Total Returns to Innovation

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ABSTRACT

Assessing market returns to innovation is difficult because of the variety of metrics, events, and strategies of innovation. The authors argue that the appropriate approach is to examine the market returns to the entire innovation project The authors demonstrate this approach via the Fama-French 3 Factor Model (including Carhart's Momentum Factor) on 5481 announcements from 69 firms in 5 markets and 19 technologies, during the period 1977-2006.

The authors find that total market returns to an innovation project are $643 million, more than 13 times the $49 million due to an average innovation event. Returns to negative events are higher in absolute value than those to positive events. Returns to development activities are higher than returns to either the setup or market activities. Returns are higher for smaller firms than larger firms. Returns to the announcing firm are substantially greater than those to competitors across all stages. The authors discuss the implications of the results.

Keywords: Innovation, Market Returns, Event Study, Fama-French three factor model, High-Tech Marketing

One line Abstract: A new metric for evaluating innovation: the total stock market returns to an innovation project"

INTRODUCTION

Innovation is probably one of the most important forces in fueling the growth of new products, 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. According to the MIT Technology Review's annual survey of R&D in 2004, corporate R&D spending across a broad cross-section of industries is on the decline. 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 (Hall 1993; National Innovation Initiative Report 2004; Council on Competitiveness Report 2001). Firms may under-invest in R&D because of the high costs, the long delay in reaping market returns if any, the uncertainty of those returns, and the difficulty of adequately measuring them. Moreover, the increasing speed of diffusion across global markets (Chandrasekaran and Tellis 2008) and the diverse patterns of consumer adoption across products and countries (Sood, James, and Tellis 2008) further exacerbate the challenges for firms to predict returns to new products. Indeed, accurately assessing the market returns to innovation may be critical to motivating firms to invest in innovation. Hence, this topic is in the Marketing Science Institute's list of top research priorities for the last few years.

The market returns to innovation is one of the best means of assessing the true rewards to innovation. Past 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. 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, Devinney and Winer (1991) report market returns of 0.25% to an isolated event, new product introduction. Past research has also estimated returns to other isolated events of an innovation project (see Table 1).

There are three limitations of this approach. First, returns on specific events (e.g. launch of new products) do not reveal the total returns to innovation, which is really the sum of all events in an innovation project. A focus on returns to specific events in the innovation project may be one reason why markets appear to undervalue innovation. Second, a focus on specific events cannot reveal how returns are distributed over the entire project. Such knowledge is useful to both understand which event of an innovation project gets the most returns and what announcement strategy firms should adopt. Third, returns on specific events may be deflated due to excessive announcements or inflated due to few announcements in the innovation project. We can ascertain this effect only by recording all announcements of all firms throughout the innovation project and estimating returns to an event after controlling for other events and strategic and structural variables.

Hence, a researcher may arrive at erroneous estimates of the true rewards 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 on market returns to all events in an innovation project. This is the goal of the current study. In particular, it seeks answers to the following questions:

- How do stock markets react to each event in an innovation project, after controlling for other events?

- What are the total market returns to the innovation project?
- What are the market returns to sets of activities of the innovation project?
- What structural (e.g., size) and strategic (e.g., research productivity) variables affect the market returns to innovation?
- How do the market returns of competitors compare to those of the announcing firm?

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

CONCEPTUAL BACKGROUND

This section reviews prior findings and expectations about markets returns to innovation. To better lay out the area, it begins by defining the key terms and assumptions of the study.

Definitions

We define four key terms: technology, innovation project, event, and announcement.

Following Sood and Tellis (2005), we define a technology as a distinct principle or platform for producing products to serve a consumer need. For example neon lamps are based on fluorescence technology which produces light by the distinct scientific principle of fluorescence. Halogen lamps are based on incandescence technology which produces light by the distinct scientific principle of incandescence (Appendix A has details). Several new products and models (e.g. hard disks, floppy drives, tapes etc.) could be developed on the platform of one technology (e.g. magnetic storage).

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 technology to about a year after introduction of the new product. For example, all of Philips' research efforts in initiating, developing, and commercializing a compact fluorescent lamp (a new product based on fluorescence technology) comprises the innovation project for that new product.

We define an **event** as some progress in the project (e.g., patents or product launch). We identify seven such events detailed in later sections.

We define an **announcement** as the availability of information regarding an event either by the firm directly or by other sources.

Market Returns to Innovation Events, Activities, and Projects

We identify three distinct sets of activities in the innovation project – setup, development, and market. Each set of activities includes key events related to the overall set and may occur any time during the innovation project e.g. firms may decide to enter into new alliances any time during the innovation project. Moreover, these events may be either positive (patent registration) or negative (patent denial) (see Appendix B for details). Total market returns to the entire innovation project are the sum of returns to all activities during the innovation project. At the present state of research, the literature reports rival findings about whether returns to each of these events is negative or positive, as summarized below.

Setup activities include events about alliances (including joint ventures and acquisitions), funding (including grants, advanced orders, and funded contracts), and expansions for start of new innovation projects. Announcements about setup activities may lead to negative returns because of high investments, long gestation periods, associated uncertainty, and high risk of failures (Crawford 1977; Kelm, Narayanan, and Pinches 1995). On the other hand, such announcements may lead to positive returns as they enable market expansion, deter competitor entry, improve probability of success and enhance firms' competitive position (Aaker 1995; Suarez 2002; Anand and Khanna 2000; Das, Sen, and Sengupta 1998; Doukas and Switzer

1992). The rival arguments for positive and negative market returns to setup activities suggest the need for empirical research to resolve the conflict.

Development activities include events about prototypes (working prototypes, demonstration in exhibitions, and new materials, equipment, and processes), patents, and pre-announcements (more than a week ahead of future events). Announcements about development activities may lead to negative returns because they alert competitors of progress, reduce the element of surprise, trigger imitators, or lead to excessive discounting of the technical content. On the other hand, returns to development activities may be positive due to reduction in overall uncertainty, signaling confidence, competence, and optimism about the future (Zantout and Chaganti 1996; Paulson Gjerde, Slotnick and Sobel 2002; Austin 1993; Pakes 1985; Sorescu, Shankar and Kushwaha 2007). The rival arguments for positive and negative market returns to development activities suggest the need for empirical research to resolve the conflict.

