

Stock Price and Systematic Risk Effects of Discontinuation of Corporate R&D Programs

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May 7th, 2008

Abstract

We extend the evidence on whether investors impound efficiently into stock prices new disclosures about corporate R&D programs. We find firms that disclose the discontinuation of some of their R&D programs experience a significant negative announcement-period stock price response which is worse for growth stocks, for small-size firms, and for firms with low operating cash flow. We find no evidence that R&D-discontinuing firms experience an event-induced change in their systematic risk. We find evidence of a one-year-long price reversal; however, it is not robust to controlling for possible risk dimensions for firms with R&D capital that the three-factor model does not capture. Evidently, investors' initial response at disclosures of discontinuation of corporate R&D programs is efficient.

JEL classifications: G14; G31; O34

Keywords: Market efficiency; R&D investment; Intellectual property rights; Systematic risk

**Will attend and present.

Stock Price and Systematic Risk Effects of Discontinuation of Corporate R&D Programs

Research and development (R&D) investment creates new strategic options for a firm [Bowman and Hurry (1993); Dixit and Pindyck (1995)], and it is widely recognized as a major source of competitive advantage [Schumpeter (1934); Ansoff (1965)]. However, there is some controversy as to whether investors in U.S. capital markets value R&D efficiently. On one hand, some scholars argue that investors focus excessively on the short-term performance of the firm and do not appreciate long-term strategic investments such as R&D [e.g., Drucker (1986); Stein (1988); Porter (1992); and Hall (1993)]. Therefore, R&D-intensive firms must be under-valued, following that argument, and the cost of financing R&D is too high, which leads to sub-optimal investment. On the other hand, Jensen (1993) contends that many corporate R&D investments are in fact not profitable and investors systematically overlook this possibility, which implies that the valuation of some R&D-intensive stocks is excessively high, and therefore the cost of financing R&D is often times too low, which leads to over-investment.

The evidence from the short-term event-studies of Chan, Martin and Kensinger (1990) and Szewczyk, Tsetsekos and Zantout (1996) indicates that investors generally react positively to (i.e., value) announcements of corporate plans to increase R&D expenditures, and they rationally differentiate between value-creating and value-wasting R&D. Additionally, Chan, Lakonishok and Sougiannis (2001) find that firms with R&D capital show no long-term excess returns,¹ which suggests that the stock price of these firms incorporates fully the benefits of R&D spending (i.e. investors' expectations are unbiased). However, Eberhart, Maxwell and Siddique (2004) report that firms which increase their R&D expenditures experience significant positive abnormal stock returns during the five-year period following the increase, and therefore, investors initially under-value R&D investment. Making the evidence even more mixed,

Chambers, Jennings and Thompson (2002) report results which suggest that a positive association between R&D investment levels and excess returns is more likely the result of failure to control adequately for risk than of mispricing.

Since the evidence is mixed as to whether investors in U.S. capital markets value R&D efficiently, and therefore finance it at an appropriate cost of capital, and given the important macro-economic policy implications of that question, we extend the empirical evidence by examining whether investors impound efficiently into stock prices disclosures of discontinuation or abandonment of corporate R&D programs. Under the semi-strong form of the “Efficient Capital Markets’ Hypothesis”, the disclosure of relevant new corporate information should result in immediate and unbiased revisions in investors’ expectations, i.e., a significant short-term stock price reaction without any significant post-event long-term abnormal price drift.

It is important and interesting to examine disclosures of discontinuation or abandonment of corporate R&D programs for several reasons. First, based on the magnitude of the stock price response to this type of event, the discontinuation of a failed or failing corporate R&D program is evidently a more significant development or news to investors than periodical (perhaps predictable) increments in R&D spending. Accordingly, analysts and investors’ following may be heightened at that juncture, which provides an opportunity to examine whether the price correction is efficient. Second, announcements of discontinuation or abandonment of corporate R&D programs are specific, not-confounded, and unambiguous disclosures about (the abandonment of) some of the firm’s real growth options; unlike the case of announcements of increases in corporate-wide R&D budgets.² Third, it has not been examined in the Finance literature, and we cannot simply extrapolate the findings from other types of corporate

divestment, such as capital expenditure reductions, to this event since the attributes of corporate R&D capital are different from those for capital assets.³

Our sample of discontinuation or abandonment of corporate R&D programs consists of 218 non-contaminated announcements made in the period from April 1982 through November 2004 by NYSE, Amex and Nasdaq traded firms with sufficient data on CRSP. The sample firms are predominantly low book-to-market-ratio firms and they invest in R&D intensively. They have a noticeably high R&D-to-market-value ratio, perhaps due to the significant risk(s) of their R&D capital. They tend to have a low debt-to-market-value ratio, which is optimal for firms with mostly intangible / specific assets. In about 38 percent (versus 57 percent) of the sample cases, the announcing firm appears (does not appear) to have cash flow problems as its ratio of earnings before interest, taxes and depreciation to total assets suggests. Therefore, there may be subsample differences in the motivation for the corporate R&D program discontinuation (i.e., the desperate need to reduce cash payments versus efficiency reasons). Finally, the sample firms did not prior to event change their R&D intensity compared to three or five years earlier.

We find that the sample firms experience significant negative two-day announcement-period abnormal stock returns on the magnitude of -4.44 percent. This negative investor response is significantly worse for lower- compared to higher book-to-market-ratio firms, for smaller- compared to larger-size firms, for firms with low compared to high operating cash flows, but equally bad during bear and bull stock markets. These results indicate that: 1) shareholders of these firms are typically disappointed to learn that these R&D programs turned out to be unsuccessful; 2) the bad news are worse for investors at firms whose growth opportunities constitute a more significant portion of their market value; 3) the bad news are worse for investors at firms with fewer R&D programs / growth opportunities; 4) the bad news are worse

when the abandonment decision may be due to cash-flow-constraints; and 5) the general condition (or mood) of the stock market does not affect (or bias) the R&D event-induced revisions in investors' expectations.

Next, we examine whether the discontinuation of corporate R&D programs changes the systematic risk of the event-firms. Two reasons motivate this examination. First, with assets-in-place unchanged, the abandonment of growth options may change the firm's overall systematic risk since several theoretical models [e.g., Gomes, Kogan and Zhang (2003); Zhang (2005)] propose that growth options and assets-in-place have different systematic risk. Second, an increase (a decrease) in the event-firms' systematic risk may qualify any later found post-event long-term positive (negative) abnormal return. We estimate the changes in the factor-loadings of the Fama-French (1993) three-risk-factor model over one-, two- and three-years following the R&D discontinuation. Then, we estimate the R&D-discontinuation-induced change in the cost of equity by multiplying each of the changes in the risk-factor-loadings by the mean monthly realization of the corresponding risk factor over the sampling period and then summing up the three products. We find that none of the estimated changes in the event-firms' cost of equity is statistically significant at conventional levels.

We examine the long-term stock price performance of the sample firms over the first, second and third post-announcement years to determine whether investors' initial response is efficient.⁴ We use the Fama-French three-factor model for equally- and value-weighted event-portfolio returns and the ordinary- and weighted-least-squares (OLS and WLS) estimation methods, and we apply the bootstrapping procedure prescribed by Mitchell and Stafford (2000). We find statistically significant positive abnormal stock returns over only the first year following the disclosure of discontinuation of corporate R&D programs. This apparently robust one-year-

long price reversal (following the initial negative price response) is on the magnitude of 13.1 to 17.8 percent. However, before making a conclusion based on these results, the following evidence is worth noting.

Lev and Sougiannis (1999) report that the ratio of book-to-market value and the ratio of R&D capital-to-market value are both independently positively associated with subsequent stock returns; however, for R&D-intensive firms, the statistical significance of the book-to-market ratio vanishes with the introduction of the R&D-to-market-value ratio in regressions of subsequent stock returns. For this reason, we re-apply the bootstrapping procedure recommended by Mitchell and Stafford (2000), but we replace the size and book-to-market matching criteria by two other criteria: 1) industry affiliation and R&D-to-market-value ratio; and for additional robustness 2) industry affiliation and R&D-to-sales ratio (i.e., R&D intensity). We find that upon controlling for these risk dimensions for R&D-firms that are missing in the Fama-French three-factor model, the post-event one-year-long price reversal becomes statistically insignificant at conventional levels. This latter result is further corroborated from Fama-French regressions of the benchmark-adjusted monthly returns of the post-event one-year-rolling event-portfolio, with benchmark portfolios constructed by matching each event-firm with a non-event firm with the same industry affiliation and R&D-to-market-value ratio or with the same industry affiliation and R&D-to-sales ratio.

