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R&D 費用對股價解釋能力的橫斷面分析:台灣案例 1996-2005

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摘要

本篇文章透過橫斷面的分析探討 R&D 費用對台灣股市裡公司股票報酬的解釋能力。選擇的樣本期間為 1996 至 2005 年的月資料，公司家數為 635，共 56,418 筆資料。過去經濟的直覺告訴我們，由於 R&D 具有不確定性，因此在承擔風險的同時，可以預期有更高的報酬。實證的結果我們發現公司 R&D 費用確實某種程度上與股價報酬呈現正向相關，但這種關係並非均存在於三個子樣本期間。在第一階段(1996.01-2000.03)裡，R&D 與股價報酬顯著負相關。第二階段(2000.04-2001.09)裡，R&D 對股價的影響則變成正向。在第三階段(2001.10-2005.12)裡，R&D 與股價報酬的關係又回到負向而且更顯著。另外，我們也對 R&D 與股價報酬的總風險加以探討，如事先預期的，幾乎在三個階段，R&D 與總風險都呈現正相關的關係。

關鍵字: R&D、橫斷面、股票報酬、錯誤定價、台灣股票市場。

The Explanatory Power of R&D on the Cross-Sectional Stock Return: Taiwan Evidence from 1996-2005

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ABSTRACT

The purpose of this paper is to examine the role of research and development (R&D) in explaining the cross-section of stock returns in the Taiwan market for the period from 1996 to 2005. Economic intuition suggests that expected stock return and the risk of return should be positively related to R&D. We divide the entire sample into three subperiods according to the index of the Taiwan stock market. The regression's results indicate that average stock return is moderately, positively related to R&D expenditure in the entire sample, but the relation is not stable over three subperiods. In the first bubble-forming period (1996.01-2000.03), the average return is evidently negatively related to R&D expenditure. In the second post-bubble period (2000.04-2001.09), the relation is in fact positive, while in the third post-bubble period (2001.10-2005.12), the R&D effect is negative and significant. We also examine the relation of the total risk of returns with R&D intensity and find that R&D intensity is nearly positively correlated to the total risk of returns.

Key words: R&D, Cross-section, Stock returns, Mispricing, Taiwan stock market.

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1. Introduction

In the last two decades, many articles have been devoted to studying the impact of research and development (R&D) investment. As suggested by previous literature, R&D expenditure contributes to an economy in several ways. Successful innovation generated from R&D at the firm level can result in totally new products, generating market growth for the firm and enhancing its market share. R&D can also improve existing products and processes, therefore contributing to cost-cutting and added value in the undertaking firm. Overall, R&D activities result in either new products or more efficient production processes that enable firms to enter a new market or reduce production costs, and hence to gain larger market shares and make more profits.

R&D activities usually may take a long time before they see any reward, and they may even result in failure in most cases. Unlike investment in property, plants, equipment and inventory, R&D is characterized by potential high reward and great uncertainty in future cash flows. Consequently, these characterizations also impact stock returns. It is plausible that the total risk of returns increases with R&D intensity. Eberhart, Maxwell, and Siddique (2004) observe R&D-associated mispricing in the U.S. stock market. Barron et al. (2002), Demers (2002), and Barth, Kasznink, and Mcnichols (2001) assert that analysts' forecast errors are negatively associated with a firm's level of intangible R&D and others. Kothari, Laguerre, and Leone (2002) report that earnings volatility associated with R&D expenditure is three times larger than that with tangible investment. A firm agreement reached by those above is that the higher R&D investments are, the higher uncertainty, operating risks will be.

In the past 40 years, Taiwan has created an economic miracle attracting the attention of the whole world. During the same time, the island's industry and entire economy have undergone major structural changes. Starting from the late 1950s, Taiwan took the lead among developing countries in adopting an export-oriented development strategy. Taiwanese manufacturers chose to engage in labor-intensive industries to produce and export, since wages were relatively low. In the early 1980s, it was thanks to the prosperity in capital-intensive industries that Taiwan's exports continuously expanded. From the early 1980s, global trade and competition turned more and more drastic, and in order to build their own reputation to confront worldwide competition, the government and private sectors devoted resources to generating firms with state-of-the-art innovations. The gradual dominance of such R&D investments not only enhanced Taiwanese firms' competitive positions, but also has sustained the country's economic growth momentum.

Against this background and over the past 20 years, the government has also deliberately promoted the development of strategic industries, such as electronics, computers, engineering, electrical appliances, and shipping equipment. The government in Taiwan has implemented a number of policy measures in recent decades aimed at enhancing firms' innovative investment, with such notable policy measures focusing on speeding up the development of the high-tech sector as: (i) establishing the Hsinchu Science-based Industrial Park to provide an environment conducive to the high-tech industry; (ii) organizing innovation alliances to spread out firms' R&D risks and to secure first-mover advantages; (iii) expanding government-sponsored research institutes to serve as a technology transfer channel for the private sector; (iv) providing tax incentives to absorb some of the costs of firms' R&D activities; and (v) providing access to sources of venture capital.

In this paper we will examine these empirical relationships for the Taiwan stock market to show how far R&D intensity explains the stock performance of the underlying firm. Ever since the 1990s, a few years after the initial liberalizations, the number of firms with positive R&D expenditure and the ratio of R&D expenditure to GDP has dramatically risen. At the same time, Taiwan's economy has experienced strong growth. The increasing importance of R&D in Taiwan's development motivates us to study how stocks with R&D perform under rising uncertainty and whether their R&D intensities can predict their current and future returns.

The purpose of this study is to investigate the stock market evaluation of R&D investments in Taiwan during its recent economic transition from a capital-intensive to a technology-based economy. Numerous prior studies present valuable observations on the relationship between R&D intensity and stock returns in the U.S and other well-developed markets. By comparison, there are limited comprehensive studies for other developing stock markets, e.g., the Taiwan stock market which is a fast emerging, nearly open, and currently a high-tech dominated market for international investors.

The remainder of the paper is organized as follows. Section 2 reviews some previous research related to the stock market valuation of R&D. Section 3 describes the data sources, defines the variables we use later and presents descriptive statistics. Section 4 reports cross-sectional regression results for the relation between expected return and R&D intensity. Some robustness tests including the use of different measures of R&D intensity are also performed. We also conduct cross-sectional regression results for the relation between return risks and R&D intensity. Section 5 concludes this study.