Market activities include events about new product commercialization (including launches, initial shipments, and new applications), and awards (external recognition of quality). Announcements about market events may lead to negative returns because launched products fall below expectations, costs of promotion and commercialization seem high, or the competitive advantages from commercialization seem fleeting (Crawford 1977; Berenson and Mohr-Jackson 1994). On the other hand, announcements of market events may lead to positive returns because they signal the competitiveness of the firm, the fruition of innovation project , and the expansion of the product portfolio (Sharma and Lacey 2004; Chen, Ho, Ik, and Lee 2005; Akigbe 2002; Zantout and Changanti 1996; Chaney, Devinney, and Winer 1991; Johnson and Tellis 2007; Hendricks and Singhal 1996; Urban and Hauser 1980; Chan, Kensinger and Martin 1992; Sankaranarayanan 2007; Keller and Lehmann 2006). The rival arguments for positive and negative market returns to market activities suggest the need for empirical research to resolve the conflict.

Total Returns to Innovation

Past research has estimated returns to isolated events of an innovation project (see Table 1). This approach may lead to a substantial underestimation of the total returns to innovation. We propose that the total returns to innovation can only be estimated if all events in all sets of activities of the innovation project are included in the analysis. If the returns to the entire innovation project could be estimated from a single, target event during the project, then returns for other events would not be significantly different from zero. That target 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. The total returns to innovation are the sum of returns to all events in an innovation project. Similarly, if a firm has multiple innovation projects running concurrently, the total returns to innovation to the firm are the total return to all innovation projects of the firm.

In addition to completeness, the benefit of considering all events in an innovation project is that it compensates for suboptimal or strategic announcements of the firm. For example, if the firm under-promises in early stages of an innovation project and over-delivers in later stages, the possibly low market returns in early stages will be compensated by high returns in later stages. Conversely, if a firm over-promises and then under-delivers, taking all events into consideration will compensate for possibly too high returns in earlier stages.

Activities with the Highest Returns

Researchers and managers may want to know which type of activities attracts the highest returns. We are not aware of any specific study that examines this question or any specific theory that concludes that one particular set of activities does better than others. However, past research seems to suggest that announcements of market activities may experience the highest returns for several reasons. First, only market activities signal fruition in terms of revenues from sales of the new product (Sharma and Lacey 2004; Chan, Kensinger and Martin 1992). Second, based on research to date, the market activities get the most attention of reporters.

Control Variables

Market returns during the innovation project may also be affected by the firm's announcement strategy or structure. For this reason, we include two strategic variables (announcement frequency and research productivity) and two structural variables (size of firm and age of technology) as control variables.

Announcement Frequency

Firms vary in their announcement strategy. Some firms, like Microsoft, announce all events related to the project while others, like Apple, aggregate many events into one big announcement. Some literature suggests that frequent announcements reflect transparency and timeliness and thus would either enhance returns or at least not lead to penalty in returns (Kelm, Narayanan, and Pinches 1995; Tucker 2007; Givoly and Palmon 1982). Moreover, frequent and multiple announcements lead to dilution of returns over a larger number of events and thus lower realized returns per announcement (Chaney, Devinney and Winer 1991). We use two alternate measures for announcement frequency: number of prior announcements and days since last announcement. We expect returns to be negatively correlated to the first measure and positively correlated to the second measure.

Size of Firms

Prior research suggests that the size of firm is an important structural variable that affects the market returns to innovation. Prior research suggests that returns for smaller firms are higher than the returns for larger firms because of higher salience of any single event in a small firm than a large firm (Austin 1993). Large firms are also better tracked by analysts and in general have much smaller "surprise" in event returns. We measure two alternate measures of the size of firm –annual sales and the number of technologies that a firm invests in.

Research Productivity

A high level of research productivity could increase the returns of a firm for a couple of reasons. First, customers may perceive an innovative firm as having superior quality products and thus drive up demand for its new innovations (Barney 1986; John, Weiss and Dutta 1999). Second, a firm with a reputation for a regular stream of innovative products increases the likelihood of fruitful strategic alliances (Dollinger, Golden and Saxton 1997), which could increase the probability of success with the current innovation. Hence, market returns may be high to firms with high research productivity. We measure research productivity by the number of new product launches per year prior to the date of the current event.

Age of Technology

Market returns to innovation projects may differ across old and new technologies. Prior research suggests that technologies mature with time (Chandy and Tellis 2000; Foster 1986; Christensen 1992) and the focus of innovation changes from product to process innovation as a technology matures (Utterback 1974; Adner and Levinthal 2001). Hence, the improvements in product performance might be less for older technologies. In contrast, new technologies improve rapidly, open up new opportunities and markets, and can disrupt old technologies (Christensen 1997). Thus, market returns to new technologies may be higher than those to old technologies. We measure age of technology as the number of years since the first new product launched based on the technology.

METHOD

This section describes the method for estimating abnormal returns to announcements during the innovation project in five subsections: logic of the event study, model for data analysis, and sample, sources, and procedure for the data collection.

Logic of Event Study

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 arrival of new information reflects the present value of all expected current and future profits from that new information. The method has been widely used in the finance, accounting, economics, management, and marketing literatures to assess the market value of information contained in various events of interest. The market returns 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 next subsection explains how we compute such market returns to an event. Total returns to innovation are the cumulative returns to all events within an innovation project.

Model

We estimate abnormal returns to the event using the Fama French 3 factor model (Fama and French 1993) including Carhart's momentum factor (Carhart 1997). Prior studies in event studies have relied on the standard Capital Asset Pricing Model that assumes that the market portfolio is the benchmark for normal returns to a stock (McKinlay 1997). However, the Fama-French 3 Factor Model expands the completeness of the model by adding two more factors: market capitalization and value. More recently, Carhart proposed the addition of a fourth factor, price-momentum, to account for persistence effect in returns reported by Jegadeesh and Titman (1993). Thus, the combined four-factor model is:

$$R_{it} - R_{ft} = \alpha_i + \beta_{1i}(R_{mt} - R_{ft}) + \beta_{2i} SMB_t + \beta_{3i} HML_i + \beta_{4i} UMD_i + \varepsilon_{it} \qquad \ldots (1)$$

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

where t : is a subscript for time of the estimation window, such that $-270 \leq t \leq -6$

i : is a subscript for announcement

R_i : Returns on announcement *i* on day *t*

R_m : Returns on corresponding daily equally-weighted S&P 500

R_f : Theoretical rate of return attributed to an investment with zero risk

SMB : Returns on a portfolio of small stocks minus returns on large stocks

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

UMD : Carhart's Price-Momentum Factor that captures one-year momentum in returns

ε_{it} is the disturbance term. α_i, β_{1i}, β_{2i}, β_{3i}, and β_{4i}, and σ^2 are the parameters of the model to be estimated. The risk-free rate represents the interest that one expects from a risk-free investment over a specified period of time. The interest rate on a three-month U.S. Treasury bill is commonly used as a proxy for the risk-free rate because short-term government-issued securities have virtually zero risk of default.

