Empirical Evidence On Corporate R&D Investment, Risk and Security Returns

By

Mohsen Saad and Zaher Zantout[*]

May 6th, 2008

ABSTRACT

Some scholars argue there is under-investment in corporate R&D; however, Jensen (1993) argues some R&D projects are not profitable and investors often overlook that fact. Consistent with this latter argument, we find large-size firms which acquire technologies from external sources or which significantly increase their R&D expenditures experience *subsequent negative three-year-long abnormal stock returns* on the magnitude of 74 and 56 basis-points per month, respectively. The large-size technology-acquirers experience also an increase in their cost of equity on the magnitude of 21 basis-points per month due to an *increase in their systematic risk*. We find no robust evidence of significant event-induced abnormal returns or systematic risk changes for the small-size sample firms. The large-size sample firms generate relatively much larger cash flows (i.e., have significantly greater over-investment discretion) and have significantly larger (over-) valuation multiples than the small-size firms. Evidently, investors initially underestimate the (perhaps desperation-induced) *risk-increasing over-investment in R&D by some large-size firms*.

JEL classifications: G14; G31; O32
Keywords: Corporate R&D investment; Capital market efficiency; Growth Options; Systematic Risk

Dr. Mohsen Saad is Assistant Professor of Finance at the American University of Sharjah, School of Business & Management, P. O. Box 26666 Sharjah, U.A.E.; telephone: (971) 6 515-2325; e-mail: msaad@aus.edu
Dr. Zaher Zantout is Associate Professor of Finance at the American University of Sharjah, School of Business & Management, P. O. Box 26666 Sharjah, U.A.E.; telephone: (971) 6 515-2347; e-mail: zzantout@aus.edu

Empirical Evidence On Corporate R&D Investment, Risk and Security Returns

Many scholars (e.g., Drucker (1986); Hall (1993); Porter (1992); Stein (1988)) maintain that investors in U.S. capital markets focus excessively on short-term profits and do not value or appreciate enough long-term investments, such as research and development (R&D) which creates new strategic options for a firm and is a major source of competitive advantage (e.g., Schumpeter (1934); Ansoff (1965)). As a consequence, managers often feel compelled to forego some profitable R&D investment (which is expensed) so as to avoid lowering short-term earnings and disappointing investors. However, Jensen (1993) proposes that many corporate R&D investments are in fact not profitable and investors systematically overlook this possibility. This latter implies that the valuation of some R&D-intensive stocks is excessively high, and Jensen (2005) argues further that when a firm's equity becomes substantially overvalued it makes even the most efficient manager unable to deliver the performance required to support the excessive stock market's valuation. In an attempt to support the over-valuation so as to avoid disappointing current shareholders, the manager ends up destroying part of the firm's core value.[1]

The empirical evidence on whether investors in U.S. capital markets value corporate R&D investment efficiently is mixed. On one hand, Chan, Lakonishok and Sougiannis (2001) report that firms with R&D capital show no long-term excess returns, which indicates that investors' expectations about the value of R&D capital are unbiased. On the other hand, 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, conclude that investors initially under-react to (i.e., initially undervalue) R&D investment.[2] Making the evidence even more mixed, Chambers, Jennings and Thompson (2002) report results that 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.

Given the important public policy and macro-economic implications of the question of whether investors in U.S. capital markets value R&D-investing firms efficiently, and given the mixed evidence, we extend the empirical literature by examining the long-term stock price and systematic risk effects of corporate R&D investment using two different samples: 1) 806 cases of acquisitions of patented or patent-pending technologies from persons that are outsiders to the firm from the period 1979 through 2004; and 2) 438 observations of significant (i.e., abnormal / unexpected) increases in corporate-wide R&D expenditures from the period 1962 through 2005. Each sample has some advantages and disadvantages that are discussed later in the paper.

We also recognize several important theoretical and methodological issues that are related to our inquiry on whether investors value R&D investment efficiently. First, even within the same industry, large- and small-size firms (or strategic groups) may have different sets of growth opportunities and may pursue different R&D strategies. Second, R&D investment may change the firm's systematic risk since assets-in-place and growth options have different systematic risk, and the magnitude of that change may be related to the size of the firm because large-size firms have more ongoing projects (assets-in-place) than small-size firms which derive most of their value from growth options ((Berk, Green and Naik (1999); Gomes, Kogan and Zhang (2003); Carlson, Fisher and Giammarino (2004)). Third, Fama (1998) argues correctly that all models for expected returns are incomplete descriptions of the systematic patterns in average returns during any sample period. Accordingly, if the sample is tilted toward characteristics that the return model used cannot price in the first place, then the null hypothesis of zero abnormal long-term return may be inappropriate. Failing to recognize these issues may lead to erroneous conclusions about investors' valuation of R&D-investing firms.

We begin our examination of the long-term stock price effects of corporate R&D investment by applying the three-factor model of Fama and French (1993) and the four-factor model of Carhart (1997), using *equally- and value-weighted* calendar-month returns of the rolling-event-portfolio for both samples. We find in the sample of external technology acquisitions some evidence of subsequent positive abnormal stock returns over three- and five years but only in the case of equally-weighted rolling-portfolio returns. In the sample of significant increases in R&D expenditures, we find the equally-weighted portfolio return results statistically insignificant, but the value-weighted return results significantly negative over the three- and five-year post-investment periods. This difference between the equally- and value-weighted results persists in sub-samples defined by: 1) the technology level of the industry in which the R&D-investing firm operates; 2) the book-to-market classification of the sample event-firms; and 3) the percent R&D expenditure increase for firms significantly increasing their R&D expenditures.

Accordingly, we classify our sample R&D-investing firms into sub-samples defined by their relative market capitalization (i.e., appurtenance to NYSE size quintiles) and we apply the three- and four-factor models for each sub-sample. We find that firms in the smallest-size quintile (in both samples) experience significant positive abnormal returns over the three- and five-year periods following the R&D investment; whereas, firms in the largest-size quintile appear to suffer negative abnormal returns, which are significant in the sample of significant R&D expenditure increases. An investment strategy of going short with the largest-size and long with the smallest-size sample firms generates statistically significant and economically very large positive abnormal monthly returns of about 1.5 percent over three- and perhaps five-years following the R&D investment (clearly not accounting for transaction costs). These results may reflect different sets of growth opportunities and/or different R&D investment strategies pursued by large- versus small-size firms. However, before making any conclusion(s) based on these initial results, we follow Fama's (1998) recommendation to examine the robustness of any found long-term abnormal returns.

Our robustness test is based on the recognition of two issues. First, the acquisition and/or exercise of R&D-investment-growth options may result in changes in the risk attributes and, therefore, the expected returns of the sample firms (Berk, Green and Naik (1999); Gomes, Kogan and Zhang (2003)), which may qualify the above findings. Second, Fama and French (1993) and Mitchell and Stafford (2000) show that the three-factor model does not completely explain the cross-sectional variation of stock returns.[3] For these two reasons, we run three-risk-factor regressions of the difference between the post- and pre-event rolling-portfolio returns. These regressions serve two reasons: 1) testing / controlling for a significant change in the systematic risk of the event-firms; and 2) providing a robustness test of whether the post-R&D-investment negative price drift reported above for large-size firms is due to the event or is simply the consequence of a pricing deficiency in the expected return model. In the absence of an event-induced-change in the systematic risk of the R&D-investing firms, the risk-factor loadings should not change significantly. Also, in the absence of a subsequent R&D-event-induced long-term abnormal return, the intercept term (whether it is significant or not, positive or negative prior to the event) should not change significantly.

We find that the intercept term decreases significantly in the regressions for the large-size R&D-investing-firms. The duration of the event-induced negative abnormal return is three-years long and is on the magnitude of 74 basis-points per month for large-size technology-acquirers and on the magnitude of 56 basis-points per month for large-size firms increasing their R&D expenditures significantly. Additionally, the large-size technology-acquirers experience a significant increase in their systematic risk that translates to an estimated increase in their cost of equity on the magnitude of 21 basis-points per month. We find no evidence of a change in the intercept term in the regressions for the small-size firms. Moreover, we find no evidence of any significant change in the systematic risk (or cost of equity) of small-size R&D-investing firms.

Finally, we examine the cash flow characteristics and valuation multiples of large- and small-size firms acquiring technologies from external sources or significantly increasing their R&D expenditures. We find that the large-size firms in our samples have significantly greater (over-) investment discretion compared to the small-size firms since they generate, in relative terms, significantly much larger cash flows at the time of the R&D investment. Additionally, judging from their ratios of book-to-market value of equity (B/M), a significantly greater proportion of them (compared to small-size firms) have a low book-to-market ratio (i.e., high valuation or over-valuation). These results are consistent with Jensen's (1993; 2005) arguments that *investors often overlook the over-investment in R&D*, and that when a firm's equity becomes substantially over-valued some managers end up destroying part of the core value of the firm while attempting to sustain the over-valuation.

Our evidence on large-size firms over-investing in R&D (despite the fact that other things constant, including technological opportunities, there are typically scale and scope economies in R&D spending by large-size firms) is related to a recent study by Higgins and Rodriguez (2006). They find that pharmaceutical firms experiencing the greatest deterioration in their internal R&D productivity (i.e., that are desperate) are most likely to engage in an R&D outsourcing type acquisition in an effort to replenish their research pipelines.[4] Our long-term evidence from the sample of external technology acquisitions (and one can add the sample of firms significantly / aggressively increasing their R&D expenditures) may, therefore, be interpreted as the consequence of the excess-cash-flow based investment-discretion of the large-size sample-firms coupled with perhaps some desperation to find new technological capabilities. This search for new capabilities naturally involves irreversible costs, considerable uncertainty, and overlapping (sub-additive) exploratory investments (Vassolo, Anand and Folta (2004)), which investors do not initially recognize, and which in its turn explains the negative price drift.

As to the reason why investors fail to recognize the over-investment in R&D initially, it is clearly difficult to reconcile this evidence with the efficient capital markets hypothesis and the rational expectations' model. If it were confined to small-size / illiquid stocks whose trading costs are so high that they can account for most of the paper profits from a long-short strategy designed to exploit this pricing anomaly, one could invoke this limit-to-arbitrage argument and, therefore, consider this anomaly to be within the parameters of an efficient market. However, it is confined to large-size firms, instead. Explanations for this anomaly might be sought in behavioral-based models (Daniel, Hirshleifer and Subrahmanyam (1998); Odean (1998); Barberis, Shleifer and Vishny (1998); Hong and Stein (1999); Grinblatt and Han (2005)) which offer an alternative perspective to investor behavior.