2. Literature Review

Many efforts have been made to explore the relationship between R&D investments and the stock performance of the undertaking firms. Most focus on whether the stock price can react to the input of R&D readily and accurately - that is to say, numerous attempts have been made by scholars to demonstrate the existence of the efficient market hypothesis (EMH). In an efficient market, the stock price impounds the value of a firm engaged in R&D activities, and so there is no association between its R&D intensity and future stock returns. By comparison, within an inefficient market, the uncertain nature of the future benefits from R&D investments might trigger mispricing. Chan, Lakonishok, and Sougiannis (2001) argue that when a firm owns a large amount of intangible assets such as R&D capital, the lack of accurate information about future cash flows generally complicates the task of equity valuation, possibly leading to mispricing of the stock. If, for example, a firm's market value merely reveals the firm's financial statement at book value without reflecting the long-term benefits of R&D investments, then underpricing might arise. In opposition, if analysts and investment clubs devote great effort to promoting R&D-intensive firms by exaggerating their past successes, then investors are likely to be overoptimistic about their future R&D benefits and inflate their market values. Overpricing inevitably takes place.

Some of these studies report that firm characteristics reveal mispricing for which the market take years to correct. Lakonishok, Shleifer, and Vishny (1994), for example, find that value (glamour) stock portfolios experience significantly positive (negative) long-term abnormal returns following the portfolio's formation. In this paper, we work from a slightly different angle to discuss the issue about R&D. Our concern is to examine the explanatory power of R&D for the cross-section of stock returns.

Many studies on the relation between R&D intensity and stock returns have been conducted on US firms. Griliches (1981) and Pake (1985) support the notion that higher R&D activities are associated with higher market values. Hirschey and

Weygandt (1985), Cockburn and Griliches (1988), and Bublitz and Ettredge (1989) find an unambiguously positive relationship between R&D expenditures and subsequent stock returns. Chan, Martin, and Kensinger (1990) conduct an event study on the stock market reaction to R&D expenditure increase announcements and find that the average abnormal return following the announcement is positive. R&D investments are likely to be more beneficial for high-tech firms than for low-tech firms. Szewczyk, Tsetsekos, and Zantout (1996) conclude that firms with better investment opportunities (i.e., high-growth firms, where their market-to-book (MB) ratio is greater than unity) are more likely to make better investments.

Aboody and Lev (2000) suggest that R&D expenditures generate information asymmetry and insider gains. They argue that insider gains in R&D-intensive firms are substantially larger than insider gains in firms without R&D. R&D is thus a major contributor to information asymmetry and insider gains, thus raising issues concerning management compensation, incentives, and disclosure policies. Chan, Lakonishok, and Sougiannis (2001) analyze the average returns over time for all firms in the US with available data. Consistent with the EMH, they do not find any significant difference between firms with and without R&D investments. However, within the set of growth stocks, R&D-intensive stocks are likely to outperform stocks with little or no R&D. They also find a positive relation between return volatility and R&D intensity. Eberhart, Maxwell, and Siddique (2004) examine the long-term abnormal stock returns and operating performance following unexpected R&D increases, showing a strong sign of mispricing of stocks with high R&D intensities. They argue that R&D increases are beneficial investments and the market is slow to recognize the extent of this benefit.

Tere are some studies on the other advanced countries except the U.S. Xu and Zhang (2003) find moderate evidence that the average stock return is positively related to R&D expenditure in the Japan market. Al-Horani, Pope and Stark (2003) even present that R&D intensity dominates MB as an explanatory factor for stock returns in the UK. The studies of Taiwanese firms are few. Tsai and Wang (2002) argue that R&D performance in Taiwan's high-tech industry is indeed noteworthy. Chiao and Hung (2006) investigate the market valuation of R&D investments in the Taiwan stock market from July 1988 to June 2002. The results support not only the existence of mispricing, but also the persistence of it. While there are studies on the economic importance of R&D in Taiwan, there has not been systematic research that documents the explanatory power of R&D intensities for the stock returns of Taiwanese firms. Our research will fill this vacancy.

We analyze the relationship between expected stock return and R&D intensity for Taiwanese firms from 1996 to 2005 using a cross-section regression approach. Rather than on instantaneous responses of stock prices to R&D announcements, our inquiry is whether firm's R&D activities every year affect the risk-reward patterns of stock returns in the next year.

3. Data and Preliminary Analysis

3.1 Data

Data used in this study are from the Taiwan Economic Journal. Our data sample contains all firms listed on the Taiwan Stock Exchange (TSE) from January 1996 to December 2005. The firms traded over-the-counter (OTC) are excluded in our analysis. Financial firms and firms with negative book values on each formation date are also excluded from the sample.

During the sample period we cover from 1996 to 2005, Taiwan's economy and stock market went through tremendous changes. In the middle of the 1990s, the Taiwan Weighted Stock Index skyrocketed from a low 4,700 level in January 1996 to nearly the 10,000 level in July 1997. The peak lasted for approximately three years. The summit was then followed by a sharp decline form a high of 9,854 in April 2000 to a low 3,637 level in September 2001 during less than two years. Afterward, the index traded up and down around the 6,000 level until December 2005. Obviously, both the market conditions and the business cycles were greatly different over the entire sample period, and so how the relationship between stock returns and R&D intensity evolved over time is an interesting issue by itself.

For the sake of analysis, we divide the entire sample into three subperiods: the bubble-forming period from January 1996 to March 2000, the burst-of-bubble period from April 2000 to September 2001, and the post-bubble period from October 2001 to December 2005. The final sample consists of 635 firms including 56,418 observations that exclude invalid and insufficient data.

In this paper we use two measures of R&D intensity: R&D expenditure relative to total assets and that relative to the book value of equity. It is conceivable to use the relative amount rather than the absolute amount. These definitions are standardized in the literature. There are still other possibilities of normalization in defining R&D intensity. For instance, aside from using total assets and book value of equity, Chan, Lakonishok, and Sougiannis (2001) also take the market value of equity, sales or earnings as the denominator. The reason we choose total assets as a measure from these candidates is because sales and earnings are more changeable over time. We try to find a relatively stable measure to reflect a comparatively long-term strategy of the firm. Using sales and earnings as the denominator to normalize R&D expenditure will make the consequent variables of R&D intensity too volatile than they actually are. Furthermore, according to many other studies, for example, Chiao and Hung (2006), the book value of equity is another appropriate measure. Therefore, for the sake of a robustness check, we also perform the analysis using R&D expenditure relative to book value of equity as the R&D intensity. The two measures of R&D intensity are denoted as RD/A and RD/BE, respectively.

From Table 1 we see that only 65% of the sample firms carry out R&D activities every year. The ratio is especially low for the bubble-forming period from 1996 to 1999. After 2000, the number of samples with positive R&D expenditure climbs to 3,315, and since then the ratio has continued to increase gradually. Table 1 also provides statistics of R&D intensity at the aggregate level. It is obvious that R&D intensities are on the rise over the entire sample period whether we observe from the view of RD/A or RD/ME. In the late 1990s, the value-weighted average R&D expenditure was below 0.3% of total assets or less than 0.5% of the book value of equity, while in the 2000s the value-weighted average R&D expenditure increased to more than 0.4% of total assets or near 0.65% of the book value of equity. The equally-weighted R&D intensities also show an upward trend, indicating that R&D expenditures in both large and small firms have increased. The figures here are less than the ones in Japanese firms presented by Xu and Zhang (2003).