Finally, it may be that some of our sample firms are abandoning some of their R&D programs because they are compelled to reduce their cash payments; whereas, our other sample firms may be doing it mainly for investment-efficiency reasons. Accordingly, and to explore the evidence further, we examine the post-announcement long-term price drift in sub-samples defined by the appurtenance of the event-firm to the two-top versus two-bottom NYSE-quintiles

of ratio of earnings-before-interest-taxes-and-depreciation to total assets (EBITD/TA). We find no robust evidence of a post-event price drift in either sub-sample. Therefore, our evidence does not appear to change with the likely motivation of the R&D program discontinuation.

We believe that our paper makes an important contribution to the evidence on whether a free-market economy allocates resources into R&D efficiently. We examine the valuation and systematic risk effects of announcements of discontinuation of corporate R&D programs, which have not been examined in previous studies, despite the fact these decisions form an essential component of implementing efficiently the R&D strategy for a firm in the science and technology-based industries. Our study indicates that, upon controlling for the deficiency of the Fama-French three-factor model in pricing firms with R&D capital, there is no evidence that investors exhibit some cognitive bias when it comes to incorporating into stock prices the new information that is disclosed in announcements of discontinuation or abandonment of corporate R&D programs.⁵

The remainder of this paper is organized as follows. Section I describes the sample of announcements of discontinuation of corporate R&D programs. Section II analyzes the short-term stock price effects of these announcements. Section III examines the systematic risk effects. Section IV examines the post-event long-term stock price performance of the sample firms. Section V concludes the paper.

I. Sample

We used the *Dow Jones Factiva* computerized database and tried several key words to search for corporate announcements of discontinuation or abandonment of R&D programs, over the period from 1980 through 2004. Since an announcement is often times reported by several news media, we made sure that we have the date and source of the first public announcement of

the event. The *Dow Jones News Service*, *PR Newswire* or *Business Wire* are typically the first to report it. Following are examples of the type of announcements we looked for:

Atlantic Research halts work on PCB destruction process

Alexandria, VA -- Atlantic Research Corp. said it stopped work on the development of LARC, a patented process for the destruction of PCB's (Polychlorinated Biphenyls)... the company said it decided there was an inadequate market for the service...

Dow Jones News Service 31 May 1984 at 11:47 AM

Storage Technology to end optical disk drive project

Louisville, Colo. -- Storage Technology Corp. said it will discontinue development funding of its optical disk drive program, a \$100 million project that the company once considered a crucial element in its future product line... The cost to finish development of the disk drive and to begin manufacturing it by 1988 was too great and that the disks to store the data from the drive might not be available within a reasonable time... Storage Technology said it will continue to concentrate its research and development funding on its business in printers, tape, magnetic disk and solid-state disk storage subsystems.

Dow Jones News Service 24 December 1985 at 1:19 PM

Medco Research discontinues development of anti-arrhythmic drug NAPA

Research Triangle Park, NC -- Medco Research Inc. announced that it has discontinued further development of its anti-arrhythmic drug NAPA (N-Acetyl procainamide). Based on early results from a Phase 3 clinical trial, NAPA appears to provide no increased clinical benefit over currently marketed agents for use in preventing atrial arrhythmias... "The substantial costs saved by discontinuing this program can be redirected to development of our other products..." said Dr. Prestayko, president and chief executive officer.

Business Wire 10 December 1993 at 15:51 ET

We note that we found many cases of companies reporting write-offs of discontinued R&D programs in their quarterly financial disclosures without having publicly announced the discontinuation decision prior to the quarterly financial report.⁶ Clearly, without a specific announcement date, we cannot include these cases in our sample. We also note that public announcements of discontinuation or abandonment of R&D programs, often include a direct admission of the failure of the R&D program by using phrases such as: "unlikely successful development program," "lack of positive results" or "slow progress and high cost of R&D," etc. However, they also often include expressions or phrases such as: "to eliminate redundancy in R&D," "as part of re-focus strategy," "to re-prioritize R&D initiatives," "to trim non-core R&D," "re-allocate substantial cost savings," etc. These observations suggest that managers are reluctant

to disclose the type of event we examine, and if they disclose it, they often times use phrases which are apparently intended to soften the bad news to investors.

We had to exclude some of the relevant announcements that we had obtained, because they are contaminated by some other corporate events, or they pertain to firms that are not in the database of the Center for Research in Security Prices (CRSP). We also had to exclude all announcements made by a company within a three-year period following a similar announcement because we examine the post-announcement long-term abnormal returns. The resulting final sample of abandonment or discontinuation of corporate R&D programs consists of 218 announcements over the period from April 1982 through November 2004.

Panel A of Table I displays the distribution of the sample events by year of announcement. Most of the announcements pertain to the second half of the sampling period; although, we used the same keywords for each sampling year to search the *Dow Jones Factiva* database. Apparently, these types of voluntary disclosures of bad news were made less frequently in the 1980s. It may also be the result of many new technology-based firms getting listed on the stock exchanges during the 1990s. We also notice that over the sampling years the number of observations changes in a way that apparently mimics the general condition of the economy.

Panel B of Table I presents the distribution of the sample events over calendar months. We observe that the events in our sample do not cluster at times of disclosures of sales or earnings data at the end or beginning of a fiscal period, as is the case with announcements of corporate-wide R&D budgets. Therefore, they are less likely to be confounded than these latter announcements. In addition, they are less likely to be motivated by window dressing or earnings' management. This issue is important because several studies propose that R&D budgets at U.S.

companies are often reduced (increased) when they have downturns (upturns) in profitability [e.g. Hundley, Jacobson and Park (1996); Bange and De Bondt (1998)].⁷

Table II presents information on the characteristics of the sample firms. In Panel A, we follow Fama and French (1993) and Mitchell and Stafford (2000) by classifying each event-firm in our sample into a NYSE market capitalization quintile and a NYSE quintile of book-to-market value of equity ratio. These classifications provide good measures of the *relative* size and growth options of the sample firms, while controlling for the normal up-trend in the market capitalization of firms over time and for the effects of business cycles on security prices. We observe that about 63 percent of our sample announcements are made by firms in the lowest book-to-market quintile (i.e. firms with most / highest growth options). This clustering of events is a reflection of the underlying population of our sample. Companies that are significantly engaged in R&D investment, and therefore have some failures, typically have high growth opportunities. In terms of size representation, we observe that about 39 percent of the sample firms pertain to the smallest-size quintile and about 45 percent pertain to the largest-size quintile. Therefore, our sample includes some of the largest- and some of the smallest-firms in the U.S. stock markets.

In Panel B of Table 2, we classify our sample firms into NYSE quintiles of R&D expenditures to sales ratio (using data from fiscal year prior to event), R&D expenditures to market value ratio (this latter is measured at end of month prior to event), total debt-to-market-value ratio, and ratio of earnings before interest, taxes and depreciation (EBITD) to total assets (using data from fiscal year prior to event). These classifications show, respectively, the sample firms' R&D-investment intensity relative to other publicly traded firms, the stock market's relative valuation of the sample firms' R&D investment, the sample firms' relative indebtedness

or financial leverage, and the sample firms' relative asset productivity and internal cash flow generation.

As expected, we find that most of our sample firms invest in R&D intensively. About 86 percent of them belong to the quintile of the most R&D intensive firms. In terms of the R&D expenditures to market value ratio classification, we find that about 79 percent of our sample firms (58.13% + 20.69%) belong to the two top quintiles. This finding may reflect either investors' under-valuation of the R&D capital of these firms and / or the high risks associated with it. In terms of the debt ratio classification of these firms, about 79 percent (56.8% + 21.84%) of the sample firms belong to the two bottom debt-ratio quintiles. This finding is not surprising as firms with mostly intangible assets and growth opportunities typically have lower debt ratios than firms with mostly tangible assets, due to the typical asset-specificity of the former. In terms of the asset productivity or level of cash flows at these firms, about 43 percent of them are among the most productive / cash flow liquid NYSE firms and about 29 percent of them are among the least productive / cash flow liquid firms. Therefore, the R&D discontinuation decisions may be motivated by cash flow problems at some of our sample firms, and therefore, may be myopic or inefficient capital budgeting decisions.