We believe that our paper is related and contributes to several research areas in the Finance literature. It contributes to the debate on whether a free-market economy allocates resources into R&D efficiently since the evidence we report indicates that large-size firms that acquire technologies from external sources and / or increase their R&D expenditures significantly (or aggressively) appear to over-invest in R&D. More broadly, our paper contributes to the literature on the efficient capital markets hypothesis. Cooper, Gulen and Schill (2008) propose that examining asset growth in relation to the cross-section of returns is a comprehensive approach since it accounts for all the components of a firm's total investment or financing activities, many of which are shown to be followed by abnormal stock returns. Clearly, however, since R&D investment is expensed / not capitalized, asset growth does not account for it directly. We report a robust pricing anomaly for our large-size R&D-investing firms over a period of three-years, and the limit-to-arbitrage argument cannot be invoked to reconcile it with the efficient capital markets' hypothesis.[5]

An additional contribution of our paper is to the literature and empirical evidence on the effects of corporate investment on the systematic risk and expected returns of the investing firms Following the models of Berk, Green and Naik (1999) and Gomes, Kogan and Zhang (2003) the optimal exercise of growth options reduces the average systematic risk of the firm's cash flows in subsequent periods. Carlson, Fisher and Giammarino (2006) argue that regardless of their risk, the new assets are less risky than the options they replace. Additionally, other things constant, the exercise of investment options should have a less dramatic effect on the systematic risk of large- versus small-size firms because the former have more ongoing projects whereas the latter derive most of their value from growth options. Our evidence provides mixed support for the predictions of these models. On one hand, we find the acquisition (opposite to exercise) of technology growth options by large-size firms to be associated with an increase in the systematic risk of these latter. On the other hand, we find no such effect with small-size technology-acquiring firms where the risk-change effect should be more pronounced, following the prediction of these models. Our conclusion is similar to the one of Titman, Wei and Xie (2004) on capital expenditures and Cooper, Gulen and Schill (2008) on asset growth.

A final contribution of our paper is to the literature on the estimation of expected security returns and the robustness of long-term pricing anomalies, which is an important research question in itself (Fama (1998); Barber and Lyon (1997); Loughran and Ritter (2000); Mitchell and Stafford (2000)). We propose that long-term studies check the robustness of any found long-term pricing anomaly by using Fama-French three-risk-factor regressions of the difference between the post- and pre-event rolling-portfolio returns, because the ideal non-event-firm (or portfolio) to match to an event-firm (or portfolio) is often times the event-firm (or event-portfolio) itself at a time when it does not have the event (i.e., prior to the event). In the absence of an either event-induced or coincidental change in the systematic risk of the sample firms (null hypothesis), the risk-factor loadings should not change significantly from the pre-event period. Also, in the absence of a subsequent event-induced long-term abnormal return (null hypothesis), the intercept term (whether it is significant or not, positive or negative prior to the event) should not change significantly. Therefore, these regressions can serve two objectives: 1) testing and controlling for a significant change in the systematic risk of the event-firms; and 2) providing a robustness test of whether any post-event price drift found using the Fama and French (1993) model is due to the event itself or is simply the consequence of a pricing deficiency in the return model when applied to the sample being examined.

The remainder of our paper is organized as follows. Section I describes our samples. Section II examines the post-R&D-investment long-term stock price effects for the entire sample and different sub-samples, including the large- versus small-size market capitalization sub-samples. Section III presents the results of the robustness tests and the examination of the systematic risk effects of corporate R&D investment. Section IV examines agency-cost related indicators for the large- and small-size firms. Section V concludes the paper.

I. Samples of corporate R&D investment

We examine two types of corporate R&D investment: 1) acquisitions of patented and/or patent-pending technologies from persons that are outsiders to the firm (e.g., individual scientists, research foundations, universities or companies); and 2) significant increases in corporate-wide R&D expenditures. Each sample has some advantages and disadvantages. The sample of technology acquisitions comprises clear disclosures of acquisition of (as opposed to and separate from the optimally-timed exercise of) real growth options, and these disclosures are not contaminated by other corporate events. Disclosures of increases in corporate-wide R&D expenditures, on the other hand, typically do not include information that may help an outside investor determine what part of the increase constitutes investment that creates new real growth options, what part represents the exercise of existing options, and what part is due to unexpected cost over-runs at already existing programs. Also, these latter are typically made concurrently with announcements pertaining to end-of-fiscal-period financial results (see Chan, Martin and Kensinger (1990); Szewczyk, Tsetsekos and Zantout (1996)). Regrettably, announcements of technology acquisitions seldom include detailed information about the financial terms of the agreement, particularly relating to the price that is paid to acquire the technology-rights, and the acquisition of a particular real growth option may be a more significant event for a small- compared to a large-size firm. On the other hand, with corporate-wide R&D expenditure increases, the magnitude of the investment increase is available, and a certain percentage increase will be most likely equally significant to a large- and a small-size firm, other things constant; although, studies that examine R&D expenditure increases assume that any increase is unexpected and therefore an event, which is not necessarily true.

A. Sample of technology acquisitions

We obtain our sample of publicly announced acquisitions of patented and/or patent-pending technologies that are not yet developed commercially from the Factiva computer-search database. We use several search or key words to find relevant announcements made on one of the top newswires (i.e., top sources) during the period from January 1979 through December 2004. Since a relevant announcement is often times reported by several news media, we make sure that we have the date, the time and the source of the first public announcement of the event. The *Dow Jones News Service*, *PR Newswire* and/or *Business Wire* are typically the first to report it. The following are examples of the types of announcements we consider relevant:

> **Du Pont, Houston University in superconductivity pact**
> 23 August 1988 *Dow Jones News Service* 10:57AM and 13:34 EDT *PR Newswire* 12:58 EDT
> Du Pont Co. said it signed an agreement with the University of Houston to license patent applications relating to high-temperature superconductors and any patents that may issue from those applications. Du Pont said it made an initial payment of $1.5 million to the university and will pay an additional $1.5 million upon issuance of a patent to Professor Paul Chu. The additional $1.5 million payment will cover Chu's original high-temperature superconducting compositions, which are the so-called ''1-2-3'' compounds (attrium-barium-copper oxide). The company will also make a third payment of $1.5 million two years after issuance of the patent. The agreement grants Du Pont exclusive rights to commercial applications under any patent for Chu's original high-temperature superconducting compositions. Under the pact, Du Pont also has a right of first refusal for rights to other superconductivity inventions coming from Chu's laboratory over the next three years. Royalties for particular products will be negotiated on an individual basis, and Du Pont will share sublicensing royalties with the university, the company said. Additionally, Chu will have a consulting agreement with Du Pont…Superconductors, which conduct electricity without loss through heat, are expected to lead to major breakthroughs in computer, transportation and energy technology…Chu filed for a patent on his discoveries in January 1987. It is not known when or if the patent will be granted because other researchers have made similar applications that still must be considered by the U.S. Patent Office.

> **Environmental Technologies purchases rights and patent to nylon recycling technologies**
> 21 September 1994 *PR Newswire* 11:54 EDT *Dow Jones News Service* 1:37 PM
> Environmental Technologies USA, Inc. announced today that it has purchased the rights, including a patent, to a unique technology for recycling nylon. The technology will allow ETI to separate the components in carpeting into two of the most commonly used plastic resins – nylon and polypropylene. Initial samples indicate that this process will produce a post-consumer nylon material (both Nylon 6 and Nylon 66) with purities that have approached 95%. Previously, ETI's subsidiary, URI, Inc., had achieved only an 80% purity… For the year ended December 1993, over 7.6 billion pounds of nylon fiber were produced in the United States. ETI purchased this technology from Minnmark, Inc., a Minnesota based R&D firm, for a combination of cash and common stock in ETI.

> **Axcan, Cincinnati Children's Hospital in licensing pact**
> 25 September 2000 *Dow Jones News Service* 14:32 EDT
> Axcan Pharma Inc. has signed a licensing agreement with the Children's Hospital Research Foundation, an operating division of Children's Hospital Medical Center of Cincinnati, for a series of sulfated derivatives

> of ursodeoxycholic acid compounds, or SUDCA. In a news release, Axcan said under the terms of the agreement, it will obtain the exclusive worldwide right to commercially exploit a series of patented SUDCA developed by the foundation in consideration of a one-time $589,000 licensing fee; payments of up to $425,000 once the foundation validates the proof of concept on the use of SUDCA to prevent the recurrence of colorectal adenomatous polyps; royalties based on a certain percentage of sales; and bonus payments upon achievement of certain milestones. Axcan said it is believed that the compound can be used to prevent colorectal cancer and TNP-induced cholestasis. It said the compounds are now in preclinical trials and may constitute a significant improvement over regular ursodeoxycholic acid, or UDCA, for the prevention of recurrence of colorectal adenomatous polyps.

We observe that many of the relevant announcements pertain to technologies that require significant additional investment during the commercialization phase, which can be several years long, and they may even need further scientific research before starting the commercial development phase. Therefore, they entail significant risks and the commercial potential of these technologies is difficult to determine for a typical outside investor. We exclude cases that are contaminated by the disclosure of some other corporate information,[6] or that pertain to acquirers that are not in the database of the Center for Research in Security Prices (CRSP).[7] We also exclude all cases that are preceded during a five-year period by a similar disclosure by the same company. The resulting final sample of technology acquisitions consists of 806 non-contaminated disclosures which are made over the period from January 1979 through December 2004 by firms listed on the NYSE, AMEX and NASDAQ.

Panel A in Table 1 displays the chronological distribution of the sample events. There is no major clustering of announcements in any sub-period of the 1979-2004 sampling period, during which the performance of the economy and the stock market varied substantially. We observe that the number of events per year trends up over the sampling period despite the annual fluctuations, but this latter is a reflection of the underlying population. The acquisition of intellectual capital from external sources started to emerge in the early 1980s and gradually became an essential part of the R&D strategies of U.S. firms during the 1990s.

Panel B in Table 1 examines whether the sample events cluster during certain month(s). We find no clustering of events in any calendar month, which is evidence that these events do not coincide with other 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 expenditure increases. It also indicates that our results will less likely be affected by any seasonal stock price effects, such as the January effect.