Although our focus in this paper is on the relation between stock returns and R&D intensity, we cannot say that R&D intensity is the only variable. According to the Capital Asset Pricing Model (CAPM), investors will be rewarded with a higher expected return on stocks with a higher systematic risk as measured by the market beta of the stocks. We therefore include market beta as an additional explanatory factor for expected returns. In addition, Fama and French (1992) document that, for US stocks, firm equity size and book-to-market ratio are two important variables that have predictive power on stock returns while the market beta based on the CAPM does not have much power. A similar situation could be found in the study of other countries. Chan, Hamao, Laconishok (1991) relate cross-sectional differences in returns on Japanese stocks to the underlying behavior of four variables including the size and the book-to-market ratio. They find that the book-to-market ratio plays a significant role in explaining the cross-sectional changes of stock returns in the Japan stock market. Size effect also exists but the statistical significance of size is sensitive to the specification of the model. These results are confirmed by Kubota and Takehara (1996, 1997), Chui and Wei (1998), Jagannathan, Kubota, and Takehara (1998) and Daniel, Titman, and Wei (2001). In this paper we will examine the explanatory power of R&D intensity with and without size, the book-to-market ratio and the market beta respectively.

The size of a firm for month *t* is measured as the market value of equity at the end of the last month. The book-to-market equity for month *t* uses a firm's latest available book value of equity divided by its market value in the same month. A natural logarithm is taken on both size and the book-to-market ratio as standard in the literature. Using the Taiwan Weighted Stock Index as a proxy for the market, we estimate the market beta for month *t* from the most recent 60 months of return data for each stock. For a given month *t*, a firm's R&D intensity is calculated using its most recent accounting numbers before month *t*.

R&D activities are important and beneficial for the development of the economy, but for every individual firm, especially firms in traditional industries, the R&D intensity may differ across different industries. High-tech industries naturally require more R&D activities than low-tech industries. Whether or not a firm is regarded to have invested more in R&D expenditure may depend on the industry it belongs to. Table 2 lists the R&D intensities of the electronics industry and the non-electronics industry respectively by year over the entire sample period. We see that the R&D intensities of the electronics industry are much higher than those of the non-electronics industries every year. Table 3 shows the industrial R&D intensities for included industries in 2005. Except for automobile and electronics, there is no one industry with R&D intensity over 0.5% according to the RD/A measure.

3.2 Preliminary Analysis

Table 4 reports some descriptive statistics of variables we will use later. First, we calculate the cross-sectional average of monthly returns for each month. We then report the mean and the standard deviation (S.D.) of the return averages over time. Similarly, we report the statistics for size, book-to-market ratio, and R&D intensity. Considering that firms with or without R&D activities may present differences in sample characteristics, we report the statistics for the two categories separately: one includes firms with no R&D expenditure and the other includes firms with positive R&D expenditure. As shown in Panel A, for the entire sample, the average monthly return of stocks with positive R&D expenditure is larger than that of stocks with no R&D expenditure, with a difference of 0.27%, but the standard deviation of return average is smaller than that of stocks with no R&D expenditure. The result is contrary to the argument that firms with higher returns should endure higher risk. The size ln(ME) of stocks with positive R&D expenditure is nearly close to that of stocks with no R&D expenditure, which indicates that larger firms have no tendency to invest more in R&D projects. However, there is a strong difference in the book-to-market ratio between the two categories.

Panels B to D report the same statistics for the three subperiods. In the bubble-forming period from January 1996 to March 2000, the average returns are high and standard deviations are low, relatively speaking. Returns are higher for firms with R&D expenditure than for firms without R&D expenditure. The standard deviation of return average for firms with R&D expenditure is also larger than for firms without R&D expenditure. During the burst-of-bubble period, the return averages of both categories decline sharply, but the one with R&D expenditure declines more. On the contrary, the standard deviation of return average in this period is larger than the first one.

Taiwan's economy entered into a prolonged adjustment after 2002. During the post-bubble period, Taiwan encountered a global economic recession and unprecedented domestic political chaos. It happened that the price of raw materials and metals rose up rapidly. We find that firms without R&D expenditure have higher returns as well as standard deviation of return on average than ones with R&D expenditure. We explain the phenomenon that most firms with R&D expenditure are electronics industries whose stock performance is easily affected by the preceding factors. In conclusion: first, the average returns of stocks with positive R&D expenditure is smaller than that of stocks with no R&D expenditure, and the standard deviation of return average is also smaller for the for the category of positive R&D firms; second, the size ln(ME) of stocks with or without R&D expenditure makes no difference; finally, the book-to-market ratios of firms with R&D expenditure are higher than those with no R&D expenditure for each subperiod.

Table 5 provides pairwise correlations of these variables for the entire sample and for the three subperiods separately. For the entire sample, the average return is higher for R&D intensity based on total assets than on the book value of equity. The subperiod analysis reveals that most of the R&D effect comes from the bubble-forming period and the burst-of-bubble period. In the post-bubble period, R&D intensity is in fact negatively correlated with the average return on the basis of RD/A or RD/ME. The correlations between the stock return and the R&D intensities are typically small, partially because the size of the cross-sections is large and some of the firms actually have zero R&D expenditure. The main findings of Table 5 can be summarized as follows: first, in the post-bubble period, the R&D expenditure is not advantageous to stock performance; second, the positive correlation between the stock return and two R&D measures, though not large, suggests that R&D might be another potential explanatory variable for stock returns; finally, the correlation between size, book-to-market ratio and two R&D measures is not large, and so potential collinearity in the later regression analysis will not be problematic.

4. Empirical Analysis

4.1 Expected Return and the R&D Intensity

This section inspects the relation between expected return and R&D intensity. It is sensible that firms with a higher proportion of R&D expenditure should have higher expected returns. To examine whether R&D intensity plays a role in the cross-sectional regressions of stock returns on size, book-to-market ratio, market beta, and the R&D intensity measure, jointly and separately, we apply a cross-sectional regression, following Fama and MacBeth (1973), to test for the explanatory power of these characteristics as follows:

$$r_{i,t} = \theta_1 + \theta_2 \ln(ME)_{i,t} + \theta_3 \ln(BE/ME)_{i,t} + \theta_4 \beta_{i,t} + \theta_5 RD_{i,t-1} + \varepsilon_{i,t}, \quad (1)$$

where $r_{i,t}$ is the monthly return on stock I in month t; RD is a measure of the R&D intensity of RD/A or RD/BE. The regression is run monthly from January 1996 to December 2005.