In Panel C of Table II, we examine whether the sample firms had any significant change in their R&D-investment intensity over three or five years before the announcement of abandonment of some of their R&D programs. The purpose of this examination is to ensure that if there are any significant post-event long-term abnormal stock returns then these latter would not be the result of a change in their R&D intensity. Based on the *t*-test for mean differences, we find no evidence of a significant change in their R&D intensity over three or five years prior to the abandonment event.

In brief, the results of Table 2 indicate that our sample events do not represent the twenty-five size and book-to-market portfolios of Fama and French (1993) equally, and they are made by very R&D intensive firms with low valuation of their R&D capital (perhaps because of the risks involved). These sample-firm characteristics are important to recognize, since they raise the question of whether the Fama-French three-factor model can describe well the returns of our sample firms (or the sample firms of any study on R&D investment). We recognize this issue through the robustness tests we conduct later in the paper.

II. Analysis of the short-term stock price effects of R&D discontinuation announcements

A. Short-term stock price effects

We compute the short-term abnormal stock return for an event firm as the prediction error ε_{jt} in the market model: $R_{jt} = \alpha_j + \beta_j R_{mt} + \varepsilon_{jt}$ where R_{jt} and R_{mt} are respectively the continuously compounded rates of return to stock j and the value-weighted CRSP index over day t , and α_j and β_j are ordinary-least-squares (OLS) estimates. We use the period from day -331 through day -31 (relative to the initial announcement day 0) to estimate the parameters of the market model. We determine the statistical significance of each of the cumulative average abnormal returns (CAAR) using the parametric t -test, based on the cross-sectional standard deviation of the abnormal returns. We report the results in Panel A of Table III.

We find that investors are typically disappointed to learn the news of discontinuation of corporate R&D programs.⁸ The two-day announcement-period average abnormal return is on the magnitude of -4.44 percent, which is significant at the 1% level. This announcement-period abnormal return is not preceded by any significant abnormal return over thirty trading days before the announcement date, which suggests that these events are generally unanticipated. Also, the announcement-period abnormal return is not followed by any significant abnormal return over

the following thirty trading days. Therefore, these announcements resulted in immediate and *apparently* efficient revisions in investors' valuation of these firms.

The (absolute) magnitude of the average abnormal return is more pronounced than the one reported for increases in R&D investment. Chan, Martin, and Kensinger (1990) report an announcement-period average abnormal return of 1.38 percent in a sample of 95 announcements of plans to increase R&D expenditures over the 1979-1985 period. Szewczyk, Tsetsekos, and Zantout (1996) report an abnormal return of 0.477 percent in a sample of 252 announcements over the 1979-1992 period. The discontinuation of a corporate R&D program is evidently a much bigger surprise to investors than increments in R&D spending.

B. Cross-sectional regression analysis of the announcement-period abnormal returns

To further analyze investors' initial response to the R&D discontinuation announcements and the rationality thereof, we propose and test four hypotheses. First, investors' response should be more dramatic at firms whose market value is mostly derived from their technological assets / growth opportunities (as opposed to assets-in-place). Second, investors' response should be worse for firms with fewer R&D programs, i.e. smaller and perhaps less diversified portfolio of growth options.⁹ Third, investors' response should be worse if the R&D discontinuation decision is driven by the need to reduce cash payments instead of efficiency reasons. Fourth, investors' response to these firm-specific announcements should not be affected / biased by the condition of the stock market condition (for instance being worse during bear markets because of the general pessimism). We test these hypotheses by performing the following cross-sectional regression analysis:

$$CAR_j = \varphi_0 + \varphi_1 BM_j + \varphi_2 SIZE_j + \varphi_3 CASH_j + \varphi_4 MARKET_j + \delta_j$$

CAR_j is the cumulative two-day announcement-period abnormal return to event-firm j . BM_j is a categorical (integer) variable that represents the classification of the event-firm into a NYSE quintile of book-to-market value of equity ratio, it takes values ranging from 1 (for event firms in the smallest book-to-market ratio quintile) to 5 (for event firms in the largest book-to-market ratio quintile) and is used as a proxy for the firm's growth options. $SIZE_j$ is a categorical (integer) variable that represents the classification of each event-firm into a NYSE market capitalization quintile, it takes values ranging from 1 (for event firms in the smallest-size quintile) to 5 (for firms in the largest-size quintile) and is used as a proxy for the size of the firm's R&D portfolio. $CASH_j$ is a categorical (integer) variable that represents the classification of the event-firm into a NYSE quintile of EBITD/TA ratio, and it takes values ranging from 1 (for event firms in the lowest cash flow ratio quintile) to 5 (for firms in the highest cash flow ratio quintile). $MARKET_j$ is a categorical (integer) variable that represents the condition of the stock market during the announcement-month, and it takes a value of -1 if the variable market return minus the risk-free return (measured by the value-weighted CRSP index and the rate on the one-month U.S. Treasury bill, respectively) has in the announcement-month a value in the bottom one-third of its distribution (over our sampling period), it takes a value of 0 for the middle-third of its distribution, and a value of +1 for the top one-third of its distribution. $\varphi_0, \varphi_1, \varphi_2, \varphi_3$ and φ_4 are ordinary-least-squares (OLS) estimates. We determine the statistical significance of an estimated parameter using the White (1980) corrected t -statistic. The number of observations for the model is 204 due to some missing Compustat data. We report the regression results in Panel B of Table III.

We find that the above specified regression model is a good fit. The F -statistic is significant at the 1 percent level and the coefficient of determination (R^2) is close to 16 percent. The

intercept term is negative and statistically significant at the 1 percent level. We also find that the BM_j , $SIZE_j$ and $CASH_j$ attributes of the sample event-firms are the statistically significant factors in the model with the positive signs predicted by the above hypotheses. The condition of the stock market $MARKET_j$ is not a significant determinant of the two-day abnormal return CAR_j . Therefore, the two-day abnormal return is significantly worse for low book-to-market firms, worse for small-size firms, worse for firms with low cash flow, but unaffected by the condition of the stock market. These results indicate that investors' initial response to the R&D discontinuation announcements is consistent with rationality. However, we still need to examine the post-event effects before we can make a more affirmative statement about the efficiency of investors' initial response.

III. Systematic risk effects of discontinuation of corporate R&D programs

Gomes, Kogan and Zhang (2003), Zhang (2005) and Carlson, Fisher and Giammarino (2006) propose that investment-growth options and assets-in-place have different systematic risk. Accordingly, with assets-in-place the same, the abandonment of technology-growth options may change the systematic risk of our event-firms. We explore this possibility and test for any R&D-event-induced change in the systematic risk of our sample firms by using the following method.

If we set $R_{p,t}$ as the equally- or value-weighted return during month t of the portfolio comprised of sample-firms discontinuing R&D programs during the following n months, then $R_{p,t+n+1}$ is the return during month $t+n+1$ of the portfolio comprised of sample firms that discontinued R&D programs during the preceding n months, with $n = 12, 24$ or 36 and $t = -n$ before the chronologically earliest sample case to -1 before the chronologically latest sample case in our sample. The value-weighted portfolio returns are based on the market values of the firms in the rolling portfolio as of the end of the month before the announcement date.

Using the Fama and French (1993) three-factor model, we can then model:

$$R_{p,t} - R_{f,t} = \alpha_{preevent} + \beta_{m,preevent} (R_{m,t} - R_{f,t}) + \beta_{s,preevent} SMB_t + \beta_{h,preevent} HML_t + \varepsilon_t \quad \text{and}$$

$$R_{p,t+n+1} - R_{f,t+n+1} = \alpha_{post} + \beta_{m,post} (R_{m,t+n+1} - R_{f,t+n+1}) + \beta_{s,post} SMB_{t+n+1} + \beta_{h,post} HML_{t+n+1} + \varepsilon_{t+n+1}$$

where R_{ft} is the one-month U.S. Treasury bill rate in month t , $R_{m,t}$ is the return on the value-weighted CRSP index in month t , SMB_t is the difference between the returns on portfolios of small and big stocks (below or above the NYSE median value) with about the same weighted average book-to-market value of equity ratio in month t , and HML_t is the difference between the returns on portfolios of high and low book-to-market value of equity ratio (above and below the 0.7 and 0.3 fractiles) with about the same weighted average size in month t .

