Total Market Returns to Innovation

Ashish Sood and Gerard J. Tellis

Ashish Sood (ashish_sood@bus.emory.edu, 404-727-4226) is Assistant Professor Marketing, Goizueta School of Business, Emory University.

Gerard J. Tellis (tellis@usc.edu, 626-369-4391) is Professor of Marketing, Director of the Center for Global Innovation and Neely Chair in American Enterprise at the Marshall School of Business, University of Southern California.

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ABSTRACT

Analysts often decry the fact that managers under-invest in innovation due to their short-term orientation. The reason may be that assessing market returns to innovation is difficult. Moreover, the studies that have done so have assessed market returns to one or other innovation events, rather the entire innovation project that results in a new product. Using new data on 3 industries and 13 technologies, the authors examine the market returns to entire innovation projects. They find that the response of markets to many, but not all, innovation-related events is positive. Market returns to the development phase are the higher than either the initiation phase or the commercialization phase. Returns to the announcing firm relative to its competitors are also the highest in the development phase. Most important, limiting the analysis to any one innovation event, e.g. commercialization of a new product or any other single activity within an innovation project severely under-estimates the total returns to innovation.

INTRODUCTION

Innovation is probably one of the most important forces in fueling the growth of new products and brands, sustaining incumbents, creating new markets, transforming industries, and promoting the global competitiveness of nations. Even so, many researchers, analysts, and managers fear that firms do not invest enough in innovation. For example U.S. R&D expenditures in 1984 declined from 55 percent of the G-7 total to 52 percent in 2000 (National Science Board 2004). Some go so far as to complain that the U.S. may be losing its competitive edge and its famed leadership in innovation because of declining investment in research and development relative to other nations (National Innovation Initiative Report 2004; The Council on Competitiveness Report 2001). Firms may not invest enough in R&D because of the high costs of such investments, the long delay in reaping market returns if any, the uncertainty of those returns, and the difficulty of adequately measuring them. Indeed, accurately assessing the market returns to innovation may be critical to motivating firms to invest in innovation. For this reason, this topic is in the Marketing Science Institute's list of top research priorities for the last few years.

Prior research has examined the effect of innovation on firm performance measures like sales, profits, or market share. But these measures are subject to many other strategic and environmental factors so that the path of causality is not clear. The market returns to innovation is one of the best means of assessing the true rewards to innovation. Under the assumption that the stock market is efficient, such returns can be assessed by the event study (Fama 1998). The event study measures the stock market reaction to new information in an event, which is assumed to be proportional to the net present value of the new information. In an early application of this

method, Chaney, Deveney and Winer (1991) report positive market returns of 0.25% to the announcement of new product introductions.

However, the announcement of new product introduction is only one such event during the entire innovation project (Hauser, Tellis and Griffin 2005). Announcements are made all through the innovation project, which includes a new product's initiation, concept development, testing, technology development, patenting, prototype design, and test marketing, in addition to the new product introduction. To the extent that all information prior to the introduction is incorporated in stock prices, market returns to the announcement of only the introduction may seriously under report the total market returns to innovation.

Hence, a researcher might arrive at erroneous estimates of the true return to innovation by limiting the scope of study to announcements of only a new product's introduction, or any other single event. As far as we know, there is no study done on the market returns to all events in an innovation project. This is the goal of this study. In particular, it seeks answers to the following questions:

- How do stock markets react to announcements of event in an innovation project?
- What is the total market return to the innovation project?
- What is the market return to specific phases of the innovation project
- How do the market returns of the announcing firm compare with the market returns to its competitors in each of the three phases?

The rest of the paper is organized as follows: The next three sections present the theory, method and findings. The last section discusses the limitations and implications of the research.

THEORY

This section describes prior findings on markets returns to innovation. We then develop expectations about market returns and other events in the innovation project. To better lay out the area, we begin by defining the key terms and assumptions of the study.

Definition

We adopt the definition of platform innovation by Sood and Tellis (2005) as the emergence of a new technology based on scientific principle distinctly different from those of the existing technologies. For example fluorescent lamps use a new scientific principle – light emission by passing an electric current through a low-pressure gas chamber – relative to the prior technology, incandescence – light emission by passing an electric current through a metal in a vacuum. We define an innovation project as the total of a firm's activities in researching, developing, and introducing a new product, from the initiation of a new technological platform to about a year after introduction of the new product. For example, Philips' research efforts in developing and commercializing a compact fluorescent lamp (a new product based on fluorescence technology) comprises the innovation project for that new product. We define a technological announcement as the release of information regarding any aspect of an innovation project.

The event study (Fama, Fisher, Jensen, and Roll 1969) is one of the most widely used analytical tools in financial research. The basic assumption underlying the method is the efficient market hypothesis, which states that a stock price at a particular point in time fully reflects all available information up to that point (Sharpe 1964; Fama 1998). Thus, any change in price of a stock due to new information at some point in time reflects the present value of all expected future profits from that new information. The method has been widely used in the finance, accounting, economics, management, and marketing literatures to assess the marketing value of

information contained in various events of interest. The market return to an event of a firm is the change in the stock price of that firm due to that event, above that due to the general market at the time of the event. The method section explains how we compute such market returns to an event. Totals return to innovation is the cumulative return to all events within an innovation project.

Prior Research on Market Returns to Innovation

Prior research has estimated returns to five isolated events of an innovation project: alliance formation and acquisition, resource allocation and expansion, patents, new product introduction, and external recognition of quality. In addition, authors have highlighted other important events of an innovation project like identification of new materials, performance improvement, new applications and advance orders, development and demonstration of working prototypes, and initial shipments as well. Here we briefly summarize that research (see Table 1). We then present what we think to be a more complete assessment of the total market returns to innovation.

Innovation also creates turmoil in the industry, changing existing competitive positions and spurring competition. Most prior studies find that competitors experience negative returns in response to announcements of a target firm regarding various events in its innovation project (Zantout and Tsetsekos 1994; Chen, Ho, Ik and Lee 2002; Ferrier and Lee 2002; Akhigbe 2002). However, to our knowledge, there is no study that examines the returns to firms relative to its competitors at all or various events of the innovation project.

Alliances and Acquisitions

Joint ventures and technological alliances enhance the probability of success of R&D ventures, reduce duplication of efforts, and allow better utilization of resources (Aaker 1995; Suarez 2002). Firms frequently make announcements of the formation of joint ventures and

technological alliances for developing and marketing new products. These alliances may be between firms with complementary competencies or between firms with different value propositions in the value chain. Prior research has found that markets usually react positively to news of formation of such alliances (see Table 1).

Resource Allocation and Expansion

Technological superiority forms the basis of competition in many industries (Sood and Tellis 2005). As such, firms frequently make massive investments in innovation to the extent that the amount of R&D spending in some major industries is more than their annual earnings (Chan, Lakonishok and Sougiannis 2001). Prior research has found that markets react positively to announcements on R&D investments (see Table 1).

Identification of New Materials and Patents

The basis of competition in many industries like biotechnology and telecommunications is preemption by acquiring competencies and technologies ahead of rivals often through patent protection. Authors claim that being the first confers competitive advantages to firms (Griliches 1981; Cockburn and Griliches 1988; Lieberman and Montgomery 1988). Firms frequently release information about innovation in advanced materials including both discovery of completely new materials and identification of new ways to produce and utilize existing materials. Success also signals expertise in new technologies and sciences like chemistry, physics, optics, and mechanics (Austin 1993). While prior research (Griliches, Pakes and Hall 1987; Pakes 1985; Jaffe 1986; Connolly and Hirschey 1988) reports positive returns to firms on announcements of patents, we are not aware of any research that examines returns to announcements of identification of new materials and components (see Table 1).