Panel A of Table 6 presents the regression parameters with *t*-statistics of the regressions for the entire sample period. The results of returns on size, book-to-market ratio, market beta and the R&D expenditure relative to total assets separately show that each of the variables is helpful in explaining the cross-section of stock returns. The size effect is negative, but less significant, than previous studies on the U.S. and Japanese markets. The book-to-market effect is positive and is as strong as that in the U.S. and Japanese market. The market beta is positively related to average return and is very significant. The *t*-statistics of the coefficients indicate that the R&D effect is not significant by itself and becomes much stronger when it is combined with other variables. All of the four variables have complementary effects in explaining cross-sectional differences in expected returns. The reported R^2, which is the time-series average of those cross-sectional regressions, is low at the firm level for the regression with R&D alone, as well as for all the other regressions.

Panels B to D of Table 6 report the results of the cross-sectional regression of returns for three subperiods separately. Recall from Table 1 that from 1996 to 1999, the number of samples that reported positive R&D expenditure dropped slightly. Although R&D activities might create new products and bring in more profits in the long run, the pressure from the stock market exerted great influence on the managers of these firms and pushed them to make myopic decisions. The opportunity cost of investing in R&D was obviously larger from the managers' point of view. As a result, fewer firms were willing to invest in R&D activities and the positive R&D effect on stock returns under the normal economic environment was distorted in the bubble-forming period.

From the results of Table 5 we recall that there is a negative relationship between stock returns and R&D intensity during the bubble-forming period, which is confirmed by the coefficient of regression when R&D intensity is considered alone. However, when we combine other variables into regressions, the coefficients turn to negative significantly. We infer that some of the firms with low or zero R&D expenditures took advantage of the rising trend of the stock market. On the contrary, the remainder of the firms with positive R&D expenditures got less returns.

After 2000, the stock market index dropped sharply due to the global recession and domestic political chaos. By September 30, 2001, the index has fallen to a low of 3,637. As most of the stocks lost value during the burst-of-bubble period, the firms that did have high R&D expenditure tended to lose less than those that had low or zero R&D expenditure. This is reflected in the positive slope coefficients for the R&D intensity in Panel C of Table 6. For the post-bubble period, although stock prices drifted up and down without much recovery, the R&D effect remained negative and became more significant. In the post-bubble period, Taiwanese firms confronted global economic fatigue and record-breaking high prices of raw materials, meaning that it was not so easy to find a favorable opportunity for R&D investment. Those which had more R&D expenditures suffered more damage from their stock returns.

There is little special to be said for the firm size, book-to-market, and market beta across the subperiods. The size slopes remain negative in explaining expected returns, however, are not significant for all regressions for three subperiods. The book-to-market effect remains strong, and the market beta effect is significant in three subperiods. With the concern that firms of zero R&D expenditure may contaminate the result, we run the same regressions for firms with positive R&D expenditure only in Table 7. It turns out that both the magnitude and the significance of the coefficients on R&D intensity are much the same as those for the sample that includes firms with zero R&D expenditure. The R^2s increase thanks to the smaller cross-sectional samples. From this we can infer that the main reason we only find a modest R&D effect on expected returns in the whole sample is actually not because firms mis-report R&D expenditure as regular investments.

4.2 R&D Intensity on the Expected Return for the Electronics Industry

As we mentioned earlier in Section 3, R&D intensity may differ across different industries. Whether a firm's R&D intensity is high depends on which industry the firm is in. In the Taiwan stock market, the electronics industry accounts for the largest part of market weighted value. The stock performance of the electronics industry almost decides the trend of the total market index. From Table 2 and Table 3, we know that the R&D intensity for the electronics industry is highest among all industries in the Taiwan stock market. Hence, it is reasonable to investigate the above relation for merely the electronics industry. We pick the firms classified into the electronics industry according to the classification by the Taiwan Stock Exchange Corporation and run the Fama-MacBeth regression.

Table 8 reports the results of regressions for the electronics industry only. The results again are very similar to the ones for total industries in Table 6. There is a negative relationship between R&D intensity and stock returns in the bubble-forming period and in the post-bubble period. However, R&D expenditure has a positive effect in the burst-of-bubble period. It is noteworthy in every subperiod that R^2s are larger than the ones in Table 6 when R&D intensity is considered with other variables. As an explanatory factor, R&D intensity has more explanatory power for the electronics industry than for total industries.

4.3 Lag and Cumulative Effect on R&D Intensity

The lag effect and cumulative effect of R&D expenditure have recently been considered in finance and accounting fields. Given the existence of the R&D lag effect, we may argue that the current and past R&D expenditures keep releasing the benefits from the so-called know-how. Since R&D activities usually yield benefits with a time lag, the R&D effects may take time to materialize, and it is interesting to consider the cumulative R&D intensity when we examine the relationship between stock return and R&D expenditure. There have been many studies on appropriate choices of time delay in R&D effects. According to Rapoport (1971) and Wagner (1968), a range of values between 1.2 and 2.5 years is thought as an appropriate mean lag. Rather than adding lagged values of the R&D intensity, we calculate the cumulative R&D intensity as follows:

$$(CRD/A)_{i,t} = 0.4(RD/A)_{i,t} + 0.3(RD/A)_{i,t-1} + 0.3(RD/A)_{i,t-2}\,. \qquad (2)$$

We now conduct a similar analysis of the regression model (1), substituting the R&D intensity with the cumulative R&D intensity. Since we need 2 years of data prior to year t to calculate the cumulative R&D intensity, the sample period is shortened. As shown in Table 9, the patterns are the same as before. Overall, both the slope and the t-statistics of the cumulative R&D intensity increase, though not necessarily for all subperiods. This confirms that R&D activities indeed have a long-term impact on stock returns.

We also do the analysis using the R&D intensity measure relative to market value to equity. The results are similar to those we got earlier. For the sake of saving space, we do not show the results again. Overall, the evidence presented in Tables 6 to 9 indicates that there is a positive relation between expected return and the R&D intensity when R&D intensity is used alone in the regression. However, when the other three variables are used together in the regressions, the R&D expenditure is negatively significantly related to expected returns.

4.4 Risks of Returns and R&D Intensity

We next turn to the relationship between risks of the returns and the R&D intensity. Such a relation is an indispensable part of our analysis. It is relatively easy to understand why R&D activities may cause the total risk of stock returns to be larger. We use the standard deviation of the return estimated from monthly data and run regressions on an annual basis. This is a practice widely adopted in the literature. For each firm i at the end of January in each year, we calculate the sample variance of the actual stock returns over the next 12 months and denote it as $\sigma_{i,t+1}^2$. Its square root is then defined as the total risk for the year from February to the next January. The total risk is regressed on the explanatory variables known at the end of this January as the following:

$$\sigma_{i,t} = \gamma_1 + \gamma_2 \ln(ME)_{i,t} + \gamma_3 \ln(BE/ME)_{i,t} + \gamma_4 RD_{i,t-1} + \varepsilon_{i,t}. \quad (3)$$

The coefficients are estimated in the cross-sectional regression for the years from 1996 to 2005, using the Fama-MacBeth approach. Table 10 reports the regression results of the total risk on R&D intensity. From Panel A of Table 10, we see that when used alone in the regression, the slope coefficient of R&D intensity is significantly negative. The slope becomes significantly positive after other variables are added into the regression. One possible reason is that the R&D intensity indeed has a positive effect. However, because of the positive relationship between R&D expenditure with the book-to-market ratio, the positive effect is swamped by the book-to-market ratio effect when the R&D intensity is used alone in the regression.