If $\alpha_{post} = \alpha_{preevent} + \alpha_{\Delta}$; $\beta_{m,post} = \beta_{m,preevent} + \beta_{m,\Delta}$; $\beta_{s,post} = \beta_{s,preevent} + \beta_{s,\Delta}$; and $\beta_{h,post} = \beta_{h,preevent} + \beta_{h,\Delta}$ then by subtracting from each post-R&D-event rolling-portfolio calendar-month excess return the corresponding pre-event calendar-month excess return, we obtain the following model:

$$\begin{aligned} R_{p,t+n+1} - R_{f,t+n+1} - (R_{p,t} - R_{f,t}) &= \alpha_{\Delta} + \beta_{m,preevent} [R_{m,t+n+1} - R_{f,t+n+1} - (R_{m,t} - R_{f,t})] + \beta_{m,\Delta} (R_{m,t+n+1} - R_{f,t+n+1}) \\ &+ \beta_{s,preevent} (SMB_{t+n+1} - SMB_t) + \beta_{s,\Delta} SMB_{t+n+1} + \beta_{h,preevent} (HML_{t+n+1} - HML_t) + \beta_{h,\Delta} HML_{t+n+1} + \varepsilon_{\Delta} \end{aligned}$$

We estimate α_{Δ} , $\beta_{m,\Delta}$, $\beta_{s,\Delta}$ and $\beta_{h,\Delta}$ using the ordinary- and the weighted-least-squares procedures (OLS and WLS). The WLS model weighs each difference in the calendar months returns with the square root of the number of firms.

We compute the R&D-discontinuation-induced change in the cost of equity (required return) by multiplying each of the changes in the risk-factor-loadings (i.e., $\beta_{m,\Delta}$, $\beta_{s,\Delta}$ and $\beta_{h,\Delta}$) by the mean monthly realization of the corresponding risk factor (i.e., mean of $(R_{m,t} - R_{f,t})$, mean of SMB_t and mean of HML_t) over the sample period and then summing up the three products. We determine the statistical significance of the change in the cost of equity by running the above

rolling-portfolio pre- versus post-return difference regression with the following linear restriction:

$$\beta_{m,\Delta} [\text{mean of } (R_{m,t} - R_{f,t})] + \beta_{s,\Delta} [\text{mean of SMB}_t] + \beta_{h,\Delta} [\text{mean of HML}_t] = 0$$

With reference to Table IV, we find that the mean monthly change in the required return on equity is not statistically significant at any conventional level during any of the first, second or third post-event years. Additionally, even the magnitude and sign of the mean monthly change are not robust to using equal- versus value-weighting and OLS versus WLS estimation. These results indicate that there is no significant change in the cost of equity (or systematic risk) of the sample R&D-abandoning firms. We examine next the post-event long-term price drift.

IV. Long-term stock performance following discontinuation of corporate R&D programs

A. Post-event long-term abnormal stock returns

We estimate the post-announcement long-term abnormal common stock returns for the R&D-abandoning firms using the rolling portfolio method, which Fama (1998) and Mitchell and Stafford (2000) recommend. Specifically, for every calendar month, we compute the equally- and value-weighted returns on the portfolio which contains all firms which discontinued some R&D program(s) during the preceding 1 to 12, 13 to 24, or 25 to 36 calendar months. We use both equally- and value-weighted returns because Fama (1998) favors using the latter, but Loughran and Ritter (2000) show that these latter tend to under-estimate the abnormal return. We examine each the abnormal return in each post-event year separately because Fama (1998) points out correctly that an initial abnormal return can grow with the investment horizon even if there is no abnormal return after the initial period. We compute the value-weighted returns using the market values of the firms in the rolling portfolio as of the end of the month before the announcement

date as the weighing vector. We apply the corrections of Shumway (1997) and Shumway and Warther (1999) for delisted firms.

Then, we use the computed calendar-time event-portfolio returns in the following Fama and French (1993) three-factor model to estimate the “raw” abnormal return of the rolling portfolio:¹⁰

$$R_{pt} - R_{ft} = \alpha + \beta_m (R_{mt} - R_{ft}) + \beta_s SMB_t + \beta_h HML_t + \phi_t$$

where R_{pt} , R_{ft} , R_{mt} , SMB_t , HML_t are defined earlier and α , β_m , β_s and β_h are either OLS or WLS estimates. The intercept α is considered the average “raw” abnormal monthly return of the event-portfolio across the first-, second- or third-year following the event. The weights we use in the WLS model are equal to the square root of the number of event firms in the monthly portfolio. For the reader’s convenience, we transform the raw monthly abnormal stock returns to cumulative compounded abnormal returns (CCAR) over the first-, second-, and third-year following the R&D discontinuation announcement by applying the following formula: $100 * [(1 + \alpha)^{12} - 1]$. The results are reported in Table V.

We find some evidence of a positive price drift over the first-year following the R&D discontinuation. The equally-weighted portfolios exhibit a significant positive price drift on the magnitude of 13.96 to 16.72 percent. However, the value-weighted portfolios do not exhibit significant results. This asymmetry in the results between the equally- versus value-weighted portfolios is interesting. It suggests that small-size firms experience a price reversal following the initial negative reaction, but large size firms do not experience a similar reversal. Yet, none of the investor cognitive biases modeled in the area of behavioral finance [e.g., Daniel, Hirshleifer and Subrahmanyam (1998); Odean (1998); Barberis, Shleifer and Vishny (1998); Hong and Stein (1999); and Grinblatt and Han (2005)] should lead to such asymmetric results for large- versus small-size firms.

B. Adjusting the abnormal returns using Mitchell and Stafford's (2000) procedure

Fama and French (1993) and Mitchell and Stafford (2000) show that the three-factor model does not explain well the cross-sectional variation of stock returns for low book-to-market and small-size firms.¹¹ This observation is particularly important to note in this study (and very likely in any study using a sample of R&D firms) since about 63 percent of our sample firms are in the lowest book-to-market quintile. It follows that since our sample is tilted toward characteristics that the three-factor model cannot price in the first place, then the null hypothesis of zero α may be inappropriate.

Mitchell and Stafford (2000) recommend a correction for this pricing deficiency. They prescribe a bootstrapping procedure that is similar to the one used by Brock, Lakonishok and LeBaron (1992) and Ikenberry, Lakonishok and Vermaelen (1995). Specifically, they recommend the decomposition of the intercept α into two parts: 1) the expected abnormal performance, given the sample composition (i.e. size and book-to-market portfolio classification and calendar time frequency); and 2) the amount of abnormal performance attributable to other sources, including the event being examined. Accordingly, we estimate the expected intercept, given the attributes of our sample, as the mean intercept from 1,000 calendar-time portfolio regressions of random samples of otherwise similar non-event firms. Each of the 1,000 random samples has the same calendar-time frequency, and at each point in time, the portfolio of randomly selected firms has the same size and book-to-market composition as the corresponding event portfolio. The difference between the estimated (raw) intercept and the expected intercept is the adjusted intercept and the new t -statistic is calculated using this difference and the original standard error estimate.

With reference to Table V, we find that after applying the procedure of Mitchell and Stafford (2000), our sample firms apparently experience a significant *positive* abnormal return over one-year following the R&D discontinuation announcement. The adjusted cumulative compounded abnormal return (Adjusted CCAR) is estimated at about 13.11 to 17.83 percent. While the magnitude of that positive price drift is different for equally- versus value-weighted portfolios and using the OLS versus WLS procedures, it is statistically significant at the 5 percent level or better in all cases. There is no robust evidence of an abnormal price drift over the second or third year. The announcement-period negative price response followed by the post-announcement one-year-long price reversal may represent evidence of investor mis-reaction to the news, which is slowly corrected after the disclosure. However, before making such a conclusion, we perform an important additional robustness test.

C. Recognizing missing risk factors for R&D firms

The procedure prescribed by Mitchell and Stafford (2000) may not correct for missing risk dimensions in the three-factor model when applied to R&D firms. By adjusting the intercepts obtained from this model with the expected intercepts from 1,000 calendar-time portfolio regressions of random samples of “*otherwise similar*” non-event firms, an assumption is implicitly made that the randomly selected firms with the same size and book-to-market characteristics as the event firms must also have the same unidentified risk dimensions. However, this assumption is unwarranted. Accordingly, we propose that the random samples of “*otherwise similar*” non-event firms would be more likely similar if they have either the same industry affiliation and R&D-to-market-value ratio or the same industry affiliation and R&D-intensity ratio as the event-firms.