The returns variables are also computed at the level of project, *p*. We have suppressed subscripts for this level in the first four equations, for ease of reading.

We estimate the parameters of Equation (1) using an estimation period from 270 to 6 days prior to the announcement. For some new firms that 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_{it}) 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:

$$AR_{it} = R_{it} - E[R_{it}] = R_{it} - R_{ft} - \left\lfloor (\hat{\alpha}_i + \hat{\beta}_{1i}(R_{mt} - R_{f\,t}) + \hat{\beta}_{2i} SMB_t + \hat{\beta}_{3i} HML_t + \hat{\beta}_{4i} UMD_t \right\rfloor \qquad \ldots (2)$$

for $-1 \leq t \leq 1$

where AR_{it}, R_{it} and $E(R_{it})$ are the abnormal, observed, and normal returns respectively for announcement i and event window t. We also try windows centered on the date of announcement of varying widths, ±1 and ±2 days before and after the event.

We estimate average abnormal returns and the t-statistic θ (Brown and Warner 1985) for the portfolio of N announcements of an event, thus:

$$AAR_t = \frac{1}{N} \sum_{i=1}^{N} AR_{it} \qquad \ldots (3)$$

$$\theta = \frac{AAR_t}{SD(AAR_t)} = \frac{AAR_t}{\sqrt{\frac{1}{(T_0 - 1)} \sum_{t=1}^{t=T_0} (AAR_t - \overline{\overline{AAR}})^2}} \qquad \ldots (4)$$

where,

AAR_t is the average (abnormal) returns for an event,

T_0 is the numbers of days in the estimation window, which in our case is 270 - 5= 265,

and $\overline{\overline{AAR}} = \frac{1}{T_0}\sum_{t=1}^{T_0} AAR_t$

Note that this portfolio t-test statistic explicitly takes into account any potential cross sectional dependence in the abnormal returns.

We compute cumulative average abnormal returns (CAR_i) in the event window as follows:

$$CAR_i = \sum_{t=t_1}^{t=t_2} AR_{it} \quad \ldots (5)$$

where t_1 and t_2 denote the beginning and end of the event window.

We also estimate the cumulative average abnormal returns using alternative models (see Figure 2), which are explained in the results section. We estimate the following model to ascertain the effect of hypothesized independent variables on cumulative abnormal returns (CAR_{ijk}), thus

$$CAR_{ijk} = \alpha + \beta_1 AL_i + \beta_2 FN_i + \beta_3 EP_i + \beta_4 PR_i + \beta_5 PT_i + \beta_6 PA_i + \beta_7 PL_i + \beta_7 RQ_i + \beta_8 AF_j + \beta_9 SZ_j + \beta_{10} RP_j + \beta_{11} AT_k + \eta_{ijk} \quad \ldots (6)$$

Where AL_{ijp} Announcements of alliances

FN_{ijp} Announcements of funding

EP_{ijp} Announcements of expansion

PR_{ijp} Announcements of prototypes

PT_{ijp} Announcements of patents

PA_{ijp} Pre-announcements

PL_{ijp} Announcements of commercialization

RQ_{ijp} Announcements of awards

AF_{jp} Announcement frequency

SZ_j Size of firm

RP_j Research productivity of the firm

AT_p Age of technology

where subscripts refer to announcement *i*, firm *j*, project *p*, respectively

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 few decades and the key global players are in U.S. markets. The first requirement is essential to ensure that we have a large sample of announcements and the second 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 collected data using the historical method (Golder 2000; Golder and Tellis 1993) on 19 technologies from five industries - external lighting, display monitors, computer memory, data transfer technologies, and desktop printer product categories (Appendix A). We identify a total of 69 firms in the five industries and collect a total of 5481announcements from 1977 till 2006 (see Table 2). There is substantial innovative activity in all the categories during this period.

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

Sources

Although many studies limit their focus to *a single* source of announcements, we posit the information on innovation projects reaches the markets through a variety 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 that 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 (which includes *Wall Street Journal)*, 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.

Procedure

After selection of the industry, we identify all major firms in the industry and collect information on each firm. We use the following key words to identify all the announcements: name or ticker symbol of firm, names of technology, and events of the innovation project. We sort the results based on oldest press report first to identify the first release of information to the market. We exclude press reports appearing in non-daily publications because of inherent inaccuracy of determining the exact date of release of information. Of the remaining press reports, when multiple reports contain identical information about an event, we retain only the first press report, which we treat as the announcement. However, an event may have multiple announcements because of new information in each announcement. Finally, we include announcements in the analysis of only firms whose data are available from CRSP (firms traded on NYSE, AMEX or NASDAQ) because we need price information to estimate returns.

We examine each announcement to classify the announcement by firm, innovation project of the firm, activity of the innovation project, and event within the set of activities.

RESULTS

Market response to announcements using the event study method suggests that the cumulative average abnormal returns to all announcements in the sample are positive (see Table 3). Across all categories, the cumulative average abnormal returns to all announcements are 0.4% on the event day. This result holds even when examined at the individual category level. Moreover, the returns are the highest on the day of the announcement and not significantly different from zero for event windows longer than 5 days (±2 days around the day of announcement) (see Table 3 and Figure 2). Hence, in the rest of the paper, we use the abnormal returns for an event window of only one day and use the term **returns** to mean abnormal returns. The returns that we report are for the Fama-French method (Equation 1), though in a subsequent subsection explores returns by other methods.