The subperiod analysis in Panel B to D of Table 10 uncovers certain patterns for the R&D effect on the total risk of returns that are different in different subperiods. In the bubble-forming period and burst-of-bubble period, the R&D effect on the total risk of returns is significantly positive. However, in the post-bubble period, the R&D effect is positive only when combined with other two explanatory variables. One pattern is common across the three subperiods: the coefficient is always more positive when R&D intensity is used with other variables and less when it is used alone. Again, the reason may come from the positive relationship between R&D intensity and the book-to-market ratio.

5. Summary and Conclusions

In this paper we examine the explanatory power of R&D for the cross-section of stock returns in the Taiwan stock market for the period from 1996 to 2005. Previous finance theories argued that expected stock return and the risk of return should be positively related to R&D. We find that R&D intensity is helpful in explaining the expected stock returns on average, but the association is weak. We use R&D

intensity to run the regressions that also include size, book-to-market ratio, and market beta variables. The results of the regression indicate that average stock return is moderately positively related to R&D expenditure in the entire sample.

We further divide the entire sample into three subperiods according to the index of the Taiwan stock market and run the regressions for three subperiods respectively. The subperiod analysis reveals more about what happened in the Taiwan stock market over time. The R&D effect is negative during the bubble-forming period (1996.01-2000.03), reflecting the speculative nature of the phenomenal price appreciation during that period. In the burst-of-bubble period (2000.04-2001.09), the stock returns are negative, but the R&D effect is slightly positive, indicating that firms with high R&D expenditure lost less value than those with low or zero R&D expenditure on average. The R&D effect is negatively correlated with the stock return in the post-bubble period (2001.10- 2006.12). Considering the nature of the lag and accumulated effects of the R&D activities, we conduct a similar analysis which replaces R&D intensity with cumulative R&D and reconfirm the earlier result. The result shows that R&D activities have some long-term effects.

Finally, we also examine the relationship between the R&D intensity and the total risk. It is plausible that firms with high R&D expenditure should endure higher risk of stock returns. We find some evidence that the R&D intensity is positively associated with the total risk, though not for every subperiod.

Previous accounting and financial studies suggest several hypotheses to account for the impact of a firm's R&D spending on performance. Among them, the profitability hypothesis is the most popular and acceptable one. The *profitability hypothesis* states that R&D expenditure represents investment opportunity - that is current R&D investment potentially reflects future cash flow. In particular, the increase in R&D expenditure implies the growth of investment opportunity, and so investors tend to positively react to news of an increase in R&D. The results reported in this paper for the R&D effect in the Taiwan stock market are somewhat identical to the profitability hypothesis, though the explanatory power is low.

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Table 1 Summary Report of R&D

This table reports the data availability of the Taiwan stock market and the statistics of the R&D intensity at the aggregate level during the whole sample period from 1996 to 2005. "# of samples" is the number of sample in the year with available market data such as the monthly return and market value. RD/A and RD/BE are the measures of the R&D intensity normalized by total assets and by book value of equity, respectively.

	Data Availability			Statistics of the R&D Intensity at Aggregate Level			
	# of Samples	Samples with Positive R&D		RD/A*10		RD/BE*10	
		Number	Percent	Value-Weighted	Equally Weighted	Value-Weighted	Equally Weighted
1996	2,380	1,488	62.52%	0.02477	0.03307	0.04285	0.05331
1997	2,844	1,542	54.22%	0.02636	0.04286	0.04495	0.07055
1998	3,244	1,831	56.44%	0.02589	0.04205	0.04229	0.06928
1999	3,764	2,257	59.96%	0.02803	0.04072	0.04534	0.06728
2000	4,359	2,754	63.18%	0.03637	0.03618	0.05749	0.05999
2001	4,970	3,315	66.70%	0.03890	0.03542	0.06308	0.05954
2002	5,646	3,932	69.64%	0.03988	0.03939	0.06630	0.07040
2003	6,156	4,418	71.77%	0.04085	0.03758	0.06596	0.07143
2004	6,337	4,648	73.35%	0.04023	0.03755	0.06498	0.06428
2005	6,388	4,751	74.37%	0.04226	0.03738	0.07060	0.06080
Average	4,609	3,094	65.22%	0.03435	0.03822	0.05638	0.06469

Table 2 R&D Intensities of the Electronics and the Non-Electronics Industries

This table lists the R&D intensities of the electronics industry and non-electronics industry during the entire sample period according to the measures of RD/A and RD/ME, respectively.

	RD/A*10		RD/ME*10	
	Electronics Industry	Non-Electronics Industry	Electronics Industry	Non-Electronics Industry
1996	0.07258	0.01469	0.12929	0.02640
1997	0.07059	0.01214	0.12256	0.02072
1998	0.06438	0.01148	0.11142	0.01923
1999	0.06578	0.01347	0.11207	0.02222
2000	0.06364	0.01394	0.10747	0.02305
2001	0.06689	0.01429	0.11122	0.02348
2002	0.07138	0.01434	0.11874	0.02336
2003	0.07755	0.01484	0.13324	0.02486
2004	0.07686	0.01536	0.13622	0.02629
2005	0.08408	0.01644	0.14422	0.02868

Table 3 Industrial R&D Intensities in Year 2005

This table reports the R&D intensity for most of the industries in 2005.

Code	Industry	RD/A*10	RD/ME*10
1	Cement	0.0003	0.0005
2	Food	0.0062	0.0111
3	Plastics	0.0105	0.0162
4	Textiles	0.0113	0.0212
5	Electric Machinery	0.0466	0.0928
6	Electric & Cable	0.0071	0.0138
7	Chemical, Biotech, Medical Care	0.0366	0.0534
8	Glass Ceramics	0.0129	0.0225
9	Paper & Pulp	0.0034	0.0054
10	Steel & Iron	0.0024	0.0036
11	Rubber	0.0125	0.0187
12	Automobile	0.0614	0.0907
13	Electronics	0.0841	0.1442
14	Building Material &Construction	0.0001	0.0001
15	Shipping & Transportation	0.0000	0.0000
16	Tourism	0.0000	0.0000
18	Trading & Consumers Goods	0.0000	0.0000
20	Others	0.0213	0.0377

Table 4 Sample Characteristics

This table presents the descriptive statistics for the variables used later. We report the statistics for two categories separately: one includes firms with no R&D expenditure and the other includes firms with positive R&D expenditure. The entire sample period is divided into three subperiods.