Performance Improvement

Regular improvements in product performance create long term competitive advantages (Chauvin and Hirschey 1993; Erickson and Jacobson 1992). Often product performance also takes the form of higher reliability or lower costs thereby enhancing the total value of the product. In such cases, firms benefit as this information may lead consumers to postpone purchasing competitors' products and wait for the introduction of these products. The returns from such differentiation strategies increase with the degree of competition in these markets (Schumpeter 1942). However, we are not aware of any prior studies that estimate returns on improvements in product performance.

Development and Demonstration of Working Prototypes

Firms announce the availability of or demonstrate working prototypes of future new products to signal to markets their interim success in the innovation project. Frequently these prototypes are also displayed in industry exhibitions to enhance consumer awareness and expectation of future introductions. Markets react positively to such announcements (Kelm, Narayanan and Pinches 1995; Koku, Jagpal and Viswanath 1997).

New Products

In most cases, the ultimate goal of innovation is to market new products. The introduction of a new product signals to the market the continued viability of the firm and the potential for future growth and profits (Eddy and Saunders 1980; Chaney, Divenney and Winer 1991). Past research indicates that markets react positively to introduction of new products (Koku, Jagpal and Viswanath 1997; Sorescu, Chandy and Prabhu 2003). Bayus, Erickson, and Jacobson (2003) found that effect of new product introduction yields high returns to firms because of a reduction in selling and general administrative expenses. The introduction of new

product also enhances the firm's capability to optimize its product portfolio and to replenish mature products (Urban and Hauser 1980).

New Applications

Following the introduction of new products, firms sometimes announce new applications of and markets for their new products. Expansion of markets for existing and new products results in growth for the firm and industry (Paulson Gjerde, Slotnick and Sobel 2002). Often this expansion is vast and common, especially in emerging technologies, because improvements in product performance enable new products to fulfill demand for higher performance (Rosenberg 1997). It also opens avenues for a firm's further research and development to adapt products to new markets. Moreover, procurement of orders from big suppliers for products in advance of product development reduces the uncertainty and enhances the financial resources of the firm. Such announcements also signal competence and capability of the firm and improve its corporate image. We are not aware of any prior studies to estimate returns to such events.

Initial shipments

Speed to market and dependable new product delivery provide strong competitive advantages to firms (Griffin 1993; Smith 1999). Building a reputation for fast and efficient product development and introduction can also lock competitors out. In emerging technologies, firms frequently ship small quantities of products for trial to key customers before introducing them in all markets. Information about initial shipments reduces uncertainty associated with product development and sends strong positive signals to the markets about the success of firms' endeavors. We are not aware of any prior studies that include such information to estimate returns to innovation.

External Recognition of Quality

Quality is an important factor affecting the consumer decision project and has a positive influence on market share (Jacobson and Aaker 1987; Buzzell and Wiersema 1981). Consumer perceptions about quality define success or failure of competing brands. However, prior research also suggests that consumers are imperfectly informed of quality and rely on expert opinions for assessing product quality (Tellis and Wernerfelt 1987). Hence, when consumers are informed about external recognition of quality, e.g. through quality awards, the price of that firm's stock is likely to go up. Prior research report that returns to information about quality awards of new products is positive (Balasubramanian, Mathur and Thakur 2005; Hendricks and Singhal 1996; Przasnyski and Tai 1999).

Expectation about Returns to Innovation Project

Past research has focused on returns to various isolated events of an innovation project. There are two limitations of this approach. First, returns on specific events may be biased downwards, because investors have already anticipated the gains to those events based on announcements of prior related events. Second, returns on specific events do not reveal the total returns to innovation, which is really the sum of all events in an innovation project. Third, a focus on specific events cannot reveal how returns are distributed over the entire innovation project. Such knowledge is useful to both understand what event of innovation gets the most returns as well as to inform firms about the best announcement strategy. Research on only specific events in the innovation project may be one reason why markets appear to undervalue innovation.

Phases of Innovation

In the interests of parsimony, we identify three distinct phases in the innovation project – initiation, development, and commercialization. The initiation phase is the period when firms

develop infrastructure and allocate resources to innovation projects. Announcements related to the start of new projects, alliance formation, and resource allocations are made during this phase.

The commercialization phase is the period when firms introduce new products to the markets. In the commercialization phase, most announcements are regarding output of innovation projects. Announcements related to introduction of new products, identification of new applications and news of awards of excellence based on product performance and external recognition of quality are made during this phase.

The development phase is the intervening period between the initiation phase and commercialization phases, when firms conduct basic and applied research to develop new products. In the development phase, most announcements are regarding interim successes in the innovation project. Announcements related to identification of new materials, processes, or equipment, development of working prototypes, and improvements in product performance are made during this phase.

Annexure A summarizes the various types of announcements during each phase of innovation project. Next we discuss how returns compare across these three phases, how they affect a target firm relative to competitors, and what total returns one may expect.

Phase with the Highest Returns

Researchers and managers may want to know the phase which attracts the highest returns. We are not aware of any specific study that examines this question or any theory that suggests one phase does better than others. However, prior research can suggest some expectations regarding the relative returns in each phase.

The commercialization phase may be one with the highest returns because the emergence of a new product signals that the innovation project has come to fruition. In addition, most firms introduce a new product because it represents some improvement over products currently in the

market. Often, especially for high-tech categories, new products represent some technological breakthrough or new solution to longstanding consumer need. As such, new products have the potential to win market share from available brands. In some cases, new products may also have the potential to introduce entirely new categories or markets. Moreover, based on research to date, the commercialization phase is one that gets the most attention of a marketing researcher (refer Table 1 below for details). These reasons suggest that the highest returns are in the commercialization phase.

However, there are two reasons why returns in the commercialization phase may be lower than other phases. First, firms may raise public expectations of a new product beyond what they can deliver. The new product which they introduce may have far more problems than they expect and may disappoint markets. Second, the average failure rate of new products is quite high ranging from 30 to 60% (Crawford 1977; Berenson and Mohr-Jackson 1994). Because of these reasons, returns in the commercialization phase may be the lowest of all phases.

The start of a new innovation project in firms has attracted numerous researchers from many fields – economics, finance, and technology management. Based on the total quantity of research targeted at any phase across different academic fields, the initiation phase may have the highest returns. This suggests that the highest returns are in the initiation phase.

However, the development of platform innovations takes decades of research and is fraught with a low success rate (Golder and Tellis 1993; Boulding, Morgan and Staelin 1997). So, the mere announcement of the start of new project is unlikely to lead to high returns without any indication of success. Moreover, the desired competitive advantages from new products are also fleeting. The high pace of technological innovation in most industries ensures imitators and

competitors are not far behind in introducing similar or better products. So, the initiation phase could have the lowest returns of all three phases.

Thus it is not clear a priori which phase might have the highest returns. Moreover the returns to any or all of these phases could be positive or negative. In sum therefore any estimates to the total returns to innovation must be ascertained empirically.

Total Returns to New Products

We propose that the total returns to innovation can only be estimated if all phases of the innovation project are included in the analysis. If the entire return to the innovation project could be estimated from a single, isolated event during the entire project, then returns for other events would not be significantly different from zero. That event would be critical with important implications for firms and investors. On the other hand, if firms continue to experience incremental returns to various events over the innovation project, ignoring certain events would result in underestimating the total returns to innovation. It would also mean that firms (and investors) should pay close attention to all innovation-related events and optimize their announcement (and investment) strategy. A variety of outcomes of the research between these two extremes is possible and has various other implications for firms and investors.