We propose the industry affiliation as a matching criterion because different industries have different sets of technological opportunities. Also, firms in the same industry must have similar exposure to the general macro-economic factors that impact that industry. We propose the ratio of R&D-expenditures-to-market-value of equity as a matching criterion because not all R&D investment is equally risky. Firms with a high ratio of R&D-to-market-value may be engaged in riskier R&D programs than firms with a low ratio. Additionally, Lev and Sougiannis (1999) provide robust evidence that the ratio of book-to-market and the ratio of R&D-to-market-value are both independently positively associated with subsequent returns (see Table 2 on page 429); however, for R&D-intensive firms (i.e. with a high R&D capital to total assets ratio), the statistical significance of the book-to-market ratio vanishes with the introduction of the R&D-to-market-value ratio in regressions of subsequent stock returns (see Table 3 on page 432).¹² Finally, we propose the R&D-intensity of the event-firm as one of the matching criteria because it is widely used by scholars in Strategic Management to proxy for several industry and firm specific characteristics. For instance, two firms with similar R&D-intensity may have similar risk attributes for a number of reasons: they may have a similar capital structure because of the specificity of R&D assets; they may have a similar level of diversification of R&D portfolio; and they may have similar market shares / market power [see Reinganum (1983, 1985); Rosenberg (1976); and Schumpeter (1942)].

We re-estimate the expected intercept as the mean intercept from 1,000 calendar-time portfolio regressions of random samples of non-event firms that have the same calendar-time frequency, and at each point in time, they have the same industry affiliation (as determined by the two-digit Standard Industry Classification (SIC) code) and R&D-to-market-value ratio (i.e. R&D expenditures of preceding year divided by the market value of equity as of end of month before

the event) or the same industry affiliation and R&D-intensity (i.e. the ratio of R&D expenditures divided by total sales in the year before the event). Then, we obtain the adjusted one-year-long post-announcement cumulative compounded abnormal returns. Adjusted2A CCAR is obtained using the criteria industry affiliation and R&D-to-market-value ratio, and Adjusted2B CCAR is obtained using the criteria industry affiliation and R&D-to-sales ratio. We focus on the one-year-long post-event period because the results in Table V indicate no abnormal returns over other periods. We report the results in Panel A of Table VI.

For additional robustness, we apply another (but somewhat similar) procedure to account for possibly missing risk-dimensions in the three-factor model when applied to R&D firms. We match each sample-firm with a non-event firm that has the same industry affiliation and R&D-to-market ratio and with another non-event firm that has the same industry affiliation and R&D-intensity ratio. Next, we compute the monthly returns of the one-year rolling non-event benchmark portfolios, and finally, we estimate the parameters of the following regression model:

$$R_{pt} - R_{bt} = \alpha_d + \beta_{md} (R_{mt} - R_{ft}) + \beta_{sd} SMB_t + \beta_{hd} HML_t + \eta_t$$

where R_{pt} is the monthly return of the post-event one-year rolling event-portfolio, R_{bt} is the monthly return of the corresponding one-year rolling (non-event) benchmark-portfolio, R_{mt} , R_{ft} , SMB_t , and HML_t are defined earlier, and α_d , β_{md} , β_{sd} , and β_{hd} are either OLS or WLS estimates. We report the results in Panel B of Table VI. Adjusted3A CCAR pertains to the matching criteria industry affiliation and R&D-to-market-value ratio, and Adjusted3B CCAR pertains to the matching criteria industry affiliation and R&D-to-sales ratio. We find that the results in Panels A and B of Table VI are consistent. None of the adjusted one-year-long cumulative compounded abnormal returns is statistically significant at conventional levels.

Therefore, the evidence from Table V disappears when we control for the industry affiliation and either R&D-to-market value or R&D-intensity attributes of our sample firms.

In brief, our long-term event-study indicates the following. First, the (raw) post-announcement one-year-long abnormal common stock returns obtained from the three-factor model are significant in the case of equal-weighting but not in the case of value-weighting. Yet, none of the investor cognitive biases proposed in the behavioral models predict such an asymmetric response to a corporate disclosure between large- and small-size firms. Second, the results obtained from the bootstrapping procedure of Mitchell and Stafford (2000) indicate a significant positive one-year-long price reversal following the initial negative response. However, the application of this procedure implicitly assumes that the randomly chosen non-event firms with the same size and book-to-market characteristics are in fact similar in terms of potentially missing risk-factors, which is not a warranted assumption. When we use industry affiliation and the ratio of R&D-to-market value or industry affiliation and the ratio of R&D-to-sales as matching criteria, the post-event price drift disappears.¹³ These results lead us to conclude that there is no robust evidence of a post-R&D-abandonment long-term abnormal return. The announcement-period abnormal common stock returns are apparently unbiased revisions in investors' expectations regarding our sample firms.

D. Results by sub-samples defined by operating cash flow of event-firm

About 43 percent of our sample firms are among the most productive / cash flow liquid NYSE firms and about 29 percent of them are among the least productive / cash flow liquid firms. It follows that these latter may be abandoning some of their R&D programs because they are compelled to reduce their cash payments; whereas, the former may be doing it mainly for investment-efficiency reasons. Accordingly, and to explore the evidence further, we examine the

post-announcement long-term price drift in sub-samples defined by the appurtenance of the event-firm to the two-top versus two-bottom NYSE-quintiles of ratio of earnings-before-interest-taxes-and-depreciation to total assets (EBITD/TA). We report in Table VII the raw abnormal return obtained from the Fama-French three-factor model, the adjusted abnormal return following the procedure of Mitchell and Stafford (2000), and the adjusted abnormal returns estimated using the matching criteria we propose above. Again, we find no robust evidence of a post-event price drift in either sub-sample. Therefore, our evidence does not appear to change with the likely motivation of the R&D program discontinuation.

V. Summary and discussion

In this paper, we extend the empirical evidence on the question of whether investors in the U.S. capital markets value efficiently the R&D capital of firms in the science- and technology-based industries. This question is important because any evidence of under- or over-valuation would mean inefficient allocation of capital into corporate R&D. Yet, the empirical evidence provided by the studies of Chan, Lakonishok and Sougiannis (2001), Chambers, Jennings and Thompson (2002), and Eberhart, Maxwell and Siddique (2004) does not lead to a clear unanimous conclusion.

We show that investors' initial response to announcements of discontinuation of corporate R&D programs is consistent with rationality. It is negative and worse for lower book-to-market ratio firms, whose growth opportunities constitute a more significant part of their market value. It is also more severe for smaller size firms, which due to their size must have fewer R&D programs. Moreover, it is worse for firms which may be compelled to eliminate R&D programs because of cash flow constraints as opposed to efficiency reasons. Furthermore, it is not influenced (or biased) by the condition of the stock market.

In terms of long-term effects, we find no evidence of an event-induced change in the sample firms' systematic risk. Additionally, we show that any evidence of a post-event long-term abnormal return is fragile, in that it disappears when we apply reasonable changes to the method of estimating long-term abnormal returns, and therefore, not robust enough to suggest a pricing anomaly or reject the 'rational expectations' hypothesis in our sample. These "reasonable" changes to the method of estimating long-term abnormal returns to firms with R&D capital are based on robust evidence provided by Lev and Sougiannis (1999) that indicate some deficiency in the Fama-French three-factor model in pricing firms with R&D capital. In fact, Fama and French (1993) and Mitchell and Stafford (2000) show that the three-factor model does not explain well the cross-sectional variation of stock returns for low book-to-market and small-size firms.

An important empirical implication of our study is that there is clear need to identify and validate one or more additional risk factor(s) that can complement the Fama-French risk factors in explaining the returns to firms in the science- and technology-based industries (i.e. firms with R&D capital and other intangible assets). We find that even the bootstrapping procedure prescribed by Mitchell and Stafford (2000) to adjust the abnormal returns or intercepts obtained from the Fama-French three-factor model, and which is expected to correct for any tilting in the sample toward characteristics that this model cannot price in the first place, does not adequately compensate for the inability of the size and book-to-market factors to fully capture the risks and growth opportunities of R&D intensive firms. Based on our results and the evidence provided by Lev and Sougiannis (1999), the R&D to market value ratio may be a good starting point. We hope future research will address this important issue.