We present the results in four subsections: analysis of returns, analysis of total returns, additional analyses, and test of robustness.

Analysis of Returns

We now present the results of the analysis of returns. We separate the announcements based on the content into either positive information or negative information. The number of negative announcements across all three sets of activities was approximately 5% of the number of positive announcements. We estimate the cross-sectional average return to each event in each set of activities using the univariate method (Equation 3) and the multivariate method after controlling for various strategic and control variables (Equation 6).

Both results are consistent with each other and returns to most of the set of activities and events are significantly different from 0 (see Table 4). Initial examination of the data suggests heteroscedasticity. So we used Proc GLM in SAS. Table 4 reports these consistent estimates (refer section on regression diagnostics for more details). The Adj. R^2 for the models is at least 2.2% which is comparable to prior studies (Chaney, Divenney and Winer 1991; Koku, Jagpal and Viswanath 1997; Sorescu, Shankar and Kushwaha 2007). .

Setup Activities

Across all categories, the returns to all events in the setup activities are 0.6% (t=3.7). The findings indicate that firms gain by announcing their plans about such activities. At the event level, market returns are high for positive announcements of alliances (0.6%, t=5.5), funding (0.9%, t=2.3), and expansion plans (0.6%, t=2.2) (see Table 4). On the other hand, the returns were not significantly different from zero for the negative announcements of either breakup or termination of alliances (-0.3%, t=-0.9), decrease/delay of funding to projects (-1.3%, t=-0.6), or expansion plans (-0.6%, t=-0.9). A possible reason for these results is that while firms may keep information on forthcoming joint ventures under wraps, investors have other indicators of the forthcoming negative events, such as the dissolution of existing joint ventures before the actual formal announcement. So when the actual negative event is announced, its impact is not that bad.

Development Activities

Across all categories, the returns to all development activities are 0.9% (t=5.5). At the event level, we find that market returns are strongly positive for announcements of successful demonstration of prototypes (1.0%, t=9.0), patents (1.6%, t=4.0), and pre-announcements (1.2%, t=8.8) (see Table 4). A majority of the positive announcements on patents are of firms announcing award of patents. Surprisingly, negative returns for negative announcements are even higher in absolute value than the positive returns. For example, returns are -4.2% (t=-5.9) for delays in product development deadlines or failure to meet expected performance levels, -1.6% (t=-2.5) for denial of patents or patent infringement suits, and -4.7 (t= -9.6) for postponement, delay, deferral, shelving, or suspension of launches.

Market Activities

Across all categories, the returns to all market activities are 0.3% (t=2.5). At the event level, market returns are positive for announcements of launch of new products (0.2%, t=2.5) and receipts of awards (1.2%, t=5.2) (see Table 4). In contrast, market returns to delays in product launches, cancellation of plans to launch products, and product recalls due to malfunctions have a negative return of -4.7% (t=-7.2).

In summary, we find that market returns to negative announcements are negative across all events. However, the absolute value of the market returns is higher for negative announcements than for positive announcements. This result is consistent with theory and findings that losses loom larger than gains (Kahneman and Tversky 1979).

Activities with the Highest Returns

We find that the highest returns are for development activities (see Figure 1). Across all categories, the returns for the development activities are significantly greater than those for the setup activities (t=2.7) and the market activities (t=4.0). At the individual category level, the returns to development are more than market activities or setup activities in all five categories.

Results for Strategic and Structural Variables

The results of the analysis of strategic and structural variables estimated via the model in Equation 6 (see Table 4) are the following:

- A higher (or lower) number of prior announcements or longer time since last announcement within a project does not lead to higher returns. The results remain similar even if we code the prior number of positive or negative announcements separately.
- Returns are higher for smaller firms than for larger firms.
- The age of technology does not have an effect on the market returns to innovation.
- Firms with higher research productivity (across projects) do not have higher returns per announcement than firms with lower research productivity.

We used alternative measure of research productivity – the number of technologies a firm invests in. We find that returns for firms that invest in a few technologies is higher than for firms that invest across a broad set of technologies (t=-3.2).

Analysis of Total Returns

The sum of returns to all events *within* an innovation project of a firm provides the total returns to that innovation project. We exclude firms where data on shares outstanding are not available from CRSP. We then calculate the returns to each project as the sum of returns to all announcements for that project, thus:

$$TR_{jp} = RAL_{jp} + RFN_{jp} + REP_{jp} + RPR_{jp} + RPT_{jp} + RPA_{jp} + RPL_{jp} + RRQ_{jp} \ldots (7)$$

Where TR_{jp} is total returns to firm *j* for project *p*, and RAL_{jp}, RFN_{jp}, REP_{jp}, RPR_{jp}, RPT_{jp}, RPA_{jp}, RPL_{jp} and RRQ_{jp} are returns to all announcements of alliances, funding, expansion, prototypes, patents, pre-announcements, commercialization, and awards for project *p* respectively.

We estimate the average return to a project across the sample as

$$ATR_p = \frac{\sum TR_{jp}}{J} \qquad \ldots (8)$$

where J is the total number of projects in the sample. Table 5 shows that the total returns (averaged across all categories) are 10.3%. The total returns by category are about 13.1% for projects in lighting, 19.8% for projects in monitors, 7.02% for projects in memory products, 7.4% for projects in data transfer, and 3.8% for projects in printers. More importantly, the simple average return for any event is 0.6% which is comparable to estimates of returns to innovation reported by prior studies. However, *this value is substantially lower than the mean of 10.3% for the whole innovation project.* Hence, ignoring the totality of events of innovation, when estimating returns, severely underestimates the total returns to innovation.

To estimate the dollar value of returns to projects, we first compute dollar returns to announcements thus:

$$CARD_{ijp} = CAR_{ijp} * SO_j * SP_j \qquad \ldots (9)$$

Where $CARD_{ijp}$: Returns in dollars for announcement i

SO_j : Number of shares outstanding for firm *j* on day of announcement *i*

SP_j : Price of shares for firm *j* at the end of that trading day.

We then follow the same procedure as described above to compute the dollar value of returns to an event or an innovation project and that for the whole project. Across the five markets, the average return to an event is $49 million, while the average total return to any project is $643 million. Again, taken across or within categories, returns to projects are substantially more than the returns to individual events.