Returns Relative to Competitors

How do the returns of the innovating firm affect returns of competitors in each of the three phases? This information is important for the firm to time its announcements and move strategically in the competitive environment. For example, if the returns are higher for some specific events, firms could gain competitive advantages by announcing or emphasizing those activities. We now discuss the factors that affect the returns relative to competitors in each of the phases.

In the initiation phase, information about a firm's intention to develop new technologies or products might elicit positive response from the market if it deters potential entrants and helps to increase consumer awareness of new technologies (Bayus, Jain and Rao 2001). For example, Microsoft's has often been accused of using such announcements to deter competition from developing products for markets that Microsoft intends to enter.

In the development phase, information about firms achieving partial success in their research endeavors might elicit positive response from the market if it creates competitive advantages for the firm. Hence the return to firm would be positive and higher than returns to competitors.

In the commercialization phase, information about announcements of new product introductions through press releases, media coverage, and analyst reports might elicit positive response from the market as it increases consumer awareness of new products. Higher visibility of products at this phase often accompanied with some advertising enhances preferences and sales, translating to higher profits for the firm as compared to its competitors. Prior research has found that the impact of new product introduction on returns to competitors is strongly negative (Chen, Ho, and Ik 2005).

METHOD

This section describes the models for estimating returns to announcements during the innovation project and the sample, sources, and procedure of the data collected.

Model

We use the standard event study (McKinlay 1997; Fama, French, Jensen and Roll 1969). We define an event as the first release of information by a firm regarding any if its activities.

This method assumes the market is the benchmark for normal returns to a stock in the absence of an event, thus:

(1) $$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \qquad \text{for } -240 \le t \le -6$$

$$E[\varepsilon_{it}] = 0; Var[\varepsilon_{it}] = \sigma^2_{\varepsilon_i}$$

where R_{it} and R_{mt} are the period *t* returns on stock *i* and the market portfolio respectively and ε_{it} is the disturbance term, initially assumed to be IID normal with 0 mean, t is an index for time period as explained below. α_i, and β_i, and σ^2 are the parameters of the model to be estimated. Equation (1) is called the market model.

We estimate the parameters of the market model using trading days prior to the announcement (see Figure 1). We use an estimation period from 240 days prior to the announcement till 6 days prior in order to get a reasonably long time to estimate the parameters used for calculating the normal returns in absence of the announcement. For some new firms, which were listed on the stock exchange for a short period before the announcements, we use a shorter estimation period. However, we remove any announcement with an estimation period of less than 30 days.

We next compute abnormal returns (AR) to an event as the difference between the normal returns which would have occurred on that day given no event and the actual returns that did occur because of the event, thus:

(2) $$\varepsilon^*_{it} = R_{it} - E[R_{it}] = R_{it} - (\hat{\alpha}_i + \hat{\beta}_i R_{mt}) \qquad \text{for } -5 \le t \le 5$$

where ε_{it}*, R_{it} and $E(R_t)$ are the abnormal, observed, and normal returns respectively for the time period t. We also try event windows of varying widths centered on the date of announcement by including one, three, and five days before and after the event window.

We then calculate the average abnormal returns (AAR) over each day in the event window as follows:

$$\bar{\varepsilon}_t^{\,*} = \frac{\varepsilon_{it}^{*}}{N} \tag{3}$$

where N is the number of events in the sample. Finally, we calculate cumulative average abnormal returns (CAAR) in the event window as follows:

$$\bar{\varepsilon}_t = \sum_{t=t_1}^{t=t_2} \bar{\varepsilon}_t^{\,*} \tag{4}$$

where t_1 and t_2 denote the beginning and end of the event window. In the rest of the paper, we use the term returns to mean cumulative average abnormal returns.

Sample

We use two criteria in selecting product categories: a reasonable number of emerging technologies and data availability. We select product categories where a number of technologies have emerged in the last decade and the key global players are in the U.S. markets. The first requirement is essential to ensure that we have a large sample of announcements and the second requirement is essential since we require the firm to be listed on U.S. stock markets in order to assess the market value. On the basis of these criteria we choose external lighting display monitors and computer memory product categories

The present study goes further than previous studies in two important aspects. First, we collect data on all major firms within each industry and select all technologies in that industry. Second, we collect all announcements related to the innovation project made by the firms for each phase of the project.

Sources

Although many studies limit their focus to *Wall Street Journal* as the only source of announcements, we posit the phenomenon of technological innovation is covered by a much broader cross-section of sources. So, limiting the source to only one publication may not capture the date when information is first released to the markets. Indeed, Glascock, Davidson and Henderson (1987) show how *Wall Street Journal* does not publish all the news and nor always earlier than other sources. For example, they show they there is a lag of 3 days between change in bond rating by Moody's and announcement by *Wall Street Journal*. Hence, in the interests of accuracy and comprehensiveness, we include other sources of information as well. The primary sources we use are Factiva, Lexis-Nexis, and Company websites for press releases/announcements regarding technological innovations. We also include all newswire services like PR Newswire, Business Newswire, and Reuters. We collect company background information from General Business File ASAP and Yahoo Finance.

The lighting industry has a total of five platform technologies – incandescent lamps, arc discharge lamps, gas-discharge lamps, microwave electrodeless lamps, and light emitting diodes. Similarly, the display monitor industry has five platform technologies – cathode ray tube monitors (CRT), liquid crystal display monitors (LCD), plasma display monitors (PDP), and organic light emitting diode monitors (OLED). The computer memory industry has three platform technologies – magnetic memory, magneto-optical memory, and optical memory. Details of all platform technologies in this study are available in Annexure B from the authors.

Procedure

After selection of the industry, we identify all major firms in the industry and collect information on each firm. We use a variety of key words to identify all the announcements (e.g.

firm name or ticker and name of technology, names of phases of innovation project, etc. We sort the results based on oldest first to identify the first release of information to the market.

We identify a total of 52 firms in the three industries and collect a total of 1431 announcements from 1977 till 2003 (see Table 2 for details for each category). There is substantial innovative activity in all the categories during this period.

We delete the following types of announcements:

- Announcements made by firms whose data are not available from CRSP (firms not traded on NYSE, AMEX or NASDAQ) because we need price information to estimate returns.
- Announcements appearing in non-daily publications because of inherent inaccuracy of determining the exact date of release of information (Hendricks and Singhal 1997).
- Repeat announcements appearing after the first announcement unless the content of announcement is distinctly enhanced. When such an announcement is identified, it is treated as a new announcement for the incremental information contained in it.

We examine each announcement for incremental information and classify the announcement as per the system described earlier. More specifically, we identify whether the announcement contained any information on joint ventures, strategic alliances, new financial commitments, or setting up new infrastructure like production plants. We identify whether the announcement contained any information regarding new material, development of prototypes, demonstration models for exhibitions, patents etc. Finally we also investigate the announcements for news related to performance improvement, new product announcements or initial shipments.

RESULTS

We first present the findings on the returns to specific phases of innovation project separately. We then discuss the total returns to innovation projects and return to firm relative to competitors.

Returns to Specific Phases of Innovation Project

We now provide the returns to each of the phases of the innovation project. The results show that the returns were the highest on the day of the announcement, and not significantly different from zero for longer event windows (see Table 3). Hence, we only report the average abnormal returns on event day in the rest of the paper.