Variable	No R&D firms		Positive R&D firms	
	Mean	S.D.	Mean	S.D.
Panel A: Entire sample				
Return average (%)	0.88	17.41	1.15	16.43
ln(ME)	15.6220	1.0278	15.6079	1.2046
ln(BE/ME)	0.0803	0.7542	0.4838	0.7492
RD/A	0	0	0.0057	0.0067
RD/BE	0	0	0.0097	0.0117
Panel B: Bubble-forming period (1996.01-2000.03)				
Return average (%)	0.69	14.02	2.57	16.94
ln(ME)	15.6029	1.0021	15.6143	1.1122
ln(BE/ME)	0.5690	0.5370	0.8943	0.6512
RD/A	0	0	0.0047	0.0054
RD/BE	0	0	0.0081	0.0091
Panel C: Burst-of-bubble period (2000.04-2001.09)				
Return average (%)	-4.02	17.74	-3.81	19.32
ln(ME)	15.5959	0.9738	15.5792	1.2423
ln(BE/ME)	-0.3492	0.8076	0.3812	0.9087
RD/A	0	0	0.0053	0.0060
RD/BE	0	0	0.0089	0.0104
Panel D: Post-bubble period (2001.10-2005.12)				
Return average (%)	2.69	19.19	1.78	15.05
ln(ME)	15.6452	1.0628	15.6124	1.2371
ln(BE/ME)	-0.1521	0.6835	0.3115	0.6659
RD/A	0	0	0.0062	0.0072
RD/BE	0	0	0.0106	0.0129

Table 5 Correlation Analysis

This table presents the unconditional correlations between the variables used later. Return average is the cross-sectional average of the stock returns. Ln(ME) and ln(BE/ME) are the cross-sectional average of size and book-to-market ratio, respectively. β is the market beta, estimated from the most recent 36 months of return data for each month. RD/A and RD/BE are the measures of the R&D intensity normalized by total assets and by book value of equity, respectively.

	Return average (%)	ln(ME)	ln(BE/ME)	β	RD/A	RD/ME
Panel A: Entire sample (1996.01-1997.06)						
Return average (%)	1	-0.0117	0.1447	0.0204	0.0229	0.0152
ln(ME)		1	-0.0122	0.1912	-0.1105	-0.0873
ln(BE/ME)			1	0.0496	0.2010	0.1753
β				1	0.0773	0.0773
RD/A					1	0.9430
RD/ME						1
Panel B: Bubble-forming period (1996.01-2000.03)						
Return average (%)	1	-0.0394	0.2591	0.0312	-0.1036	-0.1047
ln(ME)		1	-0.0588	0.3982	-0.0988	-0.0651
ln(BE/ME)			1	0.1132	0.2868	0.2841
β				1	0.0897	0.0921
RD/A					1	0.9493
RD/ME						1
Panel C: Burst-of-bubble period (2000.04-2001.09)						
Return average (%)	1	-0.0415	0.1191	0.0519	0.0261	0.0155
ln(ME)		1	-0.0774	0.2718	-0.1259	-0.0910
ln(BE/ME)			1	0.2501	0.3258	0.3097
β				1	0.2042	0.2084
RD/A					1	0.9532
RD/ME						1
Panel D: Post-bubble period (2001.10-2005.12)						
Return average (%)	1	0.0070	0.1001	0.0178	-0.0118	-0.0207
ln(ME)		1	0.0250	0.1551	-0.1139	-0.0961
ln(BE/ME)			1	0.0227	0.2663	0.2271
β				1	0.0661	0.0603
RD/A					1	0.9387
RD/ME						1

Table 6 Regression of Returns on R&D Relative to Total Assets

This table reports the coefficients of Fama-MacBeth regression of returns on the firm-specific variables, $r_{i,t} = \theta_1 + \theta_2 \ln(ME)_{i,t} + \theta_3 \ln(BE/ME)_{i,t} + \theta_4 \beta_{i,t} + \theta_5 RD_{i,t-1} + \varepsilon_{i,t}$, where ln(ME) and ln(BE/ME) are respectively the size and book-to-market of a firm, β is the market beta, RD is the R&D intensity normalized by total assets. Numbers in parentheses are *t*-statistics.

Intercept	ln(ME)	ln(BE/ME)		RD/A	
Panel A: Entire sample (1996.01-2005.12)					
0.0366	-0.0017				0.0001
(3.83)***	(-2.72)***				
-0.0010		0.0320			0.0218
(-1.30)		(35.50)***			
0.0161			0.0066		0.0015
(12.81)***			(5.18)***		
0.0075				0.1953	0.0033
(8.00)***				(1.43)	
0.0191	-0.0013	0.0320			0.0219
(2.02)**	(-2.13)**	(35.45)***			
0.0131	-0.0005	0.0323	0.0085		0.0227
(1.39)	(-0.76)	(35.76)***	(6.61)***		
0.0296	-0.0017	0.0312		-1.1524	0.0181
(2.76)***	(-2.44)**	(28.08)***		(-8.01)***	
0.0172	-0.0001	0.0316	0.0172	-0.9497	0.0188
(1.57)	(-0.01)	(28.39)***	(5.47)***	(-6.40)***	
Panel B: Bubble-forming period (1996.01-2000.03)					
0.1046	-0.0055				0.0014
(5.86)***	(-4.80)***				
-0.0321		0.0657			0.0067
(-17.08)***		(35.08)***			
0.0369			0.0221		0.0016
(10.25)***			(5.25)***		
0.0059				-1.1857	0.0041
(3.25)***				(-2.44)**	
0.0194	-0.0033	0.0653			0.0679
(1.11)	(-2.98)***	(34.86)***			
-0.0169	-0.0009	0.0673	0.0370		0.0716
(-0.94)	(-0.70)	(35.70)***	(8.26)***		
-0.0160	-0.0008	0.0589		-0.9489	0.0553
(-0.71)	(-0.55)	(23.21)***		(-2.66)***	
-0.2841	-0.0008	0.0599	0.0154	-0.7994	0.0557
(-1.22)	(-0.47)	(23.22)***	(2.11)**	(-2.19)**	

(continued on next page)

(continued)