Additional Analyses

We now present two additional analyses: returns of first relative to later announcements and returns relative to competitors

First Announcement

Readers may suspect that the first announcement of an innovation project would yield higher returns than any other announcement. The reason may be that the first announcement tells of a whole new project or product by the firm. Subsequent announcements may not have as big an informational or signaling impact (Kleine and Leffler 1981; Le Nagard-Assayag and Manceau 2001). We test this hypothesis. We define the first announcement as the first ever release of information on an innovation project and later announcements as all other announcements during the project.

We find that the difference between the returns to the first announcement of any project and the returns to any later announcement (second, third or all subsequent) is not significantly different from zero. We also compare the returns to the first announcement in each set of activities with later announcements within the same set of activities and the results are similar. These results belie the expectation that the first announcement is more important. A possible reason might be that later announcements may have equally large (or larger) returns since what they lack in "news" value they make up for by indicating increasing confidence that the project will succeed.

Returns Relative to Competitors

How do the returns of the announcing firm affect returns to competitors in each of the three set of activities? Most past studies suggest that competitors experience negative returns in such a situation (Zantout and Tsetsekos 1994; Chen, Ho, Ik and Lee 2005; Ferrier and Lee 2002; Akhigbe 2002). We extend the analysis to examine the returns to firms relative to its competitors at various set of activities of the innovation project. We create a portfolio of all firms that did not make any announcement on the day the focal firm makes an announcement.

Consistent with the findings of prior literature, we find that in all three set of activities, the returns to competitors are negative (see Table 6). These results hold even if we expand the definition of competitors to include all firms across categories in our sample not making the announcement or use wider windows around the day of the announcement (e.g. ±1 or ±2 days).

Tests of Robustness

We carry out a number of analyses to test the robustness of the results including regression diagnostics, alternative method to estimate returns, alternate market index, non-parametric tests, accounting for lack of clean estimation period.

Regression Diagnostics

We examine the impact of residuals (outliers) on the outcome and accuracy of the regression results. First, we repeat the regression after trimming the dependent variable by symmetric capping each tail at the 1% and 2.5% levels. Second, we repeat the regression after removing observations with large residuals (outliers with potentially undue influence and/or high leverage on the results) with values of Cook's distance higher than 4/n (Cook 1979). The results are similar to original results in both cases for all variables except for new funds where the coefficient is still positive but no longer significant.

We also test for presence of autocorrelation of errors using the Durbin-Watson statistic after removing these outliers. The tests fail to reject both null hypotheses of no autocorrelation in the errors against the alternative hypotheses of positive and negative autocorrelation, respectively, for i^{th} order autocorrelation where $0 \leq i \leq 4$.

The White test is significant (Pr>ChiSq=<.0001) and suggests potential heteroskedasticity of residuals. We plot the residuals versus fitted values to investigate any patterns of increasing residuals. No such patterns are visible. We also re-estimate the model after removing observations to maintain a constant bound on the variance of residuals; the results are similar.

In both the level of set of activities and individual events of analysis, multicollinearity is not a problem among the control variables, as indicated by the coefficient variance-decomposition analysis and the condition indices.

Alternative Methods to Estimate Market Returns

We use three other models to estimate the 'normal' returns in order to verify the robustness of our results – mean, market adjusted, and market model (McKinlay 1997). First, we used the mean return model (Equation 9), in which the firm is expected to generate the same return that it averaged during a previous estimation period. Second, we used the market adjusted return model (Equation 10), in which the firm is expected to generate the same return as the rest of the market. Third, we used the market model where the firm is expected to generate the same return as a portfolio of stocks used to represent the overall market (equation 11).

$$R_{it} = R_i + \varepsilon_{it} \qquad ...(9)$$

$$R_{it} = R_{mt} + \varepsilon_{it} \qquad ...(10)$$

$$R_{it} = \alpha_i + R_{mt} + \varepsilon_{it} \qquad ...(11)$$

where R_{it} and R_{mt} are the period t returns on security i and the market portfolio respectively and ε_{it} is the zero mean disturbance term. The estimation window for all three models is the same as for Equation 1. For each firm i and event date t, we have

$$AR^*_{it} = R_{it} - \hat{R}_i \qquad ...(12)$$

$$AR^*_{it} = R_{it} - R_{mt} \qquad ...(13)$$

$$AR^*_{it} = R_{it} - (\hat{\alpha}_i + \hat{\beta}_i \mathrm{R}_{mt}) \qquad ...(14)$$

Where $AR^*_{it}, \hat{R}_i, \hat{\alpha}_i$ and $\hat{\beta}_i$ are the abnormal return, mean firm return and parameter estimates of market adjusted model respectively. The plots of CAAR in Figure 2 using all models – mean, market and market adjusted models demonstrate that the CAAR was not much different with the use of these models. Similarly, there were no significant differences in the reported results for the hypotheses with the use of these alternate models as well.

Alternate Market Index

We use the equally weighted market index to estimate the abnormal returns in equation 1 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 use the Wilcoxon sign rank test to test the null hypothesis that the observed returns are symmetrically distributed around 0 and 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. The Wilcoxon sign-rank test uses both the sign and the rank information in its test and is therefore more powerful then the simpler Binomial Sign test. The results reject the null ($p = 0.001$) and support our findings that markets returns to innovation are positive.

Accounting for 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 i.e. 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 remove the dates of all prior announcements made by the firm from the estimation period (Brown and Warner 1985) and re-estimate the returns. The results do not change much with this correction.

DISCUSSION

This section summarizes the findings and discusses implications and limitations.

Summary of Findings

The current research leads to six major findings:

- Total market returns to an innovation project are $643 million, substantially greater than $49, the returns to an average event in the innovation project.
- Of three set of activities of innovation (setup, development, and market), returns to the development activities are consistently the highest across and within categories.
- Returns to negative events are higher in absolute value than those to positive events.
- Returns are consistently higher for small firms than for large firms and for those that focus on a few rather than many technologies.
- Returns to the announcing firm are substantially greater than those to competitors across all stages.
- Number of prior announcements or time since the last announcement has no effect on the market returns to innovation.
- Returns to the first announcement of an innovation project are not different from returns to later announcements. Similarly results for older technologies and projects are not different from those for newer ones.