Initiation Phase

Some prior studies focused on events in only the initiation stage, implying that the returns in initiation phase are the most important or highest. In contrast, we find no support for this implication. For all announcements in the initiation phase, we find that the return is -0.36% (t=-0.78) in lighting, 0.09 (t=0.14) in monitors and 0.55% (t=1.85) in memory categories (see Table 3 and Figure 2a). Thus, the return is not significantly different from zero in any category. This finding indicates that, in the initiation phase, firms do not gain by announcing their future plans or that the announcements are discounted by the market. In order to examine the market response further, we calculate the returns per firm for all the announcements that it made in the initiation phase. We find only 1 in 52 firms has returns significantly different from zero.

Development Phase

Very few prior studies focus on the events during the development phase implying that the returns in this phase are neither important nor substantial. This seems particularly erroneous in our sample since the returns in the development phase are the highest among all phases. The returns are high across all categories, with 2.02% (t=5.7) in lighting, 0.92% (t=2.15) in monitors,

and 0.89% (t=4.0) in memory categories (see Table 3 and Figure 2b). Thus, the response to announcements is positive and significantly different from zero in all categories.

Commercialization Phase

Some prior research reports positive returns to events in the initiation phase. For all announcements in the commercialization phase, we find that the return is 0.89% (t=3.66) in lighting, 0.59 (t=2.27) in monitors and 0.69% (t=3.16) in memory categories (see Table 3 and Figure 2c). Thus, the returns are positive and significantly different from zero in all categories (see Table 3 and Figure 2c). However, in contrast to past research, we find returns are much higher than others have found for this stage. For example, our results are more than three times higher than those of Chaney, Devinney and Winer (1991), who report only 0.25% returns and Sharma and Lacey (2004), who report only 0.52% returns.

Total Returns to Innovation

The sum of returns to all announcements over the three phases provides the total returns to innovation. We find that the total returns are 2.55% for lighting, 1.60% for monitors and 2.13% for memory products respectively (see Tables 4 and 5). These values indicate that the prior focus of researchers on only one or other isolated phase or event of innovation severely underestimates the real returns to innovation.

Degree of Underestimation

We calculate the degree of underestimation caused by a focus on only the commercialization phase as follows:

$$(4) \qquad \text{Degree of underestimation} = 1 - \frac{\text{Returns to Commercialization Phase}}{\text{Returns to Innovation Project}}$$

The returns to the innovation project using this metric are 2.55% in lighting, 1.60% in monitors, and 2.13% in memory category (see Figure 3a). Hence, that the degree of underestimation is approximately 65% for the three categories (see Table 5 and Figure 4a).

However, a simple addition of all returns in various phases *may* be an overestimation. Some innovations apply to more than one product in the commercialization phase. For example, the discovery of a new coating material to increase the storage capacity of floppy disks was used for increasing the storage capacity of other memory products as well. In such a case, the above estimate would represent the upper bound to the total returns. Hence, a fair estimate needs to count announcements of only those innovations which directly apply to the target commercialization and no other.

We could not obtain all the new products that were associated with every innovation. However, in the interests of erring on the conservative side, we remove all announcements in the development phase which could not be directly linked to specific product announcements in later phases. Hence we retain only announcements of working prototypes and exhibition models in the development phase and remove announcements related to new material and patents, which just may have been used for more than one product. The total number of announcements reduces to 1302. The returns to the innovation projects using this revised conservative metric are 1.81% in lighting, 1.21% in monitors, and 1.61% in memory category (see Figure 3b). These more conservative results still suggest an underestimation of at least 55% from considering only one phase (see Figure 4b).

Hence, we find that ignoring announcements from prior phases in estimation of returns to innovation severely underestimates the total returns to innovation, and the range of degree of underestimation is from 55% to 65%.

Return to Firm Relative to Competitors

Some prior research suggests that returns to firms relative to their competitors are positive in all phases of the innovation project. We employ the portfolio approach described earlier to investigate this. First we create portfolios of firms within a short-term window of -7 days to +7 days of the announcement and identify all firms in that portfolio. We then create another portfolio of competitor firms that comprise all firms that did not make any announcement during that window. We then calculate difference in daily returns to both portfolios. A positive difference in returns indicates that the firm making the technological announcement attracts higher returns than competitive firms and vice versa.

The results of the test of these hypotheses are in Table 6 and Figure 6. We find that the returns of competitors are not significantly different from zero in any of the three categories for any of the three phases. However, there is a distinct difference between the returns to the firm making the announcements and its competitors. In the initiation phase, the difference between returns to firms making the announcement and competitors is not significantly different from zero in any of the three categories. Moreover, the return to all firms making announcements is even lower than the returns to their competitors in lighting and monitors. In the development phase, the returns to firms making announcements are far higher than the returns of their competitors in all three categories (see Table 6 and Figure 6). In the commercialization phase, returns to firms making announcements are higher than the returns of their competitors (see Table 6 and Figure 6). However the difference in returns is only significantly different from zero in the memory category.

In order to check the validity of these results over a broader definition of competitors, we repeat the above analysis by including all firms from three categories not making the announcement in the portfolio of competitors. This assumption is partially justified by the fact

that all three categories are in the hi-tech industry and many of the firms in one category also have divisions making products in the other category. We find results consistent with the first analysis. Overall, a firm benefits the most over its competitors by making announcements of interim successes in the development phase.

DISCUSSION

This section summarizes the findings and discusses questions, implications, and limitations of this study.

Summary of Findings

The current research has five major findings:

- The response of stock markets to announcements on innovation projects is positive.
- Limiting the analysis to any one innovation event severely under-estimates the total returns to innovation.
- Returns to the development phase are the highest in all categories.
- Returns to firms relative to competitors are also the highest in the development phase.
- The percentage of all announcements with positive abnormal returns improves as the innovation project moves closer to the commercialization phase.

Test of Robustness

We carry out a number of analyses to test the robustness of the results including use of alternative return models, use of alternate market indices, use of non parametric tests, accounting for lack of clean estimation period, examining potential bias from pre-announcements, and assessing long terms returns.

Alternative Market Return Model

We use two other models to estimate the normal returns in order to verify the robustness of our results. First, we use the Mean Return Model where the firm is expected to generate the same return that it averaged during a previous estimation period. Second, we use the Market Adjusted Return Model where the firm is expected to generate the same return as the rest of the market. The estimation window for both models is the same as for Equation 1. Similarly, returns are calculated as the difference in observed returns of the firm during the event window and the 'normal' returns. The plots of returns in Figures 6a-c using all models – mean, market and market adjusted models demonstrate that returns are not much different with the use of these models. Similarly, there are no significant differences in the reported results for the hypotheses with the use of these alternate models as well.

Choice of Market Index

We use the equally weighted market index to estimate the abnormal returns in equation 6 as per recommendation of Brown and Warner (1980; 1985). We also re-estimate the returns using the value-weighted market index to ensure robustness. The results are not materially different from the ones presented.

Non-Parametric Tests

We also estimate the returns using nonparametric tests which do not assume returns to be normally distributed (Brown and Warner 1980). If this assumption is not supported, it can lead to false inferences. We use the Wilcoxon sign rank test to test the null hypothesis that the proportion of observed sample securities having positive returns is equal to 0.5. This situation would be true if markets do not respond favorably to positive news of technological innovations and observed returns are almost evenly distributed around 0. The results reject the null ($p = .03$) and support our findings.

Lack of Clean Estimation Period

An assumption intrinsic to the market adjusted model is that the estimation period used to estimate market parameters prior to the event are clean – there is no other announcement made by the firm in that period. Since we examine multiple announcements made by the same firm over the entire innovation project, this assumption is violated. We re-estimate returns by removing the dates of all prior announcements made by the firm from the estimation period (Brown and Warner 1985). The results do not change much with this correction.