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Table I
Description of the Sample of Announcements of Discontinuation of Corporate R&D Programs

The sample of discontinuation or abandonment of R&D programs consists of 218 initial non-contaminated public announcements made in the period from April 1982 through November 2004 by NYSE, Amex and Nasdaq listed firms with sufficient data on the database of the Center for Research in Security Prices (CRSP). When a firm has more than one announcement of discontinuation of R&D program(s) in any three-year period, only the earliest one is included in the sample. The sample firms represent 61 different four-digit Standard Industry Classification (SIC) industries.

Panel A: Chronological distribution of the sample of discontinuation or abandonment of R&D programs								
Year	Number of events	Percent of sample	Year	Number of events	Percent of sample	Year	Number of events	Percent of sample
1982	2	0.92	1990	3	1.38	1998	24	11.01
1983	3	1.38	1991	10	4.59	1999	21	9.63
1984	4	1.83	1992	14	6.42	2000	14	6.42
1985	7	3.21	1993	11	5.05	2001	10	4.59
1986	3	1.38	1994	13	5.96	2002	9	4.13
1987	3	1.38	1995	16	7.34	2003	11	5.05
1988	7	3.21	1996	8	3.67	2004	5	2.29
1989	4	1.83	1997	16	7.34			
Total for all years							218	100.00%

Panel B: Frequency distribution of sample R&D program discontinuation announcements in a calendar month													
Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Number of events	20	11	23	15	16	9	25	11	24	15	25	24	218
Percent of sample	9.17	5.05	10.55	6.88	7.34	4.13	11.47	5.05	11.01	6.88	11.47	11.01	100.00%

Table II
Characteristics of Firms which Discontinue some of their R&D Programs

This table classifies the sample R&D firms into NYSE quintiles defined by market capitalization, ratio of book-to-market value of equity (B/M), R&D-to-sales ratio (R&D intensity), R&D-to-market-value ratio, total-debt-to-market-value ratio, and earnings-before-interest-taxes-and-depreciation to total assets ratio (EBITD/TA). Missing Compustat data for some of the sample firms reduce the number of observations in Panels A and B. Panel C examines any pre-event change in the sample firms' R&D intensity.

Panel A: Size and book-to-market ratio distributions of the sample R&D discontinuing firms							
	Lowest B/M quintile	Second quintile	Third quintile	Fourth quintile	Highest B/M quintile	Total	Percent of sample
Smallest-firms quintile	33	13	8	8	20	82	38.68
Second size quintile	8	2	3	0	0	13	6.13
Third size quintile	4	2	2	1	1	10	4.72
Fourth size quintile	8	0	1	1	1	11	5.19
Largest-firms quintile	80	8	1	5	2	96	45.28
Total	133	25	15	15	24	212	100.00%
Percent of sample	62.74	11.79	7.08	7.08	11.32	100.00%	

Panel B: R&D intensity, R&D valuation, leverage and cash flow characteristics of the R&D discontinuing firms						
Firm characteristic	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile	Total
R&D-to-sales ratio (from low to high intensity)	0	4	6	18	169	197
Percent of sample	0.00%	2.03%	3.05%	9.14%	85.79%	100.00%
R&D-to-market-value ratio (from low to high)	0	10	33	42	118	203
Percent of sample	0.00%	4.93%	16.26%	20.69%	58.13%	100.00%
Total-debt-to-market-value ratio (from low to high)	117	45	22	11	11	206
Percent of sample	56.80%	21.84%	10.68%	5.34%	5.34%	100.00%
EBITD/TA ratio (from low to high cash flow)	61	18	10	28	90	207
Percent of sample	29.47%	8.70%	4.83%	13.53%	43.48%	100.00%

Panel C: Pre-event change in the R&D intensity of the sample R&D discontinuing firms			
Year relative to event-year	Year -6	Year -4	Year -1
Sample mean R&D intensity	4.12%	4.19%	5.33%
t-test statistic for mean difference compared to pre-event year	[0.36]	[0.34]	

Table III
Analysis of the Two-Day Announcement-Period Abnormal Stock Price Performance
of Firms which Discontinue some of their R&D Programs

The short-term abnormal stock return for a firm discontinuing or abandoning some of its R&D programs is the prediction error ε_{jt} in the market model: $R_{jt} = \alpha_j + \beta_j R_{mt} + \varepsilon_{jt}$ where R_{jt} and R_{mt} are respectively the continuously compounded rates of return to stock j and the value-weighted CRSP index over day t , and α_j and β_j are ordinary-least-squares (OLS) estimates. The parameters' estimation period is day -331 through day -31 relative to the initial announcement date. The statistical significance of each of the cumulative average abnormal returns (CAAR) in Panel A is determined using the parametric t -test, based on the cross-sectional standard deviation of the abnormal returns. In Panel B, the two-day announcement-period cumulative abnormal returns CAR_j to the event-firms are regressed on four factors: $CAR_j = \varphi_0 + \varphi_1 BM_j + \varphi_2 SIZE_j + \varphi_3 CASH_j + \varphi_4 MARKET_j + \delta_j$ where BM_j is a categorical (integer) variable that represents the classification of the event-firm into a NYSE quintile of book-to-market value of equity ratio, and it takes values ranging from 1 (for event firms in the smallest book-to-market ratio quintile) to 5 (for event firms in the largest book-to-market ratio quintile); $SIZE_j$ is a categorical (integer) variable that represents the classification of the event-firm into a NYSE market capitalization quintile, and it takes values ranging from 1 (for event firms in the smallest-size quintile) to 5 (for firms in the largest-size quintile); $CASH_j$ is a categorical (integer) variable that represents the classification of the event-firm into a NYSE quintile of EBITD/TA ratio, and it takes values ranging from 1 (for event firms in the lowest cash flow ratio quintile) to 5 (for firms in the highest cash flow ratio quintile); $MARKET_j$ is a categorical (integer) variable that represents the condition of the stock market during the announcement-month, and it takes a value of -1 if the variable market return minus the risk-free return (measured by the value-weighted CRSP index and the rate on the one-month U.S. Treasury bill, respectively) has in the announcement-month a value in the bottom one-third of its distribution (over our sampling period), it takes a value of 0 for the middle-third of its distribution, and a value of +1 for the top one-third of its distribution; and $\varphi_0, \varphi_1, \varphi_2, \varphi_3$ and φ_4 are ordinary-least-squares (OLS) estimates. The statistical significance of each of the estimated parameters is determined using the White (1980) corrected t -statistic. The number of observations for the model is 204 due to some missing Compustat data. ***, **, and * denote significance at the 1, 5 and 10 percent levels, respectively in a two-tailed test.

Panel A: Short-term stock price effects of discontinuation or abandonment of corporate R&D programs				
Statistic	Period relative to the announcement date			
	Day -30 to day -1	Day 0 to day +1	Day +2 to day +30	
CAAR	-1.54%	-4.44%	1.04%	
[t -statistic]	[-1.01]	[-4.25***]	[0.77]	
% of negative CAR	52.7%	61.3%	46.3%	

Panel B: Regression analysis of the two-day event-period abnormal stock returns to R&D discontinuing firms								
	<i>Intercept</i>	<i>BM_j</i>	<i>SIZE_j</i>	<i>CASH_j</i>	<i>MARKET_j</i>	<i>R</i> ² (%)	<i>F</i>	<i>N</i>
Parameter estimate	-22.49	2.30	2.57	1.47	0.85	15.67%	5.85***	204
[t -statistic]	[-4.85***]	[3.00***]	[3.76***]	[1.96**]	[0.72]			

Table IV
Change in the Systematic Risk or Cost of Equity of Firms that Discontinue some of their R&D programs

This table is motivated by the argument that the discontinuation of some R&D programs (growth options) may result in changes in the systematic risk attributes, and therefore, the expected returns of the sample firms. Setting $R_{p,t}$ as the equally- (or value-) weighted return during month t of the portfolio comprised of sample firms discontinuing R&D programs during the following n months, then $R_{p,t+n+1}$ is the equally- (or value-) weighted return during month $t+n+1$ of the portfolio comprised of sample firms that discontinued R&D programs during the preceding n months, with $n = 12, 24$ or 36 and $t = -n$ before the chronologically earliest sample case to -1 before the chronologically latest sample case in our sample. Using the Fama and French (1993) three-factor model, we can then model:

$$R_{p,t} - R_{f,t} = \alpha_{preevent} + \beta_{m,preevent} (R_{m,t} - R_{f,t}) + \beta_{s,preevent} SMB_t + \beta_{h,preevent} HML_t + \varepsilon_t \text{ and}$$

$$R_{p,t+n+1} - R_{f,t+n+1} = \alpha_{post} + \beta_{m,post} (R_{m,t+n+1} - R_{f,t+n+1}) + \beta_{s,post} SMB_{t+n+1} + \beta_{h,post} HML_{t+n+1} + \varepsilon_{t+n+1}$$