Implications and Contributions to Practice

This study has several implications for managers.

First, when considering the value of innovation, it is *inappropriate* to limit the analysis to only one or other event in the innovation project. The frequently cited "under valuation" of innovation (Hall 2005; 1993; Hall, Mansfield and Jaffe 1993) may be due, not to markets not appreciating the full value of innovations immediately but to researchers computing returns to isolated events in an innovation project. In particular, across the five markets, the average returns to an event are $30.8M, while the average returns to any project are $661M. Following the approach described in this study, managers can compare the costs of an innovation project to the average returns they can get, to better assess the value of any innovation project they plan to undertake.

For example, AXT Inc. develops and markets three product lines of high-performance compound semiconductor substrates - gallium arsenide (GaAs) substrates, indium phosphide (InP) substrates, and single-element substrates. During the period 2000-2003, the firm made various announcements regarding development of new products, allocation of resources to the three innovation projects, and expansion of manufacturing facilities. With our approach, we estimate the total return to the three innovation projects to be $29.3M. These returns are substantial when compared to the total R&D expenditures $11.9M during this period.

Second, the findings on various announcement strategies indicate that a mere increase or decrease in either the frequency or total number of announcements does not lead to an increase or decrease in returns. The median number of prior announcements in our sample is 2 and the 90^{th} percentile is 9. Moreover, the first announcement of a project is no more important than later announcements. These results imply that the markets are efficient and firms cannot game the system by over-announcing or multiple announcements of a single event.

Third, the absolute value of a negative announcement is greater than that for a positive announcement. Thus, firms should be cautious not to exaggerate progress in their innovation projects or to resort to vaporware. However, because returns are positive for all positive announcements and significantly different from 0 for all but two of the positive announcements,, firms should make it a point to announce these events. Otherwise, they lose the opportunity for increasing market capitalization involved in such announcements. These findings are also consistent with recent findings in marketing literature that suggests markets react positively to new product introductions but discount short term promotions.

Fourth, returns are highest for developmental activities. Returns are higher for development activities over startup activities, probably because startup activities involve heavy up front commitment of expenditures and resources with the payoff uncertain and several years away. Returns are higher for development activities over market activities, because development activities reflect the greatest reduction of uncertainty and already capture some of the expected returns from future market capitalizations. Thus, it is important that firms exploit the progress in development by fully announcing all such developments.

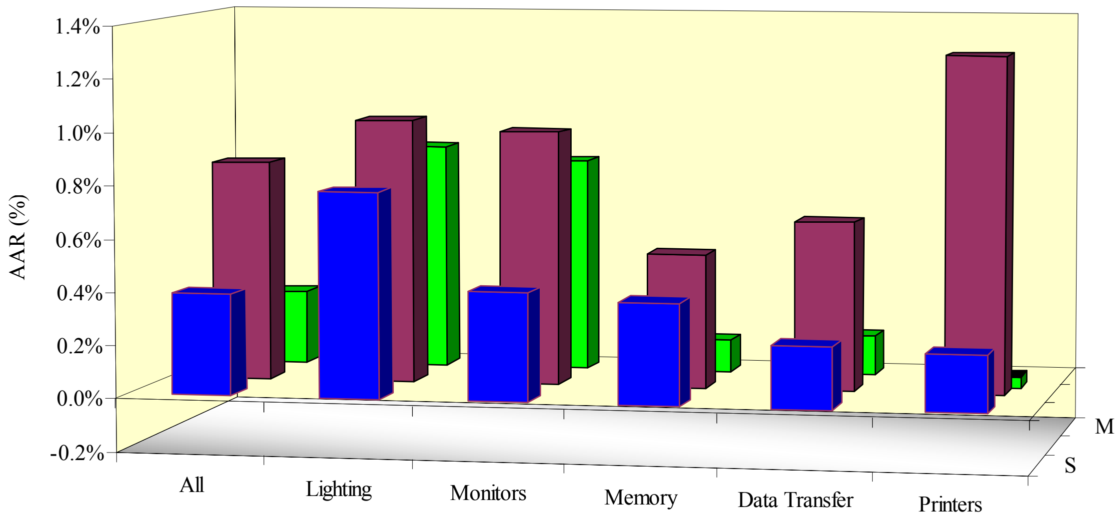
Fifth, when announcing innovations, small firms do not seem to suffer any disadvantage relative to large firms. Rather, small firms seem to gain higher returns than large firms, ceteris paribus. A possible reason for this effect is that large firms are intensely researched and covered by the investment community. Thus, good news from small firms is more likely to come as a positive surprise than that from large firms.

Limitations and Future Research

This study has several limitations which can be basis of future research. In all categories, the highest average returns are consistently for announcements in the development activities. However, we could find no strong theory for why this occurs. Second, we limit our analyses to only five industries due to the difficulty in collecting a comprehensive set of announcements on all events about innovation projects. Third, the data does not include firms not listed on the stock markets. Future research might explore whether the same results hold for such firms. Fourth, the results may be affected by a potential selection bias as firms can be more selective about the type of announcements made during set-up and development than during the market stage.

Figure 1:

Average Abnormal Returns (AAR) in Each Set of activities of Innovation Project



	All	Lighting	Monitors	Memory	Data Transfer	Printers
S	0.4%	0.8%	0.4%	0.4%	0.2%	0.2%
D	0.8%	1.0%	1.0%	0.5%	0.6%	1.3%
M	0.3%	0.9%	0.8%	0.1%	0.2%	0.0%

Figure 2:

Cumulative Average Abnormal Returns (CAAR) using OLS Market, Mean Adjusted, Market Adjusted, and FF 3 Factor (+ momentum) Models