Intercept	ln(ME)	ln(BE/ME)		RD/A	
Panel C: Burst-of-bubble period (2000.04-2001.09)					
0.0579	-0.0062				0.0015
(2.14)**	(-3.59)***				
-0.0427		0.0244			0.0146
(-21.03)***		(11.38)***			
-0.0149			0.0299		0.0030
(-2.92)***			(5.09)***		
-0.0403				1.2384	0.0023
(-15.21)***				(1.53)	
0.0031	-0.0006	0.02839	0.0473		0.0218
(0.11)	(-0.31)	(12.80***	(7.50)***		
0.0704	-0.0067	0.0296		2.2677	0.0164
(2.27)**	(-3.39)***	(10.13)***		(4.49)***	
0.0364	-0.0021	0.0327	0.0487	1.6221	0.0198
(1.14)	(-0.98)	(10.94)***	(4.78)***	(3.11)***	
Panel D: Post-bubble period (2001.10-2005.12)					
0.0050	-0.0010				0.0001
(0.41)	(-1.25)				
0.0157		0.0231			0.0100
(16.39)***		(17.56)***			
0.0235			0.0041		0.0003
(16.28)***			(3.05)***		
0.0208				-1.1730	0.0003
(17.72)***				(-2.04)**	
0.0041	-0.0007	0.0231			0.0100
(0.34)	(-0.96)	(17.54)***			
0.0012	-0.0012	0.0232	0.0049		0.0104
(0.09)	(-1.52)	(17.60)***	(3.62)***		
0.0249	-0.0003	0.0269		-1.5383	0.0120
(1.92)*	(-0.34)	(17.55)***		(-6.20)***	
0.0103	-0.0017	0.0268	0.0203	-1.2984	0.0131
(0.78)	(-1.89)*	(17.52)***	(5.58)***	(-5.52)***	

*, **, and *** indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.

Table 7 Regression of Returns on R&D to Total Assets: the Positive R&D Firms

This table reports the coefficients of Fama-MacBeth regression of returns on the firm-specific variables, $r_{i,t} = \theta_1 + \theta_2 \ln(ME)_{i,t} + \theta_3 \ln(BE/ME)_{i,t} + \theta_4 \beta_{i,t} + \theta_5 RD_{i,t-1} + \varepsilon_{i,t}$, where ln(ME) and ln(BE/ME) are respectively the size and book-to-market of a firm, β is the market beta, RD is the R&D intensity normalized by total assets. Numbers in parentheses are *t*-statistics.

Intercept	ln(ME)	ln(BE/ME)		RD/A	
Panel A: Entire Sample (1996.01-2005.12)					
0.0069				0.2417	0.0001
(5.56)***				(1.65)*	
0.0317	-0.0021	0.0352		-0.9880	0.0231
(2.63)***	(-2.77)***	(25.78)***		(-6.44)***	
0.0263	-0.0013	0.0353	0.0094	-0.9118	0.0233
(2.15)**	(-1.52)	(25.85)***	(2.57)**	(-5.83)***	
Panel B: Bubble-Forming Period (1996.01-2000.03)					
0.0090				-1.8965	0.0038
(3.12)***				(-4.65)***	
0.0171	-0.0034	0.0671		-1.0431	0.0674
(0.57)	(-1.82)*	(19.67)***		(-2.76)***	
0.0024	-0.0017	0.0682	0.0168	-0.8855	0.0679
(0.08)	(-0.79)	(19.67)***	(1.75)*	(-2.04)**	
Panel C: Burst-of-Bubble Period (2000.04-2001.09)					
-0.0396				0.1743	0.0000
(-10.03)***				(0.33)	
0.0947	-0.0085	0.0331		2.1381	0.0183
(2.48)**	(-3.53)***	(8.44)***		(3.68)***	
0.0690	-0.0040	0.0378	0.0555	1.6722	0.0225
(1.79)*	(-1.53)	(9.27)***	(4.15)***	(2.83)***	
Panel D: Post-Bubble Period (2001.10-2005.12)					
0.0165				-0.3441	0.0008
(11.68)***				(-2.43)**	
0.0186	-0.0004	0.0308		-1.1287	0.0166
(1.38)	(-0.44)	(17.55)***		(-6.75)***	
0.0129	0.0006	0.0307	0.0106	-1.0517	0.0170
(0.94)	(0.62)	(17.45)***	(2.65)***	(-6.20)***	

*, **, and *** indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.

Table 8 Regression of Returns on R&D to Total Assets for Electronics Industry

This table reports the coefficients of Fama-MacBeth regression of returns on the firm-specific variables for electronics industry only, $r_{i,t} = \theta_1 + \theta_2 \ln(ME)_{i,t} + \theta_3 \ln(BE/ME)_{i,t} + \theta_4 \beta_{i,t} + \theta_5 RD_{i,t-1} + \varepsilon_{i,t}$, where ln(ME) and ln(BE/ME) are respectively the size and book-to-market of a firm, β is the market beta, RD is the R&D intensity normalized by total assets. Numbers in parentheses are *t*-statistics.

Intercept	ln(ME)	ln(BE/ME)		RD	
Panel A: Entire sample (1996.01-1997.06)					
0.0619	-0.003				0.0004
(3.99)***	(-2.99)***				
-0.0189		0.0484			0.0375
(-11.02)***		(28.91)***			
0.023			0.0075		0.0011
(11.52)***			(4.78)***		
0.0117				0.0574	0.0000
(6.43)***				(0.32)	
0.0431	-0.004	0.0486			0.0382
(2.82)***	(-4.09)***	(29.05)***			
0.0416	-0.0362	0.0483	0.0041		0.0385
(2.73)***	(-3.68)***	(28.83)***	(2.66)***		
0.0407	-0.0032	0.0445		-0.9283	0.0310
(2.53)**	(-3.16)***	(23.06)***		(-4.17)***	
0.0408	-0.0033	0.0446	0.0008	-0.9287	0.0310
(2.53)**	(-2.92)***	(22.79)***	(0.12)	(-4.17)***	
Panel B: Bubble-forming period (1996.01-2000.03)					
0.2141	-0.0103				0.0033
(5.12)***	(-3.84)***				
-0.0571		0.0892			0.0786
(-8.82)***		(19.46)***			
0.1418			0.0959		0.0232
(15.56)***			(10.26)***		
0.0452				-0.1618	0.0000
(8.24)***				(-0.27)	
0.2273	-0.0187	0.0944			0.0892
(5.68)***	(-7.21)***	(20.47)***			
0.0983	-0.0046	0.0926	0.0956		0.1062
(2.34)**	(-1.55)	(20.23)***	(9.17)***		
0.1468	-0.0122	0.0832		-1.6129	0.0695
(2.98)***	(-3.83)***	(13.66)***		(-2.78)***	
0.1012	-0.0061	0.0819	0.05	-1.4684	0.0726
(1.96)**	(-1.60)	(13.44)***	(2.92)***	(-2.52)**	

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Panel C: Burst-of-bubble period (2000.04-2001.09)

0.0832	-0.0789				0.0021
(1.77)	(-2.62)***				
-0.0766		0.0422			0.0242
(-13.58)***		(9.01)***			
-0.0026			0.0367		0.0042
(-0.24)			(3.72)***		
-0.0409				0.1117	0.0000
(-6.31)***				(0.16)	
0.0401	-0.0075	0.042			0.0261
(0.86)	(-2.51)**	(8.98)***			
0.0406	-0.0053	0.0424	0.035		0.0298
(0.87)	(-1.74)*	(9.08)***	(3.51)***		
0.1258	-0.0122	0.049		1.9867	0.0268
(2.21)**	(-3.38)***	(7.55)***		(2.71)***	
0.1252	-0.0108	0.0491	0.0202	1.9322	0.0270
(2.20)**	(-2.70)***	(7.55)***	(0.76)	(2.62)***	