Panel C in Table 1 examines the industry representation of the sample. The sample firms represent 211 different four-digit Standard Industry Classification (SIC) industries. However, as a reflection of the underlying population and the fact that the intensity of R&D investment is not equal among different industries, SIC code 2830 accounts for 119 of the 806 sample events (i.e., 14.76 percent). This clustering of events diminishes quickly among the other industries represented in the sample. The studies of Chan, Martin and Kensinger (1990) and Zantout (1997) separate industries into two groups: high- versus low-technology industries. The high-technology industries are: aircraft/defense, electronics, information processing, instruments, pharmaceuticals, semiconductors and telecommunications. We follow this classification and find that 610 (or 75.68 percent) of the 806 announcements in our sample pertain to the high-technology industries. Therefore, most technology acquisitions from external sources are made by companies that operate in high-technology industries.

We examine the short-term stock price effects of the technology-acquisition announcements by computing the short-term abnormal common 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 estimates. Our estimation period is from day -200 through day -15, relative to the initial announcement date (i.e., day 0). We compute the short-term cumulative average abnormal common stock return (CAAR) over the period [0;+1] relative to the announcement date, and then we determine the statistical significance of the CAAR using the parametric two-tailed *t*-test, based on the cross-sectional standard deviation of the abnormal returns. We find that announcements of acquisition of patented and/or patent-pending technologies are associated with a statistically significant positive two-day announcement-period average abnormal stock return (CAAR) on the magnitude of +1.369 percent, which is significant at the 1 percent level. The positive announcement-period abnormal return we find suggests that the shareholders of these technology-acquiring firms generally consider this type of R&D investment good news. This finding is not surprising given the evidence pertaining to announcements of R&D expenditure increases. Szewczyk, Tsetsekos and Zantout (1996) report an announcement-period average abnormal return of 0.477 percent in a sample of 252 announcements from the period 1979 through 1992. The larger abnormal return we report perhaps suggests that our events are more significant and / or less expected.

Chan, Martin and Kensinger (1990) find the announcement-period abnormal stock return significantly positive for firms that operate in high-technology industries and significantly negative for firms that operate in low-technology industries. Also, Szewczyk, Tsetsekos and Zantout (1996) find a positive relation between a firm's *q*-ratio (measured as a binary variable) and its stock price reaction at the announcement. In a sub-sample of 58 announcements of R&D expenditure increases made by firms with a *q*-ratio above 1, they report a CAAR of 0.929 percent, which is significant at the 1 percent level. On the other hand, in a sub-sample of 63 announcements of R&D expenditure increases made by firms with a *q*-ratio less than 1, they report a CAAR of -0.16 percent, which is insignificant at conventional levels. The difference of

1.089 percent is statistically significant at the 5 percent level using a two-tailed *t*-test. We find that these latter results pertaining to R&D expenditure increases extend to technology growth option acquisitions. Specifically, the CAAR for our sample firms operating in high-technology industries is on the magnitude of 1.765 percent, which is statistically significant at the 1 percent level. On the other hand, the CAAR for our sample firms operating in low-technology industries is on the magnitude of 0.106 percent, which is statistically insignificant at conventional levels. Moreover, the difference of 1.659 percent between the CAARs of the two sub-samples is statistically significant at the 1 percent level assuming equal or unequal variances.

B. Sample of significant increases in corporate R&D expenditures

To ensure that our sample of corporate increases in R&D expenditures includes *unexpected events and/or abnormal increases*, we identify firms that increased their R&D expenditures 'significantly' following a period of 'no significant change.' Specifically, we first examine the distribution of the percentage annual *increase* in R&D expenditures for each firm on COMPUSTAT and across all years. We find that 90 percent of the observations pertaining to R&D-expenditures-increasing firms have a value that is greater than 4.43 percent, and the median increase is 21.83 percent. We also examine the distribution of the percentage annual *decrease* in R&D expenditures for each firm on COMPUSTAT and across all years. We find that 90 percent of the observations pertaining to R&D-expenditures-decreasing firms have a value that is more than 2.71 percent. Therefore, these statistics suggest that a firm that has an increase in R&D expenditures not exceeding 4.43 percent or a decrease not exceeding 2.71 percent during a year is a firm with relatively minimal or insignificant change in R&D expenditures. Second, we identify all COMPUSTAT firms that have an insignificant change in R&D expenditures (as just defined) for a period of two consecutive years and then have a significant increase in investment expenditures. By significant increase, we mean an increase that exceeds the median value of 21.83 percent. We obtain 462 firm-year observations. Third, we exclude from the 462 observations, all those that have an R&D intensity ratio (i.e. R&D expenditures to total sales) of less than 0.19 percent, being the minimum observation for the top 75 percent of all the COMPUSTAT annual observations for all firms across all years.

Our final sample of firms significantly increasing their R&D expenditures following a two-year period of no significant change in investment activity includes 438 observations over the period from 1962 through 2005 by firms listed on NYSE, AMEX and NASDAQ. The firms of this sample represent 151 different four-digit Standard Industry Classification (SIC) industries, and 217 (or 49.54 percent) of the 438 cases pertain to the high-technology industries. Therefore, while most technology acquisitions from external sources are made by companies that operate in high-technology industries, significant corporate-wide R&D expenditure increases apparently occur with equal frequency in high- and low-technology industries. We checked whether these sample firms had a significant change in their capital expenditures activity which may confound our results, and we find that they do not experience any significant change in their capital expenditures intensity, over neither one nor three years prior to the significant increase in R&D expenditures.

In Table 2, Panel A displays the chronological distribution of the sample events. There is no major clustering of events in any year of the 1962-2005 sampling-period, during which the performance of the economy and the stock market varied substantially. Panel B examines whether the sample events cluster during certain month(s). We find that 63 percent of the sample cases cluster in the month of December, which is evidence that these events do regrettably coincide with other disclosures of sales or earnings data at the end of a fiscal period, unlike the case of announcements of technology acquisitions. Panel C examines whether there is any industry clustering in the sample. We notice that there is much less industry clustering in this sample compared to the other one. Only 13 out of 438 (or 2.97 percent of the sample cases) pertain to one four-digit SIC industry.

C. Characteristics of the firms in both samples

We classify in Panels A and B of Table 3 the event-firms in our two samples into NYSE market capitalization quintiles and NYSE quintiles of R&D-expenditures-to-sales ratio (using data from fiscal year prior to event). These classifications provide good measures of the *relative* size and R&D-intensity 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 and sales. We observe that in terms of size representation of the sample of technology-acquisitions, about 35 percent of the sample firms pertain to the smallest-size quintile and about 36 percent pertain to the largest-size quintile. Therefore, the population of technology-acquirers is neither exclusively nor predominantly formed of the largest-firms in our economy, as may be thought. In fact, as we note earlier, we have numerous cases of technology acquisitions that we cannot include in our sample because they are made by development-stage privately-held companies. In the sample of firms significantly increasing their R&D expenditures, we find similarly that about one-third of the sample cases pertain to the smallest-size firms and about one-third of the cases to the largest-size firms.

In terms of the R&D investment intensity of the sample firms relative to other publicly-traded firms, we find that most of our technology-acquiring firms invest in R&D intensively. About 81 percent of them belong to the quintile of the most R&D-intensive firms. In the sample of significant increases in R&D expenditures, the event-firms are also R&D intensive but to a lesser degree than the technology-acquirers, as the distribution in Panel B indicates. About 38 percent of them pertain to the quintile of the most R&D-intensive firms.

II. Post-R&D-investment long-term stock price-performance

A. Method of estimating the monthly abnormal return to sample R&D-investing firms

We begin our analysis of the long-term stock price effects of acquisitions of patented and/or patent pending technologies and significant increases in corporate R&D expenditures by following the recommendation of Fama (1998) and Mitchell and Stafford (2000) to use the rolling portfolio method to control for any cross-sectional dependence among the event firms. For every calendar month, we compute the equally- and value-weighted returns on the portfolio which contains all firms which had the R&D-investment event during the preceding thirty-six or sixty calendar months. 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 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. To account for any delisting bias in our sample, we apply the corrections of Shumway (1997) and Shumway and Warther (1999) for de-listed firms. Specifically, we use as the last return for firms that are de-listed for performance reasons -30 percent for the NYSE and Amex sample firms and -55 percent for the Nasdaq sample firms.

Following the computation of the calendar-months event-portfolio returns, we use the following three-factor model of Fama and French (1993) and the four-factor model of Carhart (1997):

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

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

where R_{pt} represents the return on the event-portfolio in month t, R_{ft} is the one-month U.S. Treasury bill rate in month t, R_{mt} is the return on the value-weighted index of NYSE, Amex and Nasdaq listed stocks 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, 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, and UMD_t in the four-factor model, which captures Jegadeesh and Titman's (1993) one-year momentum, is the equal-weight average of firms with the highest 30 percent eleven-month returns lagged one month minus the equal-weight average of firms with the lowest 30 percent eleven-month returns lagged one month. Since the number of event-firms included in the rolling event-portfolio changes through time, which may introduce heteroskedasticity, we use the weighted-least-squares (WLS) method in addition to the ordinary-least-squares (OLS) method to estimate the parameters of the three- and four-factor models. The weights are equal to the square root of the number of events in the portfolio. The intercept α is interpreted as the average monthly abnormal return of the event portfolio across all 36 or 60 months.

B. Post-R&D-investment average monthly abnormal stock returns in each sample

Table 4 displays the three- and five-year post-R&D-event average monthly abnormal stock returns (i.e., the intercept α), which are estimated using the three- and four-factor models. We observe that these models explain a significant percentage of the returns of our sample firms, as the adjusted coefficients of determination (adjusted R^2) indicate. Using the three-factor model for the sample of technology-acquisitions, the intercept α is statistically insignificant for the three-year post-R&D-investment period. It is positive and significant over the five-year period in the case of equally-weighted portfolios, and negative and insignificant in the case of value-weighted portfolios. Using the four-factor model for the sample of technology-acquisitions, we observe that the additional risk-factor UMD_t increases the adjusted coefficients of determination (adjusted R^2) compared to those of the three-factor model, but only marginally. Therefore, the four-factor model is marginally a better fit than the three-factor model for our sample technology-acquiring-firms. Yet, the results pertaining to the intercept α are now different. We find that in the case of equal weighing, there is a significant positive price drift over the three- and five-year periods. However, in the case of value weighing, the intercept α is statistically insignificant at conventional levels over both time periods.