Potential Bias from Pre-Announcements

Do pre-announcements of new product introduction during the innovation project bias our results? Pre-announcements refer to announcement regarding intended introduction of new products often far ahead of actual date of introduction. The objectives of such announcements vary from informing consumers, signaling strategies, or deceiving consumers or competitors (Eliashberg and Robertson 1988). Pre-announcements regarding launch of new products can bias estimates in the analysis of market returns to new product introductions since they do not qualify as new product introduction yet release information prior to introduction (Mishra and Bhabra 2001).

We identify such pre-announcements in the sample and remove them from the sample. The total number of such announcements was approximately 15. The returns to commercialization phase reduced marginally after the exclusion of these announcements. However, in either case, the total returns were still much higher than the returns to any isolated event, and the returns in development phase were still the highest in all phases. Hence the inclusion of pre-announcements does not bias our results in any systematic way.

Long Term Abnormal Returns to Innovation

Markets may not react fully to the announcements related to innovative products at the time of announcement. This behavior could occur for various reasons. First, investors may not be

fully aware of the significance of technological advances and may take time to fully adjust prices to reflect them. The pace of change, especially in high technology industries, increases the uncertainty of future direction of research and market evolution. These factors increase the probability that there is a delay in release of full information by the firms. Second, the information may not travel efficiently from the scientific journals to investors and general consumers. Third, the process of standards formation especially in emerging technologies is unclear and slow and the returns to innovations might reflect this uncertainty.

Moreover, this delay in appropriating relevant returns to announcements may be more prominent in the development phase than in the commercialization phase. The real value of advances in technology is more ambiguous in the development phase than in commercialization phase when tangible products are already available to consumers.

Researchers have long been interested in using the event study to detect the long-term effect of events on stock performance (Fama, Fisher, Jensen, and Roll 1969). Fama (1998) and Kothari and Warner (1997) document many issues inherent in such techniques including risk adjustment, expected/abnormal return modeling, the aggregation of security-specific abnormal returns, and the testing of the statistical significance of abnormal returns. These issues become critically important with long horizons.

The calendar time portfolio approach described below can be used to detect long-term returns to technological innovations and minimizes many of the problems identified above. The method does not depend on a pre-event period for estimation of normal returns and hence also avoids some of the limitations of the classical event study approach.

We follow the approach of Jaffe (1974) and Mandelker (1974) in the financial-economics literature, and recently used by Fama (1998) and Mitchell and Stafford (2000). The approach has

been used to detect long-term abnormal returns to both one-time (e.g. announcements of technological innovations) and recurring events (e.g. earning announcements). We first identify all announcements made by firms and segregate them as per the phase of innovation project. We then create portfolios of firms making announcements within a certain period and calculate the mean return to all the firms in the portfolio. Since the number of firms is not uniformly distributed over the sample period, the number of firms included in a portfolio is not constant through time. As a result, some new firms are added each month and some firms exit each month. Accordingly, the portfolios are reformed each month to calculate the mean portfolio return. The resulting time series of monthly portfolio returns is regressed on the three-factor Fama-French model (see equation 5). The estimated intercept from the regression of portfolio returns against factor returns is the post-event abnormal performance of the sample of event firms.

(5) $$R_{pt} - R_{ft} = \hat{\alpha}_p + \hat{\beta}_p (R_{mt} - R_{ft}) + \hat{\delta}_j SMB + \hat{\lambda}_j HML$$

where α_p : average monthly abnormal return on the portfolio of event

R_{pt} : Return on a portfolio of stocks

R_{mt} : Return on market portfolio, also known as systematic risk

R_{ft} : Rate of a "risk-free" investment e.g. one month T-bill

SMB : Return on a portfolio of small stocks minus return on large stocks

HML : Return on a portfolio of stocks with high book-to-market ratio minus the return on a portfolio of stocks with low book-to-market ratio

α_p is also called Jenson's alpha in the finance literature and measures the average return on a portfolio over and above that predicted by the factors in the model. Inferences about the abnormal performance are on the basis of the estimated α_p and its statistical significance.

We test the long term abnormal return to innovation using portfolios of varying lengths – three long-term portfolios over a period of 7, 30 and 300 days from the day of announcement. In all categories, the returns are not significantly different from zero (see Table 7) indicating that firms receive full returns close to the actual announcement. This result suggests that the market is efficient without either major leakage of information prior to the day of the event or over- or under-reaction on the day of the event.

Positive vs. Negative Returns

Prior research also suggests that it is only a fraction of all announcements that attract positive returns on the day of the announcement or during a short window around the event date. For example Chaney, Devinney and Winer (1991) report that only about half of all announcements in their sample experienced positive abnormal returns. Our data allows us to investigate this phenomenon in more detail and we expect that the number of announcements that attract positive returns to exceed the number of announcements that attract negative returns as the innovation project becomes closer to completion.

We calculate the return on event day for all the announcements of each phase and segregate them as per their valence and phase of innovation project. We then calculate the percentage of all announcements in each category that elicit a positive abnormal return for each phase.

In all three categories we observe the lowest percentage of announcements with positive abnormal returns in the initiation phase (see Figure 7). However the percentage of announcements with positive returns increases consistently as the innovation project moves closer to commercialization in all three categories.

Implications and Contributions to Practice

This study has several implications for managers especially at the strategic and tactical levels especially in industries where product development goes through various phases of innovation before a new product introduction.

First, it is inappropriate to limit analyses to only new product announcements to estimate the returns to innovation. The returns to announcements in the commercialization phase ignore all information released about the product during the early phases of the project. The impact of a wrong estimation could lead to erroneous investment decisions. In particular, it may rank new products with short lead times over those with long lead times because the former show higher returns than the latter, which are spread over a long innovation project.

Second, we find that though the overall returns to innovation are positive, a significant percentage of all announcements attract negative returns. Moreover, only few firms in our sample have a positive average return for all their announcements. These results suggest a more careful scrutiny of innovation and a better marketing communication strategy for communicating progress in innovation and managing customer expectations

Third, the absence of long term abnormal returns to announcements of technological innovations indicates that markets are efficient in estimating the returns to innovation. We fail to find market returns significantly different from zero for any period longer than 3 days for any category. This implies that the net present value of even the technical information released in announcements is incorporated into the stock fairly quickly and efficiently. The various biases and anomalies of efficient markets discussed by DeBondt and Thaler (1985; 1987) do not seem to be present in the valuation of new information related to technological innovations. Hence, managers can use the returns to announcements in the development phase to assess the future market response and marketability of products still under development. The reported under

valuation of innovation is due not to markets not appreciating the full value of innovations immediately but to researchers focus on computing returns to isolated events rather than to all the events in an innovation project.

Fourth, it is wrong to assume that the highest returns are observed at introduction of new products. In all categories, the highest average returns were during the development phase.

Limitations and Discussion for Future Research

This study has several limitations. First, we limit our analyses to only three industries due to the difficulty in collecting a comprehensive set of announcements on all events about innovation. Our focus on three industries in the hi-tech sector could drive the higher average market returns to each phase as compared to prior studies. Hence the average market return to any of the phases – initiation, development or commercialization could be either higher or lower than our findings if the sample is drawn from other industries. However, so long as the new product development process goes through distinct phases, the findings on the degree of underestimation of returns by a focus on isolated events will still hold in other industries. Second, the data does not include firms not listed on the stock markets. These firms are not obliged to release information to the market and the present method is not appropriate to estimate returns to innovation for such firms. In addition, future research may also examine optimal market communication strategies aimed at maximizing the returns to announcements.