If $\alpha_{post} = \alpha_{preevent} + \alpha_{\Delta}$; $\beta_{m,post} = \beta_{m,preevent} + \beta_{m,\Delta}$; $\beta_{s,post} = \beta_{s,preevent} + \beta_{s,\Delta}$; and $\beta_{h,post} = \beta_{h,preevent} + \beta_{h,\Delta}$ then,

$$R_{p,t+n+1} - R_{f,t+n+1} - (R_{p,t} - R_{f,t}) = \alpha_{\Delta} + \beta_{m,preevent} [R_{m,t+n+1} - R_{f,t+n+1} - (R_{m,t} - R_{f,t})] + \beta_{m,\Delta} (R_{m,t+n+1} - R_{f,t+n+1})$$

$$+ \beta_{s,preevent} (SMB_{t+n+1} - SMB_t) + \beta_{s,\Delta} SMB_{t+n+1} + \beta_{h,preevent} (HML_{t+n+1} - HML_t) + \beta_{h,\Delta} HML_{t+n+1} + \varepsilon_{\Delta}$$

where $R_{f,t}$ is the one-month U.S. Treasury bill rate in month t , $R_{m,t}$ is the return on the value-weighted CRSP index in month t , SMB_t is the difference between the returns on portfolios of small and big stocks with about the same weighted average book-to-market value of equity ratio in month t , and HML_t is the difference between the returns on portfolios of high and low book-to-market value of equity ratio with about the same weighted average size in month t . We estimate α_{Δ} , $\beta_{m,\Delta}$, $\beta_{s,\Delta}$ and $\beta_{h,\Delta}$ using the ordinary- and the weighted-least-squares procedures (OLS and WLS). The WLS model weighs each difference in the calendar months returns with the square root of the number of firms. The value-weighted portfolio returns are based on the market values of the firms in the rolling portfolio as of the end of the month before the announcement date. We estimate the R&D-discontinuation-induced change in the cost of equity (required return) by multiplying each of the risk-change factor-loadings (i.e., $\beta_{m,\Delta}$, $\beta_{s,\Delta}$ and $\beta_{h,\Delta}$) by the mean monthly realization of the corresponding risk factor (i.e., mean of $(R_{m,t} - R_{f,t})$, mean of SMB_t and mean of HML_t) over the sample period and then summing up the three products. The statistical significance of the change in the cost of equity is determined by running the above rolling-portfolio pre- versus post-return difference regression with the linear restriction that the sum of the products of the risk-change factor-loadings by the corresponding mean monthly realizations of the risk-factors is equal to zero. ***, **, and * denote significance at the 1, 5 and 10 percent levels, respectively, in a two-tailed t -test.

Pre- versus post-event period	Event portfolio return	Mean monthly change in cost of equity (%) [t -statistic]	
		OLS model	WLS model
One year	Equally-weighted	-0.308% [-1.10]	-0.389% [-1.45]
	Value-weighted	0.092% [0.36]	0.275% [1.10]
Two years	Equally-weighted	-0.450% [-0.96]	-0.530% [-1.09]
	Value-weighted	-0.098% [-0.33]	-0.036% [-0.12]
Three years	Equally-weighted	-0.007% [-0.02]	-0.004% [-0.01]
	Value-weighted	-0.295% [-1.03]	-0.313% [-1.32]

Table V

Post-Event Raw and Adjusted Cumulative Compounded Abnormal Stock Returns to Firms that Discontinue some of their R&D programs

To estimate the first- second- and third-year post-announcement raw abnormal monthly returns, each calendar month sample firms which discontinued or abandoned some of their R&D programs in the preceding 1 to 12, 13 to 24, or 25 to 36 months are identified and then equally- and value-weighted average monthly returns are calculated for these firms. The corrections of Shumway (1997) and Shumway and Warther (1999) for delisted firms are applied. The value-weighted returns are based on the market values of the firms in the rolling portfolio as of the end of the month before the announcement date. The monthly event portfolio returns R_{pt} are then used in the Fama and French (1993) model: $R_{pt} - R_{ft} = \alpha + \beta_m (R_{mt} - R_{ft}) + \beta_s SMB_t + \beta_h HML_t + \phi_t$ where R_{ft} is the one-month U.S. Treasury bill rate in month t , $R_{m,t}$ is the return on the value-weighted CRSP index in month t , SMB_t is the difference between the returns on portfolios of small and big stocks with about the same weighted average book-to-market value of equity ratio in month t , HML_t is the difference between the returns on portfolios of high and low book-to-market value of equity ratio with about the same weighted average size in month t , and α , β_m , β_s , and β_h are either ordinary- or weighted-least-squares estimates (OLS or WLS). The WLS model weighs each calendar month portfolio return with the square root of the number of firms for that month. The intercept α is considered the raw average abnormal monthly return of the event-portfolio over the first, second or third post-event year. We examine the abnormal stock return in each post-event year separately because Fama (1998) argues correctly that an initial abnormal return can grow with the investment horizon even if there is no abnormal return after the initial period. Since an R&D sample may be tilted toward characteristics that the Fama & French model cannot price, and since Fama (1998) argues correctly that all models for expected returns are incomplete descriptions of the systematic patterns in average returns during any sample period, then the null hypothesis of zero α may be inappropriate. Accordingly, we compute the adjusted abnormal returns using the bootstrapping procedure recommended by Mitchell and Stafford (2000). We estimate the expected intercept, given the attributes of our sample, as the mean intercept from 1,000 calendar-time portfolio regressions of random samples of otherwise similar non-event firms. Each of the 1,000 random samples has the same calendar-time frequency, and at each point in time, the portfolio of randomly selected firms has the same size and book-to-market composition as the corresponding event portfolio. The adjusted intercept is the difference between the estimated and expected intercepts. The new t -statistic is calculated using this difference and the original standard error estimate. The raw and adjusted intercepts are compounded using the formula: $100*[(1+\alpha)^{12}-1]$ to obtain the cumulative compounded abnormal return (CCAR) over the first, second, or third post-event year. The results using the Carhart (1997) model are similar, and they are readily available from the authors. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively in a two-tailed t -test.

Event portfolio return	Parameters' estimation method	First post-event year		Second post-event year		Third post-event year	
		Raw CCAR [t -statistic]	Adjusted CCAR [t -statistic]	Raw CCAR [t -statistic]	Adjusted CCAR [t -statistic]	Raw CCAR [t -statistic]	Adjusted CCAR [t -statistic]
Equally-weighted	OLS	13.96% [2.21**]	15.76% [2.48**]	31.33% [1.55]	31.22% [1.55]	12.63% [1.42]	-2.88% [-0.34]
	WLS	16.72% [2.61***]	17.83% [2.77***]	46.05% [1.95*]	44.02% [1.88*]	15.69% [1.69*]	-5.82% [-0.69]
Value-weighted	OLS	1.32% [0.24]	13.11% [2.32**]	5.49% [1.03]	7.95% [1.48]	-9.20% [-1.63]	-5.16% [-0.89]
	WLS	1.23% [0.23]	15.99% [2.86***]	6.94% [1.30]	10.40% [1.91*]	-7.14% [-1.22]	-2.60% [-0.44]

Table VI
Additional Robustness Tests for the Post-Announcement One-Year-Long Abnormal Stock Return to Firms that Discontinue some of their R&D programs

Given that the risk factors in the model of Fama and French (1993) may not capture all the risk attributes of R&D firms, we perform two robustness tests. First, we re-apply in Panel A the bootstrapping procedure recommended by Mitchell and Stafford (2000), but we replace the size and book-to-market matching criteria by two other criteria: 1) industry affiliation (i.e., the two-digit SIC code) and R&D-to-market-value ratio to obtain Adjusted2A CCAR; and 2) industry affiliation and R&D-to-sales ratio to obtain Adjusted2B CCAR. Second, we apply in Panel B the following regression model: $R_{pt} - R_{bt} = \alpha_d + \beta_{md} (R_{mt} - R_{ft}) + \beta_{sd} SMB_t + \beta_{hd} HML_t + \eta_t$ where R_{pt} is the monthly return of the post-event one-year rolling event-portfolio, R_{bt} is the monthly return of the corresponding one-year rolling (non-event) benchmark-portfolio, R_{mt} , R_{ft} , SMB_t and HML_t are defined earlier, and α_d , β_{md} , β_{sd} and β_{hd} are either OLS or WLS estimates. Benchmark portfolios are constructed by matching each event-firm with a non-event firm with the same industry affiliation and R&D-to-market-value ratio or with the same industry affiliation and R&D-to-sales ratio. The intercept α_d using the first (second) benchmark criteria is compounded using the formula: $100 * [(1 + \alpha_d)^{12} - 1]$ to obtain Adjusted3A CCAR (Adjusted3B CCAR) over the first post-event year. The results using the Carhart (1997) model are all similar, and they are readily available from the authors. ***, **, and * denote significance at the 1, 5 and 10 percent levels, respectively in a two-tailed test.