In the sample of significant R&D expenditure increases, the post-event average abnormal monthly stock returns over three and five years, which are estimated using the three- or four-factor models, are all statistically insignificant in the case of equally-weighted portfolios, but negative and statistically significant at conventional levels in the case of value-weighted portfolios. Therefore, the generalization which can be made based on the results of Table 4 is that the results for equally-weighted portfolios are different from those for value-weighted portfolios. More specifically, the intercept α is always lower in the case of value-weighted portfolios. We explore possible reasons for this latter difference in the results by performing next several sub-sample analyses.

C. Results in sub-samples defined by the technology-level of the industry in which the R&D-investing firm operates

We find above a difference in the two-day announcement-period average abnormal return for technology-acquirers operating in high-technology industries versus those operating in low-technology industries. This difference motivates our examination in Table 5 of the post-R&D-

investment long-term abnormal returns in sub-samples defined by the technology level of the R&D-investing firm's industry. The results reported for the sample of technology acquisitions indicate that firms operating in high-technology industries experience significant positive post-R&D-investment abnormal returns over three and five years when portfolios are equally-weighted but not value-weighted. On the other hand, results for technology-acquirers operating in low-technology industries indicate that they experience significant negative post-R&D-investment abnormal returns over three and five years when portfolios are value-weighted but not equally-weighted.

The results reported for the sample of significant increases in R&D expenditures indicate that firms operating in high-technology industries experience positive post-R&D-investment abnormal returns over three and five years when portfolios are equally-weighted and negative abnormal returns when portfolios are value-weighted; although, the statistical significance of these abnormal returns is not robust. On the other hand, the results for firms in low-technology industries indicate that these latter experience significant negative post-R&D-investment abnormal returns over three and five years when portfolios are value-weighted but not equally-weighted. Therefore, the results from both samples are consistent with above results of a difference in the post-R&D-investment long-term abnormal return to equally- versus value-weighted portfolios. Specifically, the intercept α is always lower in the case of value-weighted portfolios.

D. Results in sub-samples defined by the growth- versus value-stock classification of the R&D-investing firm

The models of Gomes, Kogan and Zhang (2003) and Cooper (2006) propose that high B/M firms have higher systematic risk than low B/M firms. For this reason, we examine in Table 6 the post-R&D-investment long-term abnormal returns in sub-samples defined by the categorization of the sample firms as growth (low book-to-market) or value (high book-to-market) stocks. The sample growth-stocks appertain to the two-bottom NYSE quintiles of book-to-market value of equity (B/M) ratio; whereas, the sample value-stocks appertain to the two-top NYSE quintiles of B/M ratio.

The results reported for the sample of technology acquisitions indicate that growth firms do not experience any significant post-event abnormal returns neither over three nor five years. However, results for technology-acquiring firms classified as value stocks indicate that these latter experience subsequent significant positive abnormal returns over three and five years when the rolling-event-portfolios are equally-weighted but not value-weighted. The results reported for the sample of significant increases in R&D expenditures indicate that event-firms classified as growth stocks experience negative post-event abnormal returns over three and five years when portfolios are value-weighted and insignificant abnormal returns when portfolios are equally-weighted. On the other hand, the results for firms in the sub-sample of value stocks indicate that these latter experience significant positive post-R&D-investment abnormal returns over three and five years when portfolios are equally-weighted but not value-weighted. Therefore, we find again a difference in the results for equally- versus value-weighted R&D-event-portfolios, which is evidently independent of the growth- versus value-stock classification.

E. Results in sub-samples of R&D-expenditure-increasing firms defined by the percent increase

Anderson and Garcia-Feijoo (2006) find that growth in capital expenditures explains the cross section of subsequent stock returns. For this reason, Table 7 displays the post-R&D-investment long-term abnormal returns in sub-samples defined by the acceleration of R&D investment spending (i.e., higher versus lower than the sample median percent increase). We find that over the three-year post-event period, the value-weighted portfolios exhibit significant negative abnormal returns, whereas the equally-weighted portfolios do not appear to have any significant abnormal return, irrespective of the high- versus low-R&D-expenditure-increase classification. The results over the five-year post-event period are similar; although, less robust across sub-samples. Specifically, in the sub-sample of increase in R&D expenditures greater than sample median, the intercepts for the equal-weighing are positive whereas those pertaining to value-weighing are negative; although, they are all statistically insignificant. In the sub-sample of increase in R&D expenditures less than sample median, the intercepts are insignificant in the case of equal-weighing but negative and significant in the case of value-weighing. Therefore, we find one more time a difference in the post-R&D-investment long-term abnormal return to equally- versus value-weighted event-portfolios that is independent of the percentage increase in the firm's R&D expenditures.

F. Results in sub-samples defined by firm size

The above sub-sample analyses indicate the persistence / robustness of the difference between the equal- and value-weighing results. Accordingly, we examine in Table 8 the post-R&D-investment long-term abnormal returns in sub-samples defined by the relative market capitalization of the R&D-investing-firm (i.e. appurtenance to the largest- versus smallest NYSE size quintiles). The results in Panel A pertaining to the sample of technology-acquisitions indicate that small-size firms experience significant positive monthly abnormal returns over three- and five-years following the R&D-investment. Large-size firms, on the other hand, do not experience any robust significant price drift. The results in Panel A pertaining to the sample of R&D-expenditure-increases indicate that small-size firms experience significant positive monthly abnormal returns whereas large-size firms experience significant negative abnormal returns, over the three- and five-year periods following the R&D-expenditure increase.

We display in Panel B of Table 8 the difference in the post-R&D-investment long-term abnormal returns of the large- and small-size firms (i.e., the monthly arbitrage return from an investment strategy of going long on large-size and short on small-size R&D-investing firms, assuming no transaction costs). The difference in the post-R&D-investment price drift is obtained from OLS regressions of the difference between the equally-weighted calendar-month-portfolio returns of event-firms in large- and small-size quintiles ($R_{L.t} – R_{S.t}$) on the risk factors of the models of Fama and French (1993) and Carhart (1997):

$$R_{L.t} - R_{S.t} = (\alpha_L - \alpha_S) + (\beta_{mL} - \beta_{mS})\,(R_{mt} – R_{ft}) + (\beta_{sL} - \beta_{sS})\,SMB_t + (\beta_{hL} - \beta_{hS})\,HML_t + \varepsilon_t$$

$$R_{L.t} - R_{S.t} = (\alpha_L - \alpha_S) + (\beta_{mL} - \beta_{mS})\,(R_{mt} – R_{ft}) + (\beta_{sL} - \beta_{sS})\,SMB_t + (\beta_{hL} - \beta_{hS})\,HML_t + (\beta_{uL} - \beta_{uS})\,UMD_t + \gamma_t$$

Since the sub-samples are defined by market capitalization quintiles, we use in the three- and four-factor models equally-weighted portfolio returns only.

As expected, we find that the difference in the intercepts is negative and statistically significant over the three- and five-year post-R&D-investment periods and in both samples. The evidence clearly indicates that large-size R&D-investing firms under-perform the small-size R&D-investing firms by a significant monthly return difference on the magnitude of 1.19 to 2.44 percent. In the following section, we follow Fama’s (1998) recommendation to conduct some robustness tests in long-term event-studies before making conclusions that are based on some initial results.

III. Robustness tests and systematic risk effects of corporate R&D investment

The models of Berk, Green and Naik (1999) and Gomes, Kogan and Zhang (2003) propose that the exercise of investment-growth options results in a decline in the systematic risk and consequently the expected return on the stock of the investing firm. Therefore, the change in the systematic risk of the R&D-investing firms in our samples could be the cause of / explanation to the post-R&D-investment negative abnormal returns to the large-size firms. Additionally, our sample may be tilted toward characteristics that the return models we use above cannot price in the first place. For these reasons, we apply the following method as a robustness test.

If we set $R_{p,t}$ as the equally-weighted return during month t of the portfolio comprised of sample-firms making R&D investments during the following n months, then $R_{p,t+n+1}$ is the equally-weighted return during month $t+n+1$ of the portfolio comprised of sample firms that made R&D investments during the preceding n months, with $n = 36$ or 60 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:

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

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

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 by subtracting from each post-event rolling-portfolio calendar-month excess return the corresponding pre-R&D-investment calendar-month excess return, we obtain the following model:

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

In the absence of an event-induced change in the systematic risk of the sample firms, $\beta_{m,\Delta}$, $\beta_{s,\Delta}$ and $\beta_{h,\Delta}$ should be zero. Also, in the absence of an event-induced long-term price drift, α_{Δ} should be zero. Moreover, if the three-factor model explains well the return to the sample firms, $\alpha_{preevent}$ should be zero as well, but even if it is positive or negative, α_{Δ} will not be affected.

We apply this model and test for the statistical significance of α_{Δ}. The test on α_{Δ} is a robustness test of whether the above reported post-R&D-investment long-term abnormal returns are robust to controlling for potential changes in the systematic risk of the R&D-investing firms. We also examine the R&D-investment-induced change in the cost of equity (required return), which is estimated by multiplying each of the risk-change factor-loadings (i.e., $\beta_{m,\Delta}$, $\beta_{s,\Delta}$, and $\beta_{h,\Delta}$) from the rolling portfolio regressions 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 respective sampling periods and then summing up the three products. The mean monthly realizations for these latter are: 0.0065535, 0.0018144, and 0.0038506, respectively over the period 1979-2004; and 0.0044771, 0.0022871, and 0.0046381, respectively, over the period 1962-2005.[8] We determine the statistical significance of the change in the cost of equity by running the above rolling-portfolio 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.

With reference to Table 9, we find that the above rolling-portfolio (post- minus pre-event) return difference regressions fit the data well, as indicated by the adjusted coefficients of determination ($Adj.\ R^2$), particularly for large-size firms. Examining the statistical significance of α_{Δ} for the small-size firms, it is not significant at conventional levels in either sample, which suggests that the significant positive intercepts in the three- and four factor models for the small-size firms (displayed in Table 8) are not robust to controlling for the models' mis-specification. On the other hand, α_{Δ} for the large-size firms is clearly negative and statistically significant over the three-year period in both samples. Additionally, the results indicate that the negative price drift is confined to the three-year post-R&D-investment period as the α_{Δ} for the five-year period diminishes significantly in both samples. The evidently robust three-year post-R&D-investment negative abnormal monthly return to large-size firms is on the magnitude of 74 basis-points in the sub-sample of large technology-acquirers, and on the magnitude of 56 basis-points in the sub-sample of large firms increasing their R&D expenditures significantly. These abnormal monthly returns translate to three-year cumulative compounded abnormal returns of -23.49 and -18.36 percent, respectively. In terms of R&D-event-induced systematic risk changes, the results indicate that the large-size technology-acquiring firms have a significant increase in the cost of their equity on the magnitude of 21 basis-points per month. This estimated change in the cost of equity is robust to the estimation period (i.e., three or five years). On the other hand, for the small-size technology-acquirers and the large- and small-size firms increasing their R&D expenditures significantly, none of their estimated changes in the cost of equity is significant at conventional levels.