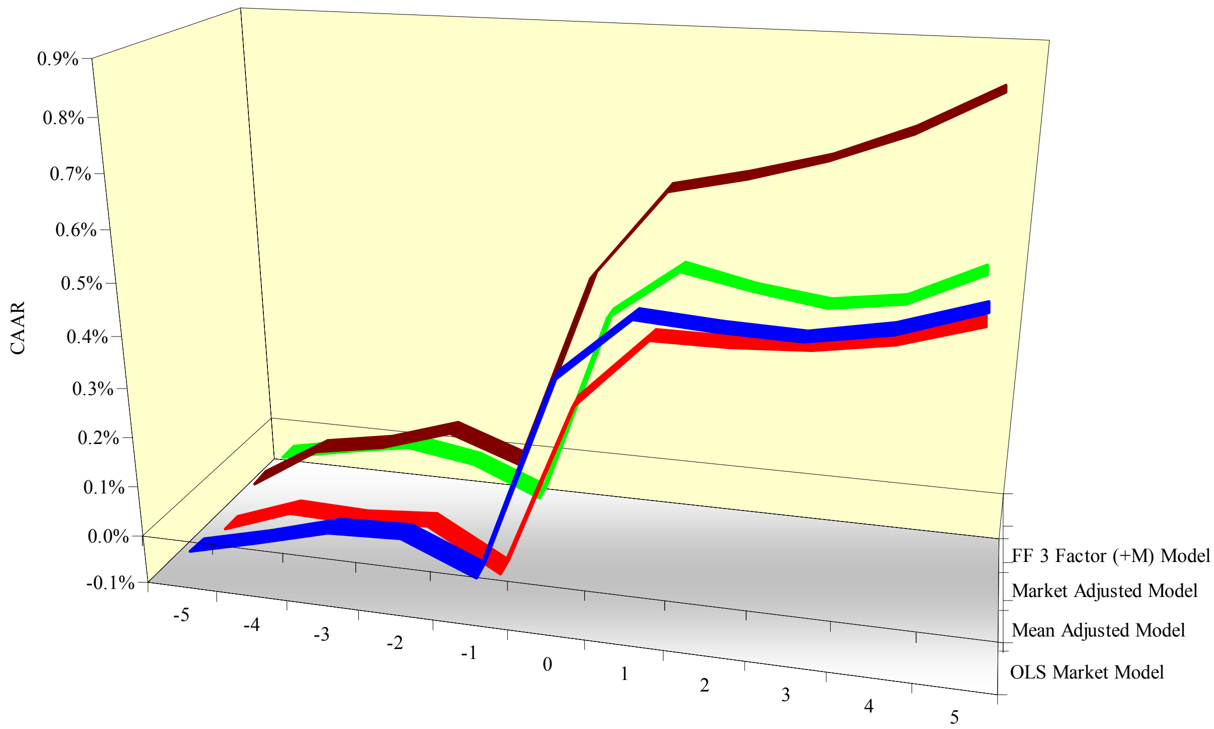


Table 1:

Events During Setup, Development, and Market Activities of Innovation Projects

Phase	**Setup**	**Development**	**Market**
Events Unique to this Study	Funding (grants, advanced order, funded contracts) Expansion (new development or manufacturing facilities)	Prototypes (Working prototypes, Identification of new materials, processes or equipment, demonstration in exhibitions)	New Product Commercialization (Shipments, New Applications)
	This Research (positive and negative events are recorded separately for announcements of all activities)		
Events Covered by Prior Research	Alliances (joint ventures, acquisitions)	Patents Pre-announcements (more than 1 week ahead of future events)	New Product Commercialization (launches) Awards (External recognition of quality)
Prior Research	Hirschey 1982 Jaffe 1986 Cockburn and Griliches 1988 Doukas and Switzer 1992 Chan, Kensinger and Martin 1992 Hall 1993 Das, Sen and Sengupta 1998 Chan, Lakonishok and Sougiannis 2001 Suarez 2002	Pakes 1985 Jaffe 1986 Erickson and Jacobson 1992 Kelm, Narayanan and Pinches 1995	Eddy and Saunders 1980 Wooldridge and Snow 1990 Chaney, Divenney and Winer 1991 Zantout and Chaganti 1996 Hendricks and Singhal 1996 Koku, Jagpal and Viswanath 1997 Przasnyski and Tai 1999 Nicolau and Sellers 2002 Sorescu, Chandy and Prabhu 2003 Bayus, Erickson, and Jacobson 2003; Pauwels, Silva-Risso, Srinivasan and Hanssens 2004 Sorescu, Shankar and Kushwaha 2007 Tellis and Johnson 2007

Table 2:

Sample Characteristics

Category	External Lighting	Display Monitors	Desktop Memory	Data Transfer	Printers
Number of firms	19	17	18	17	11
Total Number of Announcements	696	1100	1239	1323	1123
Sample Period	77 - '06	'80 - '06	'79 - '06	'82 - '06	'81 - '06
Setup Activities	155	278	270	327	117
Development Activities	171	305	274	183	126
Market Activities	370	517	695	813	880
Number/ Type of Platform Technologies	5	5	5	3	4
	Incandescence, Arc-discharge, Gas-discharge, LED, MED	CRT, LCD, Plasma, Display panels, OLED	Magnetic, Magneto-optical, Optical	Copper/ Aluminum, Fiber Optics, Wireless	Dot Matrix, InkJet, Laser Thermal

Table 3:

Descriptive Statistics

Abnormal Returns to An Average Event By Category for Various Windows

Category	N	AAR (Event Day)					CAAR (±1 days)		CAAR (±2 days)	
		Est. (%)	t-value	p-value[1]	% Positive	p-value[2]	Est. (%)	t-value	Est. (%)	t-value
ALL	5481	0.4	7.4	< .0001	52	< .0001	0.5	14.7	0.5	3.3
Lighting	696	0.9	6.3	< .0001	56	< .0001	1.1	13.7	1.4	3.6
Monitors	1100	0.8	3.5	< .0001	51	0.015	0.7	5.7	0.4	0.7
Memory	1239	0.3	2.7	0.0135	51	0.004	0.5	9.3	0.4	1.4
Data Transfer	1323	0.2	2.8	0.0047	51	0.004	0.2	4.6	0.3	1.5
Printers	1123	0.1	1.8	0.1301	51	0.026	0.1	1.6	0.3	1.5

Note:
[1] The p-value is estimated using Brown-Warner (1985) approach.
[2] The p-value is estimated by sorting the 265 average abnormal returns from minimum to maximum and calculating how far away from the tail in rank the event average abnormal return in these 265 values. We thank the anonymous reviewer for suggesting this.