Panel D: Post-bubble period (2001.10-2005.12)

0.0098	-0.0004				0.0000
(0.59)	(-0.39)				
-0.0052		0.0427			0.0289
(-3.04)***		(20.22)***			
0.018			0.0016		0.0001
(9.12)***			(1.19)		
0.015				-0.0998	0.0000
(7.80)***				(-0.35)	
0.0005	-0.0004	0.0427			0.0289
(0.03)	(-0.35)	(20.22)***			
0.0006	-0.0004	0.0428	0.0003		0.0289
(0.04)	(-0.38)	(20.18)***	(0.22)		
0.0162	-0.001	0.043		-0.8921	0.0281
(0.96)	(-0.93)	(18.50)***		(-4.84)***	
0.0163	-0.0021	0.0442	0.0156	-0.8897	0.0286
(0.97)	(-1.80)*	(18.60)***	(2.43)**	(-4.83)***	

*, **, and *** indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.

Table 9 Regression of Returns on the Cumulative R&D Relative to Total Assets

This table reports the coefficients of Fama-MacBeth regression of returns on the firm-specific variables, $r_{i,t} = \theta_1 + \theta_2 \ln(ME)_{i,t} + \theta_3 \ln(BE/ME)_{i,t} + \theta_4 \beta_{i,t} + \theta_5 CRD_{i,t-1} + \varepsilon_{i,t}$, where ln(ME) and ln(BE/ME) are respectively the size and book-to-market of a firm, β is the market beta, CRD/A is the cumulative R&D intensity normalized by total assets. Specifically, the cumulative R&D intensity is calculated as follows: $CRD_{i,t} = 0.4RD_{i,t} + 0.3RD_{i,t-1} + 0.3RD_{i,t-2}$. Numbers in parentheses are *t*-statistics.

Intercept	ln(ME)	ln(BE/ME)		CRD	
Panel A: Entire Sample (1996.01-2005.12)					
0.0099				0.3056	0.0001
(8.45)***				(1.86)*	
0.0322	-0.0023	0.0383		-0.8771	0.0281
(2.83)***	(-3.21)***	(31.49)***		(-5.27)***	
0.0286	-0.0018	0.0383	0.0052	-0.8205	0.0286
(2.51)**	(-2.47)**	(31.48)***	(3.88)***	(-4.91)***	
Panel B: Bubble-Forming Period (1996.01-2000.03)					
0.0163				-2.7890	0.0039
(6.77)***				(-5.88)***	
0.0576	-0.0063	0.0759		-1.1667	0.0801
(2.36)**	(-4.10)***	(26.61)***		(-2.44)**	
0.0138	-0.0016	0.0773	0.0408	-0.5341	0.0845
(0.55)	(-0.94)	(27.09)***	(6.50)***	(-1.10)	
Panel C: Burst-of-Bubble Period (2000.04-2001.09)					
-0.0415				1.8740	0.0004
(-11.00)***				(2.40)**	
0.0447	-0.0058	0.0302		2.3864	0.0184
(1.30)	(-2.64)***	(9.27)***		(2.09)**	
0.0256	-0.0021	0.0342	0.0472	1.9887	0.0253
(0.75)	(-0.94)	(10.31)***	(6.04)***	(2.49)**	
Panel D: Post-Bubble Period (2001.10-2005.12)					
0.0190				-0.2544	0.0001
(13.42)***				(-1.46)	
0.0189	-0.0004	0.0319		-1.2511	0.0179
(1.42)	(-0.43)	(19.31)***		(-6.90)***	
0.0177	-0.0002	0.0318	0.0019	-1.2325	0.0180
(1.33)	(-0.21)	(19.26)***	(1.46)	(-6.78)***	

*, **, and *** indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.

Table 10 Regression of Total Risk on R&D to Total Assets

This table reports the coefficients of Fama-MacBeth regression of the standard deviation $\sigma_{i,t}$ of returns on the firm-specific variables, $\sigma_{i,t} = \gamma_1 + \gamma_2 \ln(ME)_{i,t} + \gamma_3 \ln(BE/ME)_{i,t} + \gamma_4 RD_{i,t-1} + \varepsilon_{i,t}$, where ln(ME) and ln(BE/ME) are respectively the size and book-to-market ratio of a firm. Numbers in parentheses are t-statistics.

	ln(ME)	ln(BE/ME)	RD/A	
Panel A: Entire Sample (1996.01-1997.06)				
0.1879	-0.0028			0.0016
(38.36)***	(-8.84)***			
0.1530		-0.0207		0.0042
(387.68)***		(-46.20)***		
0.1475			-0.5109	0.0013
(293.54)***			(-6.73)***	
0.2042	-0.0033	-0.0209		0.0441
(42.49)***	(-10.70)***	(-46.61)***		
0.1700	-0.0012	-0.0290	0.7894	0.0682
(29.81)***	(-3.20)***	(-50.41)***	(10.10)***	
Panel B: Bubble-Forming Period (1996.01-2000.03)				
0.1819	-0.0026			0.0020
(26.43)***	(-5.85)***			
0.1372		0.0058		0.0036
(182.87)***		(7.83)***		
0.1450			1.8470	0.0053
(207.85)***			(13.71)***	
0.1745	-0.0024	0.0056		0.0053
(25.15)***	(-5.42)***	(7.52)***		
0.1894	-0.0027	-0.0021	1.9402	0.0223
(21.25)***	(-4.86)***	(-2.07)**	(14.08)***	

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	ln(ME)	ln(BE/ME)	RD/A	
Panel C: Burst-of-Bubble Period (2000.04-2001.09)				
0.2296	-0.0022			0.0007
(16.14)***	(-2.40)**			
0.1981		-0.0155		0.0214
(185.59)***		(-13.81)***		
0.1914			1.0646	0.0028
(130.40)***			(4.31)***	
0.2455	-0.0030	-0.0158		0.0226
(17.40)***	(-3.37)***	(-14.01)***		
0.1675	0.0011	-0.0349	3.9126	0.0719
(10.01)***	(1.02)	(-22.14)***	(14.40)***	
Panel D: Post-Bubble Period (2001.10-2005.12)				
0.1723	-0.0029			0.0021
(26.79)***	(-6.96)***			
0.1364		-0.0420		0.1637
(293.07)***		(-67.21)***		
0.1313			-1.0810	0.0080
(205.62)***			(-12.52)***	
0.1882	-0.0033	-0.0421		0.1666
(32.00)***	(-8.85)***	(-67.47)***		
0.1607	-0.0018	-0.0501	0.97063	0.1970
(24.86)***	(-4.44)***	(-67.07)***	(11.55)***	

*, **, and *** indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.