We believe that our results indicate clearly that the risk-change argument does not explain the above reported price-drift for the large-size R&D-investing firms. Still as additional support to this latter conclusion, we note the following observation. Using either sample, we find that the large- instead of small-size firms are the ones with the more significant post-R&D-investment price drift, which is again contrary to the prediction of a less dramatic effect on the systematic risk of large- versus small-size firms (Gomes, Kogan and Zhang (2003)).

IV. Agency-cost related indicators for the large-size R&D-investing firms

Since the cumulative evidence we report from the above robustness tests indicates that the post-R&D-investment negative price drift experienced at large-size firms is neither due to methodology, nor due to a change in systematic risk, we examine the remaining possible explanation, namely the R&D over-investment argument of Jensen (1993). For this reason, we test whether the large-size firms have more (over-)investment discretion than the small-size firms and we examine their relative valuation multiples.

A. Internally-generated cash flows and (over-)investment discretion

We classify in Panels A and B of Table 10 the large- and small-size R&D-investing firms into NYSE quintiles defined by the ratio of earnings before interest and taxes plus depreciation to total assets and the ratio of earnings before extraordinary items minus dividends plus depreciation to total assets, respectively. The first ratio measures the firm's operating cash flow. The second ratio measures the firm's net cash flow after paying the interest and dividends to investors (i.e., discretionary cash flow). Then we conduct two χ^2 tests: 1) test of equality of row cell frequencies; and 2) test of independence of column and row frequencies.

As the χ^2 tests for the equality of row cell frequencies indicate, we find that most of the large-size R&D-investing firms are classified with the NYSE firms that have large cash flow ratios; whereas, most of the R&D-investing small-size firms are classified with the NYSE firms that have low cash flow ratios. Additionally, the χ^2 tests for independence of column and row frequencies indicate significant differences between large- and small-size sample firms in terms of their cash flow ratios. These results, therefore, suggest that the negative post-R&D-investment price drift to large-size firms may be the result of their (over-)investment discretion. Apparently, being equity-dependent and more under the scrutiny of investors in the stock market, as the small-size firms appear to be, may do the firm good.

B. Valuation multiples of large- and small-size R&D-investing firms

As mentioned above, Jensen (2005) argues there are agency costs that result from firm over-valuation. Accordingly, we classify in Table 11 the largest- and smallest-size sample firms into NYSE quintiles defined by the book-to-market value of equity (B/M) ratio for the purpose of determining whether the difference in the post-R&D-investment long-run stock price performance between large- and small-size firms is likely to be agency-cost-related.

We find that while the χ^2 tests for the equality of row cell frequencies indicate that a large percentage of the technology-acquirers (large and small) have low B/M ratios (i.e., high valuation or over-valuation); however, the χ^2 test for independence of column and row frequencies indicates a significant difference between large- and small-size technology-acquirers in terms of their B/M ratio classifications. About 81 percent of the large-size compared to about 45 percent of the small-size technology-acquiring firms belong to the lowest B/M quintile.

Similarly, the χ^2 test for independence of column and row frequencies indicates a significant difference in the B/M classifications of large- and small-size firms that significantly increase their R&D expenditures. About 76 percent of the large-size compared to about 27 percent of the small-size firms increasing their R&D expenditures belong to the lowest B/M quintile. *To the extent* that being classified among the lowest B/M ratio quintile represents over-valuation, the results we report in Table 11 are consistent with an agency-cost explanation of the negative post-R&D-investment price drift for the large-size firms in our samples.[9]

V. Summary and conclusion

We examine the stock price and systematic risk effects of corporate R&D investment using two samples: acquisitions of patented and/or patent-pending technologies from external sources and significant increases in corporate-wide R&D expenditures. We find a difference in the post-R&D-investment abnormal returns to the equally- and value-weighted rolling-event-portfolios, in both samples. We examine the abnormal returns in different sub-samples and we still find a difference in the results for equally- and value-weighted portfolios. This persistent difference in the results between equal- and value weighing indicates a difference in the stock price effects of corporate R&D investment at large- versus small-size firms. We find that an investment strategy of going short with the largest-size and long with the smallest-size sample firms generates statistically significant positive abnormal monthly returns of about 1.5 percent over three- and perhaps five-years following the R&D investment (not accounting for transaction costs).

We conduct some robustness tests. We run three-risk-factor regressions of the difference between the post- and pre-event rolling-portfolio returns to control and test for any change in the systematic risk of the event-firms and for any pricing deficiency in the three-factor model as applied to our sample firms. We find that the intercept term decreases significantly in the regressions for the large-size R&D-investing-firms. The duration of the event-induced negative abnormal return is three-years long and is on the magnitude of 56 to 74 basis-points per month. We also find evidence of an increase in the systematic risk and consequently in the cost of equity of the large-size technology-acquiring firms on the magnitude of 21 basis-points per month. We find no evidence of a change in the intercept term in the regressions for the small-size firms. Moreover, we find no evidence of a significant change in their systematic risk (or cost of equity). Finally, we examine the cash flow and valuation characteristics of the sample firms and find large-size firms to have significantly much higher cash flow ratios than small-size firms and a greater proportion of them to have low B/M ratio.

Our results lead us to the following conclusion: Evidently, large-size firms that acquire technologies from *external sources* or increase their R&D expenditures *significantly* over-invest in R&D. It appears they are desperate to acquire new technological capabilities and end up wasting some of their large internally-generated cash flows by over-investing. Additionally, investors appear to initially fail to recognize the over-investment in R&D at these firms. Therefore, we report evidence of over-investment in R&D and we find a related pricing anomaly.

REFERENCES

Anderson, C., Garcia-Feijoo, L., 2006. Empirical evidence on capital investment, growth options, and security returns. Journal of Finance 61, 171-194.

Ansoff, H., 1965. Corporate Strategy. McGraw-Hill, New York.

Barber, B.M., Lyon, J.D., 1997. Detecting long-run abnormal stock returns: The empirical power and specification of test statistics. Journal of Financial Economics 43, 341-372.

Barberis, N., Shleifer, A., Vishny, R., 1998. A model of investor sentiment. Journal of Financial Economics 49, 307-343.

Berk, J., Green, R., Naik, V., 1999. Optimal investment, growth options and security returns. Journal of Finance 54, 1153-1607.

Carhart, M., 1997. On persistence in mutual fund performance. Journal of Finance 52, 57-82.

Carlson, M., Fisher, A., Giammarino, R., 2006. Corporate investment and asset price dynamics: Implications for SEO event studies and long-run performance. Journal of Finance 61, 1009-1034.

Chambers, D., Jennings, R., Thompson, R., 2002. Excess returns to R&D-intensive firms. Review of Accounting Studies 7, 133-158.

Chan, L., Lakonishok, J., Sougiannis, T., 2001. The stock market valuation of research and development expenditures. Journal of Finance 56, 2431-2456.

Chan, S.H., Martin, J., Kensinger, J., 1990. Corporate research and development expenditures and share value. Journal of Financial Economics 26, 255-276.

Cooper, I., 2006. Asset pricing implications of non-convex adjustment costs and irreversibility of investment. Journal of Finance 61, 139-170.

Cooper, M., Gulen, H., Schill, M., 2008. Asset growth and the cross-section of stock returns. Journal of Finance 62, forthcoming.

Daniel, K., Hirshleifer, D., Subrahmanyam, A., 1998. Investor psychology and security market under- and over-reactions. Journal of Finance 53, 1839-1885.

Dichev, I., Piotroski, J., 2001. The long-run stock returns following bond ratings changes. Journal of Finance 56, 173-203.

Drucker, P., 1986. A crisis of capitalism. Wall Street Journal, Sept. 30, p. 31.

Eberhart, A., Maxwell, W., Siddique, A., 2004. An examination of long-term abnormal stock returns and operating performance following R&D increases. Journal of Finance 59, 623-650.

Fama, E., French, K., 1993. Common risk factors in the returns on stocks and bonds. Journal of Financial Economics 33, 3-56.

Fama, E., 1998. Market efficiency, long-term returns, and behavioral finance. Journal of Financial Economics 49, 283-306.

Gomes, J., Kogan, L., Zhang, L., 2003. Equilibrium cross-section of returns. Journal of Political Economy 111, 693-732.

Grinblatt, M., Han, B., 2005. Prospect theory, mental accounting, and momentum. Journal of Financial Economics 78, 311-339.

Hall, B., 1993. The stock market's valuation of R&D investment during the 1980's. American Economic Review 83, 259-264.

Hertzel, M., Lemmon, M., Linck, J., Rees, L., 2002. Long-run performance following private placements of equity. Journal of Finance 57, 2595-2617.

Higgins, M., Rodriguez, D., 2006. The outsourcing of R&D through acquisitions in the pharmaceutical industry. Journal of Financial Economics 80, 351-383.

Hong, H., Stein, J., 1999. A unified theory of underreaction, momentum trading, and overreaction in asset markets. Journal of Finance 54, 2143-2184.

Jegadeesh, N., Titman, S., 1993. Returns to buying winners and selling losers: Implications for stock market efficiency. Journal of Finance 48, 65-91.

Jensen, M., 1993. The modern industrial revolution, exit, and the failure of internal control systems. Journal of Finance 48, 831-880.

Jensen, M., 2005. Agency costs of overvalued equity. Financial Management 34, 5-19.

Liu, Y., Szewczyk, S., Zantout, Z., 2008. Under-reaction to dividend reductions and omissions? Journal of Finance 63, forthcoming.

Loughran, T., Ritter, J., 2000. Uniformly least powerful tests of market efficiency. Journal of Financial Economics 55, 361-390.

Mitchell, M., Stafford, E., 2000. Managerial decisions and long-term stock price performance, Journal of Business 73, 287-320.

Odean, T., 1998. Are investors reluctant to realize their losses, Journal of Finance 53, 1775-1798.