Figure 1:

Timeline of Event Study

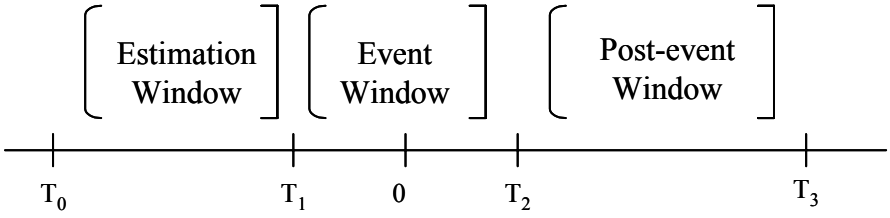

Figure 2

Cumulative Average Abnormal Returns (CAAR) in Each Phase of Innovation Project

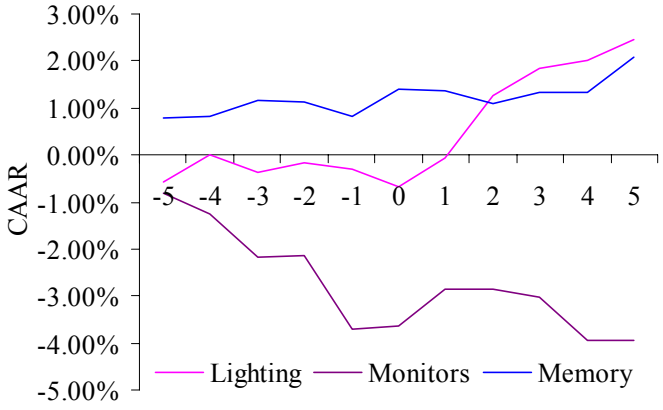

Figure 2a Initiation Phase

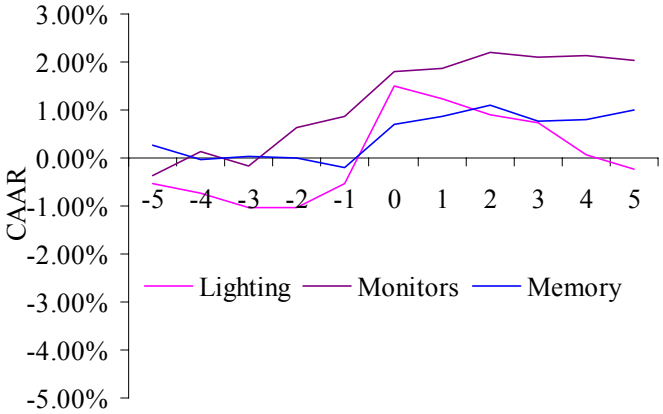

Figure 2b Development Phase

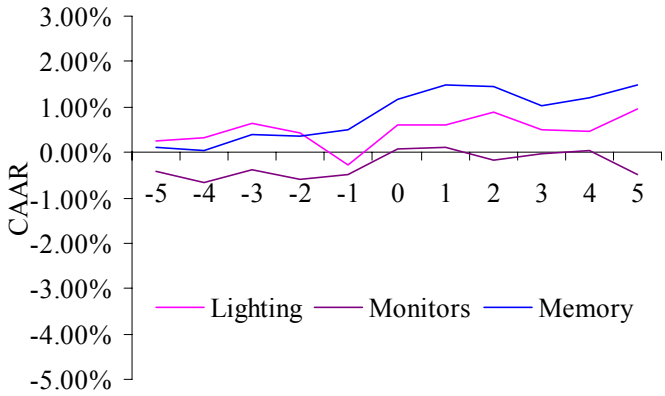

Figure 2c Commercialization Phase

Figure 3:

Average Abnormal Returns (AAR) in Each Phase of Innovation Project

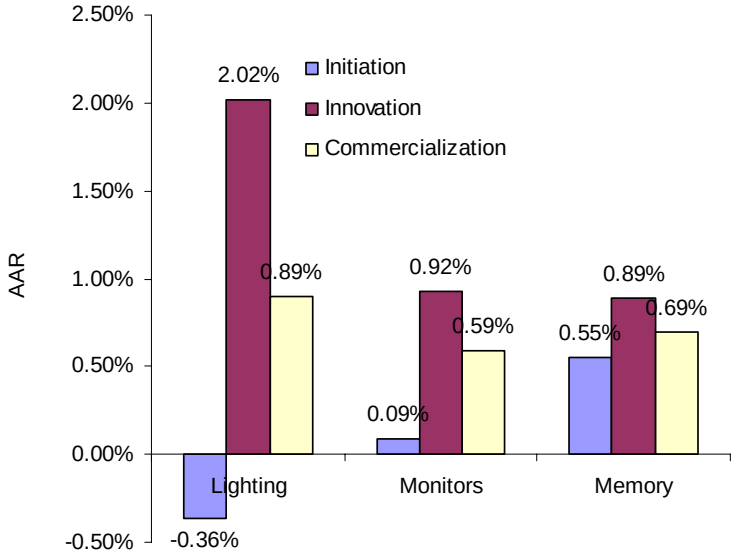

Figure 3a: Return in each phase with all announcements of Development Phase

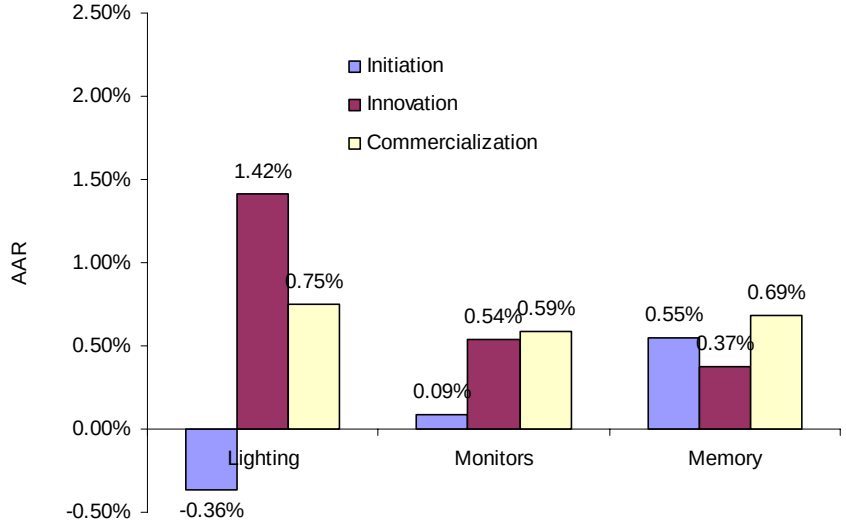

Figure 3b: Return in each phase with only announcements of Prototypes and Exhibition Products in Development Phase

Figure 4:

Comparison of Average Abnormal Returns (AAR) in Commercialization Phase With Total Returns Over the Innovation Project