Panel A: Results from the modified bootstrapping procedure of Mitchell and Stafford (2000)			
Event portfolio return	Parameters' estimation method	Adjusted2A CCAR [t- statistic]	Adjusted2B CCAR [t- statistic]
Equally-weighted	OLS	-0.98% [-0.17]	-4.91% [-0.85]
	WLS	-1.98% [-0.33]	-2.47% [-0.42]
Value-weighted	OLS	3.77% [0.69]	1.52% [0.28]
	WLS	3.53% [0.67]	2.42% [0.46]
Panel B: Results from Fama-French regressions of the benchmark-adjusted monthly event-portfolio returns			
Event portfolio return	Parameters' estimation method	Adjusted3A CCAR [t- statistic]	Adjusted3B CCAR [t- statistic]
Equally-weighted	OLS	-3.48% [-0.16]	-8.99% [-0.84]
	WLS	-11.80% [-0.53]	-12.19% [-1.16]
Value-weighted	OLS	1.12% [0.11]	-3.87% [-0.46]
	WLS	-3.52% [-0.33]	-2.77% [-0.35]

Table VII
Post-Event One-Year-Long Raw and Adjusted Cumulative Compounded Abnormal Stock Returns to Firms that Discontinue some of their R&D programs in Sub-Samples Defined by Operating Cash Flow

This table displays the post-disclosure one-year-long raw and adjusted cumulative compounded abnormal returns (CCAR) to firms discontinuing some R&D program(s) in sub-samples defined by the relative operating cash flow of the sample firm (i.e. appurtenance to two-top versus two-bottom NYSE-quintiles defined by the ratio of earnings-before-interest-taxes-and-depreciation to total assets (EBITD/TA)). It is motivated by the argument that some of the sample firms may be compelled to reduce some of their cash payments; whereas, the other sample firms have efficiency as the main reason for the R&D program(s) discontinuation. ***, **, and * denote significance at the 1, 5 and 10 percent levels, respectively, in a two-tailed *t*-test.

Sub-sample	Event portfolio return	Parameters' estimation method	Raw CCAR [<i>t</i> -statistic]	Adjusted CCAR [<i>t</i> -statistic]	Adjusted2A CCAR [<i>t</i> -statistic]	Adjusted2B CCAR [<i>t</i> -statistic]	Adjusted3A CCAR [<i>t</i> -statistic]	Adjusted3B CCAR [<i>t</i> -statistic]
High cash flow firms	Equally-weighted	OLS	2.29% [0.39]	12.37% [2.02**]	-0.35% [-0.06]	-23.70% [-4.62***]	5.02% [0.50]	-19.59% [-2.07**]
		WLS	2.43% [0.47]	13.27% [2.44**]	-2.93% [-0.58]	-18.88% [-4.05***]	-1.95% [-0.21]	-23.94% [-2.60***]
	Value-weighted	OLS	1.77% [0.26]	18.27% [2.51**]	4.58% [0.67]	-0.39% [-0.06]	1.34% [0.12]	-1.56% [-0.15]
		WLS	2.72% [0.44]	21.30% [3.22***]	4.96% [0.80]	2.37% [0.39]	-0.73% [-0.07]	-2.50% [-0.27]
Low cash flow firms	Equally-weighted	OLS	29.99% [2.22**]	24.98% [1.88*]	-4.85% [-0.41]	25.14% [1.89*]	1.36% [0.03]	17.63% [0.76]
		WLS	37.87% [2.68***]	29.62% [2.17**]	-3.09% [-0.26]	27.42% [2.02**]	-15.50% [-0.38]	11.34% [0.49]
	Value-weighted	OLS	15.27% [1.31]	23.28% [1.93*]	6.02% [0.54]	8.38% [0.74]	12.05% [0.61]	15.79% [0.88]
		WLS	19.77% [1.68*]	27.65% [2.28**]	9.00% [0.80]	8.70% [0.77]	4.52% [0.23]	17.13% [0.98]

¹ Chan, Lakonishok and Sougiannis (2001) find that firms with any level of R&D intensity (i.e. high, medium or low R&D expenditure-to-sales ratio) show no significant excess returns (based on control portfolios of stocks matched by firm size and book-to-market ratio, or firm size and book equity plus the value of R&D capital divided by market equity) over the three post-formation years of the portfolio (see Table III and footnote 15). Interestingly, Lev and Sougiannis (1999) provide evidence that the R&D capital to market value ratio of a firm appears to capture an important risk dimension for R&D intensive firms.

² These latter typically do not include information about what part of the R&D budget increase will fund new R&D programs that create new real growth options, what part is budgeted to exercise existing real growth options, and what part is to pay for unexpected cost over-runs at already existing programs. Also, they are typically made concurrently with announcements pertaining to end-of-fiscal period financial results, etc. [see Chan, Martin and Kensinger (1990); and Szewczyk, Tsetsekos and Zantout (1996)].

³ Difficulties with exclusively appropriating the rent of the R&D investment [Polanyi (1962); Nelson and Winter, (1982); Bhidé (2000); Zingales (2000); Spence (1984); Jaffe (1986)], the high uncertainty pertaining to its output, and the high information asymmetry between the scientists and the investors, all these attributes of R&D differentiate it from capital investment.

⁴ We examine the abnormal return in each post-event year separately because Fama (1998) points out correctly that an initial abnormal return can grow with the investment horizon even if there is no abnormal return after the initial period.

⁵ Daniel, Hirshleifer and Subrahmanyam (1998), Odean (1998), Barberis, Shleifer and Vishny (1998), Hong and Stein (1999) and Grinblatt and Han (2005) introduce behavioral-based models as alternatives to the ‘rational expectations’ model. These models predict either under- or over-reaction to corporate news, resulting from some cognitive biases that investors arguably have.

⁶ We doubled checked for the inexistence of a prior public disclosure of the termination decision by searching the *Dow Jones Factiva* using the company name.

⁷ Bowen, DuCharme and Shores (1995) and Cornell and Shapiro (1987) discuss several incentives for management to engage in earnings’ management, and the empirical evidence indicates that managers do in fact engage in window dressing and earnings’ management [e.g. Burgstahler and Dichev (1997); Hayn (1995)].

⁸ The studies of Blackwell, Marr, and Spivey (1990) and Gombola and Tsetsekos (1992) report that investors react also negatively to announcements of plant closings.

⁹ Investors’ disappointment may be worse at a small-size firm in the technology- and science-based industries not only because it has a smaller R&D portfolio but also because this latter is not well diversified. At many small firms, all the R&D programs are based on a common research paradigm or core scientific knowledge. Consequently, a failure in one of these programs may raise doubts about the entire core technology of that firm.

¹⁰ We also used the four-factor model of Carhart (1997). We find all the results using this latter model similar to the ones we obtain using the Fama-French three-factor model. The results using the Carhart (1997) model are readily available from the authors.

¹¹ In fact, Fama (1998) point out that “all models for expected returns are incomplete descriptions of the systematic patterns in average returns during any sample period (page 291).”

¹² Interestingly, Lev and Sougiannis (1999) further note that the association between the R&D to market value ratio and subsequent returns appears to be due to a risk factor associated with R&D, rather than the result of mispricing.

¹³ Fama (1998) argues: “if a reasonable change in the method of estimating abnormal returns causes an anomaly to disappear, the anomaly is on shaky footing, and it is reasonable to suggest that it is an illusion (page 303).”