Porter, M., 1992. Capital disadvantage: America's failing capital investment system. Harvard Business Review 70, 65-82.

Schumpeter, J., 1934. The Theory of Economic Development. Harvard University Press, Cambridge, Massachusetts.

Shumway, T., 1997. The delisting bias in CRSP data. Journal of Finance 52, 327-340.

Shumway, T., Warther, V., 1999. The delisting bias in CRSP's Nasdaq data and its implications for the size effect. Journal of Finance 54, 2361-2379.

Stein, J., 1988. Takeover threats and managerial myopia. Journal of Political Economy 96, 61-80.

Szewczyk, S., Tsetsekos, G., Zantout, Z., 1996. The valuation of corporate R&D expenditures: Evidence from investment opportunities and free cash flow. Financial Management 25, 105-110.

Titman, S., Wei, K.C., Xie, F., 2004. Capital investments and stock returns. Journal of Financial and Quantitative Analysis 39, 677-700.

Vassolo, R., Anand, J., Folta, T., 2004. Non-additivity in portfolios of exploration activities: A real options-based analysis of equity alliances in biotechnology. Strategic Management Journal 25, 1045-1061.

Zantout, Z., 1997. A test of the debt monitoring hypothesis: The case of corporate R&D expenditures. Financial Review 32, 21-48.

Table 1
The sample of corporate acquisitions of patented or patent-pending technologies from external sources

The sample consists of 806 initial non-contaminated public announcements made in the period from January 1979 through December 2004 by NYSE, AMEX and NASDAQ listed firms with sufficient data on CRSP. The sample technologies are not yet developed commercially and may require further scientific research. The sample technology acquisitions are not preceded by a similar event during the preceding five years. The sample firms represent 211 different four-digit Standard Industry Classification (SIC) industries.

Panel A: Chronological distribution of the sample technology acquisitions

Year	Number of events	% of sample	Year	Number of events	% of sample	Year	Number of events	% of sample	Year	Number of events	% of sample
1979	10	1.24	1986	20	2.48	1993	52	6.45	2000	84	10.42
1980	15	1.86	1987	31	3.85	1994	42	5.21	2001	42	5.21
1981	20	2.48	1988	23	2.85	1995	31	3.85	2002	24	2.98
1982	16	1.99	1989	25	3.10	1996	39	4.84	2003	38	4.71
1983	19	2.36	1990	31	3.85	1997	38	4.71	2004	21	2.61
1984	23	2.85	1991	33	4.09	1998	25	3.10			
1985	16	1.99	1992	48	5.96	1999	40	4.96			
Total for all years										806	100.00%

Panel B: Frequency distribution of number of sample technology acquisitions in a calendar month

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Number of events	75	53	63	61	74	78	66	58	69	76	58	75	806
Percent of sample	9.31	6.58	7.82	7.57	9.18	9.68	8.19	7.20	8.56	9.43	7.20	9.31	100.00%

Panel C: Frequency distribution of number of sample technology acquisitions in a four-digit SIC industry

Number of events in an SIC industry	1	2	3	4	5	6	7	8	9	10	11
Number of SIC industries having the above number of events	114	43	16	7	4	3	4	3	1	3	2
Number of events in an SIC industry	13	14	15	18	23	24	34	36	65	119	
Number of SIC industries having the above number of events	1	1	1	2	1	1	1	1	1	1	

Table 2
The sample of significant increases in corporate R&D expenditures

The sample of firms significantly increasing their R&D expenditures after a two-year period of no significant change consists of 438 firm-year observations. A significant increase in R&D expenditures means an increase that is greater than the median increase for all firms across all years on COMPUSTAT. An insignificant change in R&D expenditures means a change that places the sample firm among the decile of COMPUSTAT firms with the smallest increase or decrease across all years. The sample firms have R&D expenditure intensity ratios that place them among the top 75 percent of all the COMPUSTAT annual observations for all firms across all years. The sample firms significantly increasing their R&D expenditures did not experience a statistically significant change in their capital expenditures intensity, over neither one nor three years prior to the significant increase in R&D expenditures. The sample firms represent 151 different four-digit Standard Industry Classification (SIC) industries.

Panel A: Chronological distribution of the sample of significant increases in corporate R&D investment

Year	Number of events	% of sample	Year	Number of events	% of sample	Year	Number of events	% of sample	Year	Number of events	% of sample
1962	1	0.22	1973	7	1.60	1984	9	2.05	1995	25	5.71
1963	2	0.46	1974	7	1.60	1985	12	2.74	1996	14	3.20
1964	1	0.23	1975	7	1.60	1986	8	1.83	1997	14	3.20
1965	2	0.46	1976	6	1.37	1987	11	2.51	1998	17	3.88
1966	1	0.23	1977	16	3.65	1988	11	2.51	1999	14	3.20
1967	2	0.46	1978	11	2.51	1989	10	2.28	2000	9	2.05
1968	1	0.23	1979	18	4.11	1990	9	2.05	2001	11	2.51
1969	1	0.23	1980	17	3.88	1991	14	3.20	2002	17	3.88
1970	1	0.23	1981	2	0.46	1992	11	2.51	2003	17	3.88
1971	2	0.46	1982	7	1.60	1993	16	3.65	2004	21	4.79
1972	3	0.68	1983	10	2.28	1994	22	5.02	2005	21	4.79
Total for all years										438	100.00%

Panel B: Frequency distribution of number of sample significant R&D investment increases in a calendar month

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Number of events	7	4	23	3	9	41	11	12	28	15	9	276	438
Percent of sample	1.60	0.91	5.25	0.68	2.05	9.36	2.51	2.74	6.39	3.42	2.05	63.01	100.00%

Panel C: Frequency distribution of number of sample R&D investment increases in a four-digit SIC industry

Number of events in an SIC industry	1	2	3	4	5	6	7	8	9	10	13
Number of SIC industries having the above number of events	53	36	20	11	12	6	3	3	5	1	1

Table 3
Size and R&D intensity characteristics of the sample firms

This table classifies the sample R&D investing firms into NYSE quintiles defined by market capitalization (size) and R&D-to-sales ratio (R&D intensity). Missing COMPUSTAT data for some of the sample firms reduce the number of observations in Panels A and B.

Panel A: The sample of technology acquisitions from external sources

	Lowest R&D intensity quintile	Second quintile	Third quintile	Fourth quintile	Highest R&D intensity quintile	Total	Percent of sample
Smallest-firms quintile	1	9	6	17	196	229	34.64
Second size quintile	0	1	4	3	74	82	12.41
Third size quintile	0	0	3	7	43	53	8.02
Fourth size quintile	0	1	3	10	47	61	9.23
Largest-firms quintile	0	8	19	33	176	236	35.70
Total	1	19	35	70	536	661	100.00%
Percent of sample	0.15	2.87	5.30	10.59	81.09	100.00%	

Panel B: The sample of significant increases in R&D expenditures

	Lowest R&D intensity quintile	Second quintile	Third quintile	Fourth quintile	Highest R&D intensity quintile	Total	Percent of sample
Smallest-firms quintile	0	8	21	24	49	102	33.22
Second size quintile	0	3	7	15	16	41	13.36
Third size quintile	0	2	6	12	11	31	10.10
Fourth size quintile	0	5	13	11	10	39	12.70
Largest-firms quintile	1	12	22	28	31	94	30.62
Total	1	30	69	90	117	307	100.00%
Percent of sample	0.33	9.77	22.48	29.32	38.11	100.00%	

Table 4
Long-term stock price performance following corporate R&D investment

This table displays the post-R&D-investment long-term abnormal returns of the sample firms, estimated using the Fama and French (1993) and the Carhart (1997) return models. To estimate three- and five-year period abnormal monthly returns, each month sample firms that acquired some technologies (increased their R&D expenditures) in the previous 36 or 60 months are identified and then equally- and value-weighted average monthly portfolio returns R_{pt} 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 value of the firms in the rolling portfolio at the end of the month before the event date. The rolling portfolio returns, R_{pt}, are used in the models of:

$$\text{Fama and French (1993):}\quad R_{pt} - R_{ft} \;=\; \alpha + \beta_m (R_{mt} - R_{ft}) + \beta_s SMB_t + \beta_h HML_t + \varepsilon_t$$

$$\text{Carhart (1997):}\quad R_{pt} - R_{ft} \;=\; \alpha + \beta_m (R_{mt} - R_{ft}) + \beta_s SMB_t + \beta_h HML_t + \beta_u UMD_t + \gamma_t$$

where R_{ft} is the one-month U.S. Treasury bill rate in month t, R_{mt} 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, UMD_t is the equal-weight average of firms with the highest 30 percent eleven-month returns lagged one month minus the equal-weight average of firms with the lowest 30 percent eleven-month returns lagged one month, and α, β_m, β_s, β_h and β_u 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 average abnormal monthly return of the event-portfolio across all 36 or 60 months. The probability values shown in brackets pertain to two-tailed *t*-tests.

Period following R&D investment	Event portfolio return	Parameters' estimation method	Sample of technology acquisitions from external sources		Sample of significant increases in R&D expenditures	
			3-factor model α [*p*-value] *Adj.* R^2	4-factor model α [*p*-value] *Adj.* R^2	3-factor model α [*p*-value] *Adj.* R^2	4-factor model α [*p*-value] *Adj.* R^2
Three years	Equally-weighted	OLS	0.00191 [0.503] 0.666	0.00534 [0.058] 0.693	0.00096 [0.546] 0.645	0.00172 [0.291] 0.647
		WLS	0.00446 [0.120] 0.690	0.00814 [0.004] 0.722	0.00183 [0.245] 0.655	0.00281 [0.082] 0.659
	Value-weighted	OLS	-0.00191 [0.488] 0.529	-0.00021 [0.940] 0.538	-0.00588 [0.013] 0.448	-0.00469 [0.052] 0.452
		WLS	-0.00077 [0.745] 0.635	0.00128 [0.589] 0.652	-0.00668 [0.005] 0.437	-0.00516 [0.034] 0.445
Five years	Equally-weighted	OLS	0.00555 [0.075] 0.626	0.00947 [0.002] 0.659	0.00039 [0.775] 0.706	0.00098 [0.486] 0.707
		WLS	0.00902 [0.005] 0.635	0.01312 [0.000] 0.672	0.00106 [0.437] 0.714	0.00171 [0.220] 0.716
	Value-weighted	OLS	-0.00317 [0.237] 0.547	-0.00144 [0.596] 0.557	-0.00418 [0.052] 0.474	-0.00370 [0.095] 0.474
		WLS	-0.00261 [0.247] 0.654	-0.00064 [0.777] 0.670	-0.00500 [0.017] 0.481	-0.00415 [0.053] 0.483

Table 5
Long-term stock price performance following corporate R&D investment, by technology level

This table displays the post-R&D-investment long-term abnormal returns in sub-samples defined by the technology level of the industry in which the sample firm operates. It is motivated by the finding of a difference in the initial stock price response of high- versus low-technology firms. The classification into high- versus low-technology industries follows Chan, Martin and Kensinger (1990) and Zantout (1997). 610 of the 806 cases forming the sample of technology acquisitions pertain to high-technology industries. 217 of the 438 cases forming the sample of significant increases in corporate R&D expenditures pertain to high-technology industries. All the average abnormal monthly returns (i.e., intercept α) reported below are WLS estimates. The results using OLS estimates are similar. The probability values shown in brackets pertain to two-tailed *t*-tests.