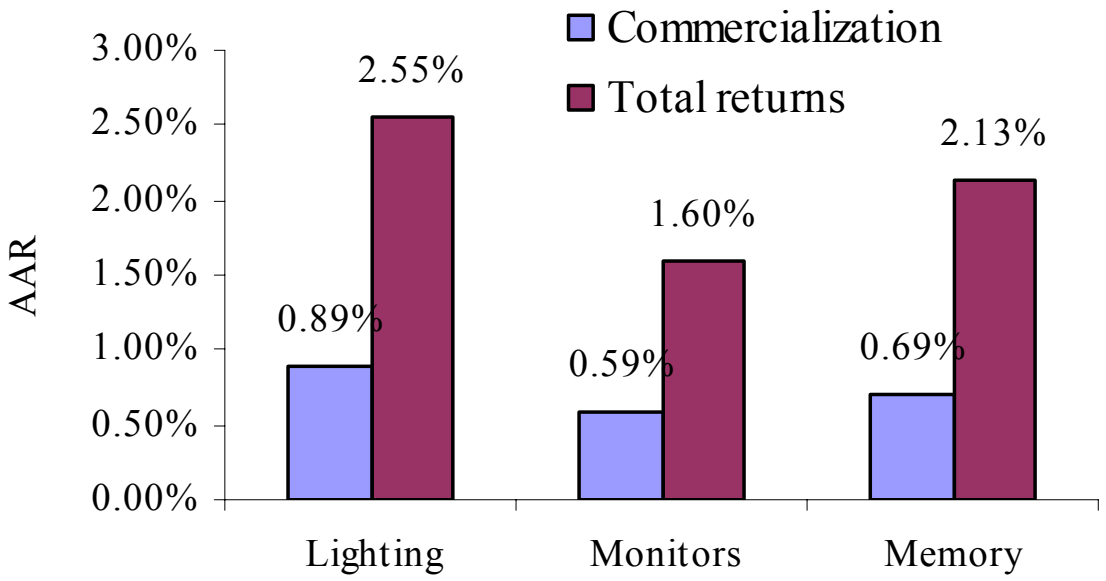

Figure 4a: Upper-bound

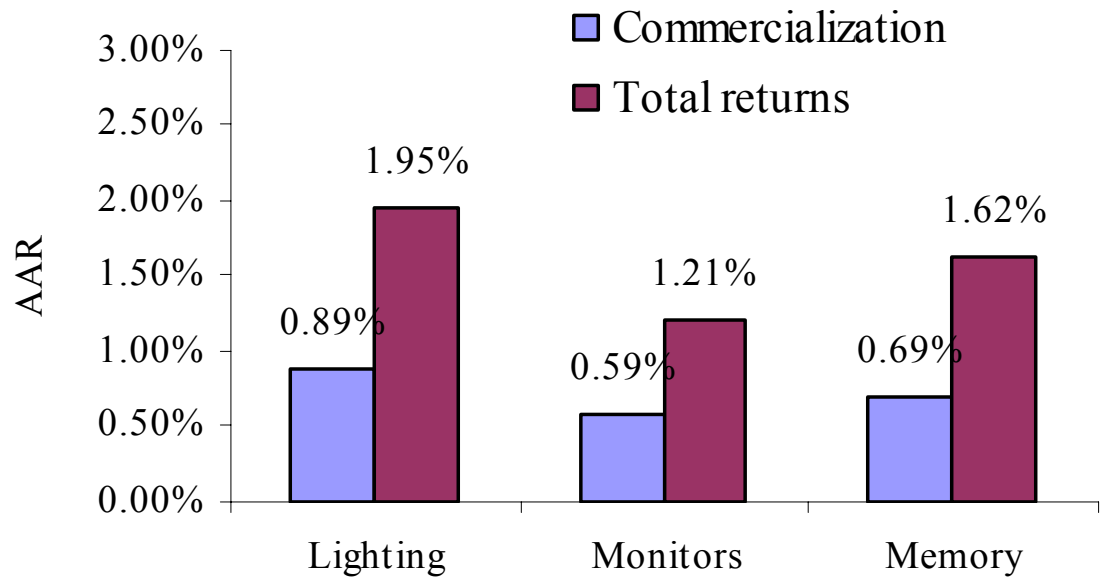

Figure 4b: Lower Bound

Figure 5:

Average Abnormal Return (AAR) to Target Firm Relative to Competitors

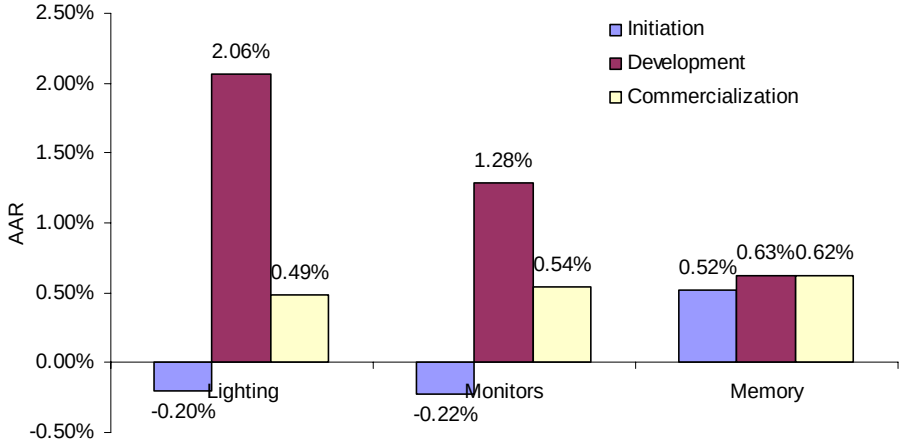

Figure 6:

Cumulative Average Abnormal Returns (CAAR) using Mean Adjusted, Market Adjusted, and OLS Market Models

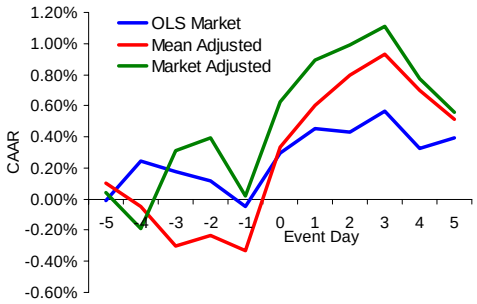

Figure 6a: Lighting

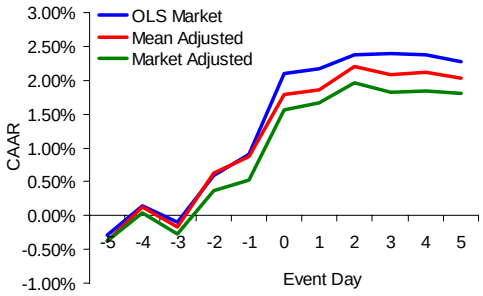

Figure 6b: Monitors

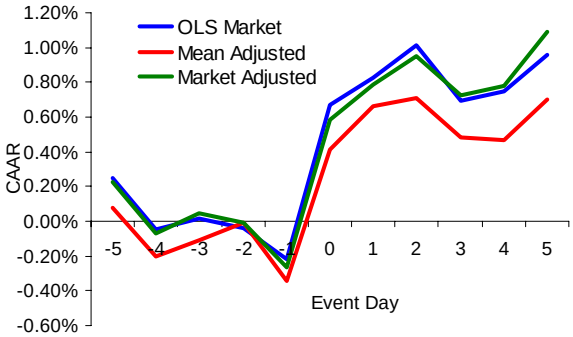

Figure 6c: Memory

Figure 7:

Positive Returns In Each Phase of Innovation Project

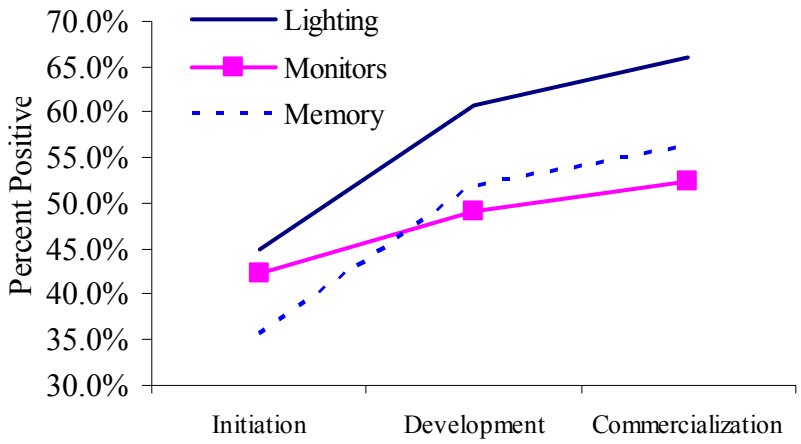

Table 1:

