&D	0.7884 (1.14)	0.9629 (13.61)***	0.0546 (0.23)	-0.1251 (-0.66)	0.83	0.7686 (1.11)	0.9671 (13.68)***	0.0585 (0.24)	-0.1461 (-0.76)	-0.2560 (-1.08)	0.83
Low	-0.1683 (-0.42)	1.0740 (25.92)***	0.0679 (0.48)	-0.3781 (-3.38)**	0.94	-0.1545 (-0.38)	1.0712 (26.00)***	0.0653 (0.46)	-0.3634 (-3.26)**	0.1789 (1.29)	0.94

Middle	0.7140	0.9962	0.0500	-0.0593	0.91	0.7055	0.9980	0.0516	-0.0683	-0.1091	0.91
	(1.46)	(19.97)***	(0.29)	(-0.44)		(1.44)	(19.85)***	(0.30)	(-0.50)	(-0.65)	
High	1.6640	0.9073	-0.2891	0.1951	0.83	1.6480	0.9106	-0.2860	0.1781	-0.2067	0.83
	(2.44)**	(12.99)***	(-1.21)	(1.04)		(2.41)**	(12.99)***	(-1.19)	(0.94)	(-0.88)	
Test: High-No	0.8756	-0.5616	-0.6308	0.2987		0.8794	-0.0565	-0.3445	0.3242	0.0493	
Test: High-Low	1.8323***	-0.1667**	-0.3570	0.5732***		1.8025***	-0.1606*	-0.3513	0.5415***	0.3856	

Note: t statistics is in parentheses. The ***, ** and * indicate statistical significance at the 1%, 5% and 10% level

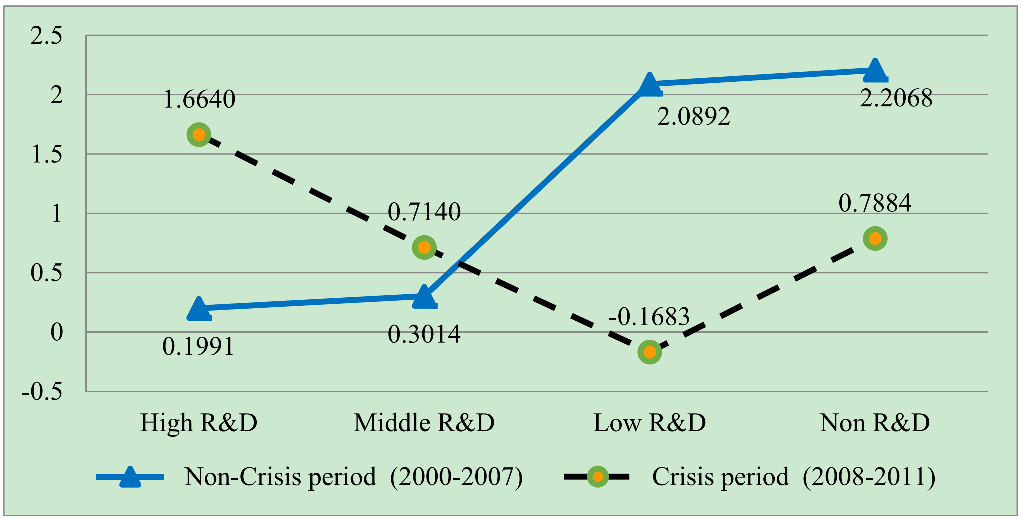

Figure 2. Abnormal returns of R&D portfolios, non-crisis and crisis period

Table 6. Cross-sectional regression of stock return volatility on R&D intensity

Variables	All time	Non-Crisis	Crisis	All time	Non-Crisis	Crisis
Intercept	20.2245	21.2481	16.6471	20.2584	21.5281	16.6141
	(31.82)***	(24.42)***	(20.51)***	(31.88)***	(24.76)***	(20.44)***
RD/sale	0.1648	0.2369	0.2157			
	(4.91)***	(4.65)***	(3.70)***			
Ln(mv)	-0.8147	-0.8037	-0.8162	-0.7914	-0.7756	-0.8288
	(-11.74)***	(-8.31)***	(-9.51)***	(-11.26)***	(-7.93)***	(-9.48)***
Ln(BM)	2.2087	3.0040	1.0481	2.2088	2.9525	1.0066
	(14.88)***	(14.41)***	(5.58)***	(14.95)***	(14.30)***	(5.31)***
Age	-0.0029	0.0684	-0.0136	-0.0038	0.0640	-0.0116
	(-0.29)	(4.75)***	(-1.04)	(-0.38)	(4.42)***	(-0.88)
Low				-0.6262	-1.2282	0.2645
				(-2.50)**	(-3.66)***	(0.80)
Middle				0.0467	0.3711	0.7487
				(0.18)	(1.04)	(2.23)**
High				0.9536	0.5163	1.3225
				(3.35)***	(1.69)*	(3.62)***
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.1496	0.1921	0.1304	0.1508	0.1927	0.1317
Observation	7499	4574	2925	7499	4574	2925

Note 1: Low, Middle and High are dummy variables representing for low R&D, middle R&D and high R&D firms.

Note 2: t statistics is in parentheses. The ***, ** and * indicate statistical significance at the 1%, 5% and 10%level.

With regard to the other control variables, MV and Age have significant negative coefficients, suggesting that larger and older firms have less return volatility. The positive coefficients of the book-to-market variables indicate that undervalued firms tend to be more volatile. The results for the control variables are consistent with those reported in Xu and Zhang (2004) for the Japan market, and Lakonishok et al. (1994) for the US market.

In short, the findings indicate that R&D firms have higher stock return volatility than no R&D firms, and high and middle R&D firms have relatively higher return volatility in the crisis period than the non-crisis period. It is suggested that greater information asymmetry makes it more difficult for investors to evaluate the outcomes of firms' R&D projects, and thus may increase the chance of mispricing during crisis period.

5. Conclusion

This study examines whether R&D investment in a more uncertain environment, such as during the global financial crisis of 2008, will aggravate the level of information asymmetry and increase the likelihood of undervaluation of R&D stocks. We use a sample of Taiwanese firms and classify the sample into four portfolios: no R&D, low R&D, middle R&D and high R&D firms. We estimate the excess returns of each portfolio using the Fama and French three-factor (1993) and Carhart (1997) four-factor models, based on both equal- and value-weighted portfolio returns.

We find that the no R&D portfolio has the highest positive abnormal returns in the non-crisis period (2000-2007), while the high R&D portfolio has highest positive abnormal returns in the crisis period (2008-2011). The results of the risk factor analysis show that low growth potential may contribute to the undervaluation of the no R&D firms during the non-crisis period, but investors may underprice high R&D firms due to market imperfections. The results of our multivariate analysis provide supporting evidence that high R&D firms have a greater extent of information asymmetry in the financial crisis period. Recent studies propose that investors may misprice high-tech firms.Our results provide international evidence that investors might have different reference points to estimate the value of firms that do and do not engage in high levels of R&D spending. Our findings also suggest that R&D investments that are made during a crisis period may deepen the shock of the external crisis, as reflected in higher extent of return volatility and undervaluation.

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