Sub-sample	Period following R&D investment	Event portfolio return	Sample of technology acquisitions from external sources		Sample of significant increases in R&D expenditures	
			3-factor model α [*p*-value] *Adj.* R^2	4-factor model α [*p*-value] *Adj.* R^2	3-factor model α [*p*-value] *Adj.* R^2	4-factor model α [*p*-value] *Adj.* R^2
Firms in high-technology industries	Three years	Equally-weighted	0.00593 [0.089] 0.647	0.01008 [0.003] 0.678	0.00327 [0.142] 0.560	0.00426 [0.062] 0.562
		Value-weighted	0.00112 [0.685] 0.611	0.00353 [0.200] 0.629	-0.00654 [0.021] 0.366	-0.00455 [0.113] 0.378
	Five years	Equally-weighted	0.01081 [0.003] 0.641	0.01543 [0.000] 0.679	0.00280 [0.166] 0.598	0.00338 [0.104] 0.599
		Value-weighted	-0.00177 [0.508] 0.630	0.00037 [0.891] 0.645	-0.00444 [0.0887] 0.375	-0.00239 [0.366] 0.391
Firms in low-technology industries	Three years	Equally-weighted	-0.00200 [0.538] 0.458	0.00084 [0.794] 0.485	0.00020 [0.926] 0.472	0.00135 [0.544] 0.476
		Value-weighted	-0.00586 [0.035] 0.388	-0.00570 [0.046] 0.386	-0.00545 [0.076] 0.315	-0.00516 [0.102] 0.314
	Five years	Equally-weighted	0.00320 [0.559] 0.222	0.00572 [0.306] 0.230	-0.00113 [0.479] 0.612	-0.00020 [0.902] 0.616
		Value-weighted	-0.00468 [0.032] 0.518	-0.00431 [0.053] 0.518	-0.00442 [0.081] 0.379	-0.00455 [0.081] 0.377

Table 6
Long-term stock price performance following corporate R&D investment, by book-to-market classification

This table displays the post-R&D-investment long-term abnormal returns in sub-samples defined by the categorization of the sample firms as growth (low book-to-market) or value (high book-to-market) stocks. It is motivated by the proposition / argument in recent models (Gomes, Kogan and Zhang (2003); Cooper (2006)) that high B/M firms have higher systematic risk than low B/M firms. The sample growth-stocks appertain to the two-bottom NYSE quintiles of book-to-market value of equity (B/M) ratio; whereas, the sample value-stocks appertain to the two-top NYSE quintiles of B/M ratio. Accordingly, the sub-sample of technology acquisitions pertaining to growth (value) stocks includes 583 (115) cases; whereas, the sub-sample of significant increases in corporate R&D expenditures pertaining to growth (value) stocks includes 269 (85) cases. All the average abnormal monthly returns (i.e., intercept α) reported below are WLS estimates. The results using OLS estimates are similar. The probability values shown in brackets pertain to two-tailed *t*-tests.

Sub-sample	Period following R&D investment	Event portfolio return	Sample of technology acquisitions from external sources		Sample of significant increases in R&D expenditures	
			3-factor model α [*p*-value] *Adj.* R^2	4-factor model α [*p*-value] *Adj.* R^2	3-factor model α [*p*-value] *Adj.* R^2	4-factor model α [*p*-value] *Adj.* R^2
Growth stocks	Three years	Equally-weighted	0.00006 [0.979] 0.735	0.00323 [0.181] 0.762	-0.00101 [0.578] 0.600	0.00016 [0.931] 0.606
		Value-weighted	-0.00081 [0.735] 0.632	0.00122 [0.610] 0.648	-0.00697 [0.004] 0.422	-0.00556 [0.026] 0.429
	Five years	Equally-weighted	0.00131 [0.537] 0.782	0.00454 [0.024] 0.815	-0.00043 [0.759] 0.725	0.00009 [0.952] 0.726
		Value-weighted	-0.00264 [0.244] 0.654	-0.00068 [0.765] 0.670	-0.00534 [0.013] 0.463	-0.00451 [0.042] 0.465
Value stocks	Three years	Equally-weighted	0.01939 [0.031] 0.250	0.02636 [0.004] 0.278	0.01248 [0.007] 0.307	0.01360 [0.004] 0.308
		Value-weighted	0.00156 [0.746] 0.291	-0.00117 [0.810] 0.304	-0.00253 [0.433] 0.414	0.00014 [0.966] 0.436
	Five years	Equally-weighted	0.05162 [0.001] 0.140	0.06081 [0.000] 0.159	0.01041 [0.023] 0.282	0.01133 [0.016] 0.282
		Value-weighted	0.00042 [0.926] 0.282	-0.00196 [0.667] 0.293	-0.00219 [0.454] 0.454	0.00047 [0.872] 0.478

Table 7
Long-term stock price performance following significant increases in corporate R&D expenditures, by percent R&D expenditure increase

This table displays the post-R&D-investment long-term abnormal returns in sub-samples defined by the acceleration of R&D spending (i.e., greater versus lower than the sample median percent increase). This table is motivated by the finding of Anderson and Garcia-Feijoo (2006) that growth in capital expenditures explains the cross section of subsequent stock returns and the theoretical models of Berk, Green and Naik (1999) and Gomes, Kogan and Zhang (2003) which propose that the exercise (acquisition) of investment options reduces (increases) the firm's systematic risk. It follows that in the absence of controlling for the predicted change in systematic risk, firms exercising (acquiring) growth options should exhibit a post-exercise (-acquisition) negative (positive) abnormal return. All the average abnormal monthly returns reported below are WLS estimates. The OLS results are similar. The probability values shown in brackets pertain to two-tailed *t*-tests.

Period following R&D expenditure increase	Event portfolio return	Sub-sample of increases in R&D expenditures greater than sample median		Sub-sample of increases in R&D expenditures less than sample median	
		3-factor model α [*p*-value] *Adj.* R^2	4-factor model α [*p*-value] *Adj.* R^2	3-factor model α [*p*-value] *Adj.* R^2	4-factor model α [*p*-value] *Adj.* R^2
Three years	Equally-weighted	0.00304 [0.225] 0.500	0.00382 [0.137] 0.501	0.00075 [0.664] 0.575	0.00199 [0.258] 0.581
	Value-weighted	-0.00662 [0.041] 0.340	-0.00561 [0.090] 0.342	-0.00609 [0.036] 0.345	-0.00476 [0.109] 0.349
Five years	Equally-weighted	0.00264 [0.242] 0.511	0.00328 [0.157] 0.512	-0.00019 [0.884] 0.688	0.00054 [0.693] 0.690
	Value-weighted	-0.00288 [0.311] 0.367	-0.00350 [0.230] 0.367	-0.00562 [0.029] 0.383	-0.00441 [0.094] 0.387

Table 8
Long-term stock price performance following corporate R&D investment, by firm size

This table has two motivations. First, following Berk, Green and Naik (1999) and Gomes, Kogan and Zhang (2003), the exercise (acquisition) of investment options reduces (increases) the firm's systematic risk of small-size firms more than the systematic risk of large-size firms because the former derive most of their value from growth options whereas the latter have more ongoing projects (assets-in-place). It follows that in the absence of controlling for the predicted change in systematic risk, small-size firms compared to large-size firms exercising (acquiring) growth options should exhibit a post-exercise (-acquisition) negative (positive) abnormal return that is greater in absolute terms. Second, the results above indicate a difference in the long-term results for large- versus small-size R&D-investing firms. Panel A displays the long-term abnormal returns in sub-samples defined by appurtenance to largest versus smallest NYSE market capitalization quintiles. All the average abnormal monthly returns reported in Panel A are WLS estimates. The results using OLS estimates are similar. Since the sub-samples are defined by market capitalization quintiles, we use equally-weighted portfolio returns only. The sub-sample of largest- (smallest-) size technology-acquirers consists of 258 (290) cases; whereas, the sub-sample of largest- (smallest-) size firms significantly increasing their R&D expenditures consists of 132 (124) cases. Panel B displays the monthly arbitrage return from an investment strategy of going long on largest-size and short on smallest-size R&D-investing firms, assuming no transaction costs. The difference in the post-R&D-investment price drift is obtained from OLS regressions of the difference between the equally-weighted monthly-portfolio returns of event-firms in largest- and smallest-size quintiles ($R_{L.t} - R_{S.t}$) on the risk factors of the models of Fama and French (1993) and Carhart (1997):

$$R_{L.t} - R_{S.t} = (\alpha_L - \alpha_S) + (\beta_{mL} - \beta_{mS})\,(R_{mt} - R_{ft}) + (\beta_{sL} - \beta_{sS})\,SMB_t + (\beta_{hL} - \beta_{hS})\,HML_t + \varepsilon_t$$

$$R_{L.t} - R_{S.t} = (\alpha_L - \alpha_S) + (\beta_{mL} - \beta_{mS})\,(R_{mt} - R_{ft}) + (\beta_{sL} - \beta_{sS})\,SMB_t + (\beta_{hL} - \beta_{hS})\,HML_t + (\beta_{uL} - \beta_{uS})\,UMD_t + \gamma_t$$

The probability values shown in brackets pertain to two-tailed *t*-tests.