Comparison of Past Studies Analyzing Innovation Events With Current Study

Phase	Content	Prior studies	This study
Phase 1	Alliance formation including acquisitions	Anand and Khanna (2000)	Yes
		Das, Sen and Sengupta (1998)	
		Meng and Lee (2003)	
		Woolridge and Snow (1990)	
		Zantout and Chaganti (1996)	
		Suarez (2002)	
	Resource allocations including expansion plans	Doukas and Switzer (1992)	Yes
		Woolridge and Snow (1990)	
		Koh and Venkataraman (1991)	
	Overall Phase 1	None	Yes
Phase 2	Identification of new materials	None	Yes
	Patents	Austin (1993)	Yes
	Development and demonstration of working prototypes	None	Yes
	Identification of new applications and advance orders	None	Yes
	Overall Phase 2	Kelm, Narayanan and Pinches (1995)	Yes
Phase 3	New products	Chaney, Divenney and Winer (1990)	Yes
		Sharma and Lacey (2000)	
		Chan, Kensinger and Martin (1992)	
	Initial shipments	None	Yes
	External recognition of quality	Hendricks and Singhal (1996)	Yes
		Adams, McQueen and Seawright (1999)	
	Overall phase 3	Kelm, Narayanan and Pinches (1995)	Yes

Table 2:

Sample Characteristics

Category	External Lighting	Display Monitors	Desktop Monitors
Number of firms	18	16	18
Total Number of Announcements	382	423	626
Sample Period	’77 – ‘03	’83 – ‘03	’82 – ‘03
Initiation Phase	60	54	129
Development Phase	80	159	210
Commercialization Phase	242	210	287
Number/ Type of Platform Technologies	5	5	5
	Incandescent, Arc-discharge, Gas-discharge, LED and MED	CRT, LCD, Plasma, Display panels and OLED	Magnetic, Magneto-optical and Optical

Table 3:

Mean Abnormal Return Using Event Study

Category	Phase	N	Event Day	t-val	CAAR (-1,+1)	t-val	CAAR (-3,+3)	t-val
Lighting	Initiation	60	-0.36%	-0.78	0.04%	0.04	0.26%	0.21
	Research	80	2.02%	**5.93**	0.76%	1.29	0.21%	0.23
	Realization	242	0.89%	**3.66**	0.06%	0.14	0.02%	0.04
Monitors	Initiation	54	0.09%	0.14	-0.23%	-0.21	-0.25%	-0.15
	Research	159	0.92%	**2.14**	0.41%	0.55	0.28%	0.25
	Realization	210	0.59%	**2.27**	0.23%	0.52	0.09%	0.13
Memory	Initiation	129	0.55%	1.85	0.08%	0.16	0.07%	0.09
	Research	210	0.89%	**3.92**	0.29%	0.73	0.11%	0.19
	Realization	287	0.69%	**3.16**	0.37%	0.98	0.14%	0.25
Total sample		1431	0.76%	**7.95**	24.00%	1.51	0.11%	0.44

Table 4:

Returns Over Different Events in the Innovation Project

Phase	Content	Returns		
		%	N	t-val
Phase 1	Alliance formation including acquisitions	0.21%	201	0.827
	Resource allocations including expansion plans	0.38%	77	0.97
Phase 2	Identification of new materials	2.12%	30	**2.05**
	Patents	0.46%	128	1.19
	Development and demonstration of working prototypes	0.60%	361	**2.96**
	Identification of new applications and advance orders	1.06%	253	**3.55**
Phase 3	New products	0.62%	559	**4.32**
	Initial shipments	1.42%	63	**2.71**
	External recognition of quality	1.56%	75	**2.87**

Table 5:

Test of Underestimation in Commercialization Phase

Stage	Upper Bound					
	Lighting		Monitors		Memory	
	average	t-val	average	t-val	average	t-val
Initiation	-0.36%	-0.79	0.09%	0.14	0.55%	1.82
Development	2.02%	5.69	0.92%	2.15	0.89%	4.01
Commercialization	0.89%	3.45	0.59%	2.28	0.69%	3.21
Total	2.55%		1.60%		2.13%	
Degree of underestimation	64.9%		63.3%		67.5%	

Table 5a: All announcements of Development Phase

Stage	Lower Bound					
	Lighting		Monitors		Memory	
Initiation	-0.36%	-0.79	0.09%	0.14	0.55%	1.82
Development	1.42%	3.47	0.54%	1.09	0.37%	1.67
Commercialization	0.75%	2.95	0.59%	2.28	0.69%	3.19
Total	1.81%		1.21%		1.61%	
Degree of underestimation	58.4%		51.6%		57.4%	

Table 5b: Only announcements of Prototypes and Exhibition Products in Development Phase

Table 6:

Effect of Innovation on Returns to Competitors Versus Target Firm

Category	Phase	Return to Competitors		Difference in Return		N
		Mean return	t-val	Mean return	t-val	
Lighting	Initiation	-0.17%	-0.75	-0.20%	-0.25	51
	Development	0.08%	0.34	2.06%	3.57	64
	Commercialization	0.14%	1.28	0.49%	1.68	191
Monitors	Initiation	-0.10%	-0.30	-0.22%	-0.35	43
	Development	-0.19%	-1.21	1.28%	2.67	136
	Commercialization	0.02%	0.14	0.54%	1.59	180
Memory	Initiation	0.19%	0.96	0.52%	1.03	109
	Development	0.21%	1.26	0.63%	2.06	175
	Commercialization	0.04%	0.33	0.62%	3.02	235

Table 7:

Long-term Mean Abnormal Return for Announcements in Development and Commercialization Phase (Using Calendar Time Approach)

Category	Period	Development Phase				Commercialization Phase			
		α_p	t-val	N	R^2	α_p	t-val	N	R^2
Lighting	0 - 7 days	1.21%	1.41	71	11.8%	0.83%	0.87	131	5.2%
	0 - 30 days	0.13%	0.12	90	13.9%	0.20%	0.31	154	16.2%
	0 - 300 days	0.73%	1.54	161	50.0%	0.51%	1.46	237	47.3%
Monitors	0 - 7 days	2.63%	1.70	97	4.2%	0.88%	0.59	125	2.8%
	0 - 30 days	1.61%	1.31	128	13.8%	0.45%	0.44	161	7.2%
	0 - 300 days	0.86%	1.25	210	27.7%	0.06%	0.11	220	27.3%
Memory	0 - 7 days	1.13%	1.55	137	7.1%	1.18%	1.75	142	6.8%
	0 - 30 days	-0.18%	-0.25	180	18.9%	0.80%	1.00	178	12.0%
	0 - 300 days	-0.47%	-1.00	250	29.7%	-0.12%	-0.21	217	32.0%

Appendix A

Classification of Announcements

Announcements during Initiation Phase

- Alliance formation including acquisitions
- Strategic alliances between firms
- Resource allocations including expansion plans
- Financial resources: grants, advance orders, funded development contracts etc.

Announcements during Development Phase

- Identification of new materials, processes, equipment
- Development and demonstration of working prototypes
- Patents
- Identification of new applications and advance orders
- Higher performance on primary or secondary dimensions of customer preference

Announcements during Commercialization Phase

- New product introductions
- Commercialization e.g. initial shipments of new products
- Identification of new applications for new products
- Awards of excellence / external recognition of quality

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