Panel A: Post-R&D-investment long-term abnormal returns in sub-samples defined by relative market capitalization

Sub-sample	Period following R&D investment	Sample of technology acquisitions from external sources		Sample of significant increases in R&D expenditures	
		3-factor model α [*p*-value] *Adj. R^2*	4-factor model α [*p*-value] *Adj. R^2*	3-factor model α [*p*-value] *Adj. R^2*	4-factor model α [*p*-value] *Adj. R^2*
Firms in largest-size quintile	Three years	-0.00306 [0.079] 0.772	-0.00038 [0.819] 0.806	-0.00428 [0.017] 0.585	-0.00347 [0.059] 0.587
	Five years	-0.00213 [0.251] 0.740	0.00096 [0.576] 0.786	-0.00291 [0.044] 0.686	-0.00244 [0.099] 0.687
Firms in smallest-size quintile	Three years	0.01483 [0.018] 0.462	0.02060 [0.001] 0.489	0.01492 [0.002] 0.325	0.01624 [0.001] 0.326
	Five years	0.02736 [0.001] 0.357	0.03400 [0.000] 0.386	0.01201 [0.004] 0.385	0.01255 [0.003] 0.384

Panel B: Difference in the long-term stock price performance of large- and small-size firms

Period following R&D investment	Sample of technology acquisitions from external sources		Sample of significant increases in R&D expenditures	
	α_L - α_S using 3-factor model [*p*-value] *Adj. R^2*	α_L - α_S using 4-factor model [*p*-value] *Adj. R^2*	α_L - α_S using 3-factor model [*p*-value] *Adj. R^2*	α_L - α_S using 4-factor model [*p*-value] *Adj. R^2*
Three years	-0.01279 [0.030] 0.284	-0.01549 [0.010] 0.290	-0.01564 [0.003] 0.207	-0.01632 [0.002] 0.206
Five years	-0.02123 [0.003] 0.209	-0.02441 [0.001] 0.216	-0.01197 [0.004] 0.249	-0.01215 [0.005] 0.247

Table 9
Long-term stock price performance and R&D-investment-induced change in the cost of equity, by firm size

This table examines the robustness of the above reported post-R&D-investment long-term abnormal returns while controlling for any potential systematic risk changes. It is motivated by the argument that the acquisition / exercise of R&D-investment-growth options may result in changes in the risk attributes, and therefore, the expected returns of the sample firms (Berk, Green and Naik (1999); Gomes, Kogan and Zhang (2003)). By setting $R_{p,t}$ as the equally-weighted return during month t of the portfolio comprised of sample firms making R&D investments during the following n months, then $R_{p,t+n+1}$ becomes the equally-weighted return during month $t+n+1$ of the portfolio comprised of sample firms that made R&D investments during the preceding n months, with $n = 36$ or 60 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) 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,

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

We apply this model and test for the significance of α_{Δ} . The parameters reported below are all WLS estimates. The results using OLS estimates are similar. The probability values shown in brackets pertain to two-tailed *t*-tests. This table also displays the R&D-investment-induced change in the cost of equity (required return), which is estimated 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 respective sampling periods and then summing up the three products. The mean monthly realizations for these latter are: 0.0065535, 0.0018144, and 0.0038506, respectively over the period 1979-2004; 0.0044771, 0.0022871, and 0.0046381, respectively, over the period 1962-2005. Estimating the mean monthly realizations of $(R_{m,t} - R_{f,t})$, SMB_t , and HML_t over the 1927-2005 period results in economically and statistically similar results. The statistical significance of the change in the cost of equity is determined by running the above rolling-portfolio regressions 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.

Sub-sample	Period following R&D investment	Sample of technology acquisitions from external sources		Sample of significant increases in R&D expenditures	
		3-factor model α_{Δ} [*p*-value] *Adj.* R^2	Mean monthly change in cost of equity (%) [*p*-value]	3-factor model α_{Δ} [*p*-value] *Adj.* R^2	Mean monthly change in cost of equity (%) [*p*-value]
Firms in largest-size quintile	Three years	-0.00741 [0.001] 0.800	0.20967 [0.056]	-0.00562 [0.016] 0.636	-0.07857 [0.323]
	Five years	-0.00484 [0.045] 0.788	0.21096 [0.053]	-0.00153 [0.429] 0.737	-0.05899 [0.399]
Firms in smallest-size quintile	Three years	-0.01164 [0.432] 0.228	0.06519 [0.978]	0.00447 [0.671] 0.079	0.18189 [0.632]
	Five years	-0.00042 [0.973] 0.276	-0.10958 [0.535]	0.00537 [0.457] 0.244	0.35841 [0.199]

Table 10
Internally-generated cash flows at large- and small-size R&D-investing firms

Panels A and B classify the large- and small-size R&D-investing firms into NYSE quintiles defined by the ratio of earnings-before-interest-taxes-plus-depreciation to total-assets and the ratio of earnings-before-extraordinary-items-minus-dividends-plus-depreciation to total-assets, respectively, for the purpose of determining whether the asymmetric post-R&D-investment long-run stock price performance of large- versus small-size firms is likely to be agency-cost-based.

Panel A: Classifications of sub-sample firms into NYSE quintiles of ratio of earnings-before-interest-taxes-and-depreciation to total-assets (from low to high cash flow)

Sub-sample	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile	[*p*-value] for χ^2 test of equality of row cell frequencies
Largest-size technology-acquirers	18 6.87%	38 14.50%	56 21.37%	66 25.19%	84 32.06%	[0.000]
Smallest-size technology-acquirers	202 71.89%	23 8.19%	20 7.12%	19 6.76%	17 6.05%	[0.000]
[*p*-value] for χ^2 test of independence of column and row frequencies = [0.000]						
Largest-size firms increasing their R&D expenditures	4 2.76%	15 10.34%	27 18.62%	54 37.24%	45 31.03%	[0.000]
Smallest-size firms increasing their R&D expenditures	51 38.64%	19 14.39%	21 15.91%	21 15.91%	20 15.15%	[0.000]
[*p*-value] for χ^2 test of independence of column and row frequencies = [0.000]						

Panel B: Classifications of sub-sample firms into NYSE quintiles of ratio of earnings-before-extraordinary-items-minus-dividends-plus-depreciation to total-assets (from low to high cash flow)

Sub-sample	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile	[*p*-value] for χ^2 test of equality of row cell frequencies
Largest-size technology-acquirers	16 6.11%	30 11.45%	58 22.14%	66 25.19%	92 35.11%	[0.000]
Smallest-size technology-acquirers	184 65.48%	23 8.19%	22 7.83%	19 6.76%	33 11.74%	[0.000]
[*p*-value] for χ^2 test of independence of column and row frequencies = [0.000]						
Largest-size firms increasing their R&D expenditures	4 2.76%	19 13.10%	33 22.76%	55 37.93%	34 23.45%	[0.000]
Smallest-size firms increasing their R&D expenditures	37 28.03%	20 15.15%	22 16.67%	25 18.94%	28 21.21%	[0.152]
[*p*-value] for χ^2 test of independence of column and row frequencies = [0.000]						

Table 11
Valuation multiples of large- and small-size R&D-investing firms

This table classifies the largest- and smallest-size sample firms into NYSE quintiles defined by the book-to-market value of equity (B/M) ratio for the purpose of determining whether the asymmetric post-R&D-investment long-run stock price performance of large- versus small-size firms is likely to be agency-cost-related.

Sub-sample	Lowest B/M quintile	Second quintile	Third quintile	Fourth quintile	Highest B/M quintile	[*p*-value] for χ^2 test of equality of row cell frequencies
Largest-size technology-acquirers	209 81.01%	30 11.63%	12 4.65%	4 1.55%	3 1.16%	[0.000]
Smallest-size technology-acquirers	130 44.83%	39 13.45%	29 10.00%	31 10.69%	61 21.03%	[0.000]
[*p*-value] for χ^2 test of independence of column and row frequencies = [0.000]						
Largest-size firms increasing their R&D expenditures	100 75.76%	18 13.64%	8 6.06%	5 3.79%	1 0.76%	[0.000]
Smallest-size firms increasing their R&D expenditures	34 27.42%	22 17.74%	20 16.13%	17 13.71%	31 25.00%	[0.075]
[*p*-value] for χ^2 test of independence of column and row frequencies = [0.000]						

---

[1] Jensen (2005) argues that aligning the interests of the manager with those of shareholders through equity-based compensation could make the problem even worse. Also, the external corporate control mechanism cannot be triggered because there is no profit in acquiring an over-valued firm.

[2] Related evidence from corporate capital expenditures follows: First, Titman, Wei and Xie (2004) report a *negative* relation between increased corporate capital expenditures and the subsequent long-term stock price performance. This negative relation is stronger for firms with less debt / more cash flows and significant only during time periods when hostile takeovers are less prevalent. Therefore, they attribute the post-investment negative price drift to over-investment discretion that their sample firms have and suggest that investors overlook it initially. Second, Anderson and Garcia-Feijoo (2006), who similarly report that firms that accelerate investment spending experience significantly lower subsequent monthly returns, also find that firm-specific capital investment appears to condition subsequent classification of firms to size and book-to-market portfolios. Controlling for size, low (high) book-to-market firms significantly accelerate (slow down) investment prior to the portfolio classification year, their market values rise (decrease) and their book-to-market ratios decrease (increase). Therefore, they attribute the post-investment negative price drift to a reduction of the risk of their sample firms as a result of these latter exercising some of their investment options.

[3] In randomly chosen samples of firms with low book-to-market ratios and small sizes, the null hypothesis of zero abnormal return is over-rejected. This fact is particularly important to recognize in a study on R&D investment since many of the R&D investing firms may be of that group.

[4] They also report a positive announcement-period stock price response, which is consistent with what we report. They do not examine the long-term stock price performance of these firms.

[5] Some recent studies of major corporate events report significant post-announcement abnormal stock price drifts (e.g., dividend cuts and omissions: Liu, Szewczyk and Zantout (2008); private placements of equity: Hertzel, Lemmon, Linck and Rees (2002); and bond ratings downgrades: Dichev and Piotroski (2001)). This evidence is inconsistent with the ‘rational expectations’ model and the ‘efficient capital markets hypothesis,’ and it suggests that investors exhibit cognitive biases in interpreting or assessing corporate disclosures.

[6] We did not lose many announcements because of this criterion.

[7] Regrettably, there are numerous cases of technology acquisitions that we cannot include in our sample because they are made by development-stage *privately-held* companies.

[8] We used the mean monthly realizations of $(R_{m,t} - R_{f,t})$, SMB_t , and HML_t over the 1927-2005 period and our results came out economically and statistically similar.

[9] We point out that the robustness test we conduct above controls for a potential model pricing deficiency.