Table 4:

Average Abnormal Returns to Various Events during Innovation Projects

Announcements	Univariate (Equation 3)						Multivariate (Equation 6)					
	Positive only			Negative only			Positive only		Negative only		All [2]	
	N	Est. (%)	t-value[1]	N	Est. (%)	t-value[1]	Est. (%)	t-value	Est. ()	t-value	Est. ()	t-value
Intercept							-0.02	-0.1	0.6	4.6	0.2	1.0
Alliances	878	0.6	5.1	34	-0.02	-0.1	0.5	3.3	0.2	0.4	0.4	2.6
Funding	154	0.9	2.3	18	-1.3	-0.6	0.7	2.1	-1.1	-1.4	0.4	2.4
Expansion	181	0.6	2.2	29	-0.6	-0.9	0.4	1.1	-0.3	-0.2	0.2	0.7
Prototypes	776	1.0	9.0	21	-4.2	-5.9	0.6	3.5	-2.3	-2.4	0.5	2.6
Patents	218	1.6	4.0	85	-1.6	-2.5	1.4	4.9	-1.8	-4.4	0.4	1.6
Pre-announcements	762	1.2	8.8	39	-4.7	-9.6	0.9	5.3	-3.2	-4.3	0.6	3.6
Commercial-ization	2106	0.2	2.5	16	-4.7	-7.2	0.2	1.6	-2.2	-2.2	0.01	0.1
Awards	488	1.2	5.2				0.8	3.9	0.0	1.8	0.7	3.0
Announcement Frequency[3]							1.8E-05	1.0	-7.9E-08	-3.9	2.4E-05	1.4
Size of firm[4]							-8.6E-08	-4.2	-8.0E-05	-1.07	-8.2E-08	-4.0
Research Productivity							-5.8E-05	-0.8	1.3E-05	0.4	-5.7E-05	-0.8
Age of Technology							3.4E-05	1.1	1.3E-05	0.4	2.6E-05	0.8
Adj. R^2							2.48		2.24		1.48	

Note:

1 Estimated using Brown-Warner (1985) Method (Equation 4)

2 Announcement Frequency measured as the number of prior announcements

3 Positive announcements coded as "1" and negative announcements coded as "-1"

4 Size of Firm was also measured as the number of technologies that a firm invests in

Table 5:

Total Abnormal Returns to Innovation By Category

Stage	**Total Abnormal Returns (%)** (Equation 7)	**Total Abnormal Returns ($M)** (Equation 8)
All	10.3	972
Lighting	13.1	712
Monitors	19.8	1,275
Memory	7.02	446
Data Transfer	7.4	2635
Printers	3.8	432

Table 6:

Effect of Innovation on Abnormal Returns to Competitors

Category	Phase	Competitors		Difference in Abnormal Returns to Competitors vs. Announcing Firm	
		Est. (%)	t-val	Diff (%)	t-val
ALL	S	0.1	0.7	-0.3	2.5
	D	0.1	2.5	-0.7	5.1
	M	0.1	2.3	-0.2	2.2
Lighting	S	-0.1	-0.6	-0.9	2.3
	D	0.0	-0.4	-1.1	2.9
	M	0.1	1.6	-0.7	2.4
Monitors	S	0.1	1.1	-0.4	1.3
	D	0.1	0.7	-4.7	3.1
	M	0.1	0.8	-0.8	3.1
Memory	S	0.1	1.6	-0.3	0.9
	D	0.1	1.1	-0.4	1.7
	M	0.0	-0.1	-0.1	0.8
Data Transfer	S	0.0	0.3	-0.1	0.6
	D	0.2	1.2	-0.4	1.8
	M	0.1	1.5	-0.1	0.5
Printers	S	-0.2	-1.5	-0.5	1.7
	D	0.5	3.1	-0.9	2.0
	M	0.1	1.5	0.2	-1.5

Note: S- Setup; D – Development; M – Market

Appendix A

Operating Principles of Sampled Technologies

(Adapted from Sood and Tellis 2005)

	Technology	Principle
External lighting		
1	Incandescence	Generate light by heating up thin metallic wires with an electric current
2	Arc-Discharge	Emit light by arc formed between two electrodes oppositely charged by an electric current in a high-pressure gas chamber
3	Gas-Discharge	Electrons excited by passing an electric current in a low-pressure gas chamber emit light
4	Light Emitting Diode (LED)	Emission of the light in n-p transition zone under influence of an electric potential
5	Microwave Electrodeless Discharge (MED)	Emission of light by microwaves from induction coil inside the bulb to excite the gas.

Display Monitors

1	Cathode Ray Tube (CRT)	Form an image when electrons, fired from the electron gun, converge to strike a screen coated with phosphors of different colors
2	Liquid Crystal Display (LCD)	Create an image by passing light through molecular structures of liquid crystals
3	Plasma Display Panel (PDP)	Generate images by passing a high voltage through a low-pressure electrically neutral highly ionized atmosphere utilizing the polarizing properties of light
4	Organic Light Emitting Diode (OLED)	Generates light by combining positive and negative excitons (holes emitted by anodes and electrons emitted by cathodes) in a polymer dye through the principle of Electroluminescence.

Desktop Memory

1	Magnetic	Records data by passing a frequency modulated (FM) current through the disk drive's magnetic head thereby generating a magnetic field that magnetizes the particles of the disk's recording surface.
2	Optical	Stores data using the laser modulation system and changes in reflectivity are used to store and retrieve data.
3	Magneto-Optical	Records data using the magnetic-field modulation system but reads the data with a laser beam.

Computer Printers

1	Dot-Matrix	Create an image by striking pins against an ink ribbon to print closely spaced dots that form the desired image
2	Inkjet	Form images by spraying ionized ink at a sheet of paper through micro-nozzles
3	Laser	Form an image on a photosensitive surface using electrostatic charges, then transfer the image on to a paper using toners, and then heat the paper to make the image permanent
4	Thermal	Form images on paper by heating ink through sublimation or phase change processes.

Digital Data transfer

1	Cu/Al	Transmit data in the form of electrical energy as analog or digital signals.
2	Fiber Optics	Transmit data in the form of light pulses through a thin strand of glass using the principles of total internal reflection.
3	Wireless	Encodes data in the form of a sine wave and transmits it with radio waves using a transmitter-receiver combination.

Appendix B

Examples of Positive and Negative Announcements

Joint Ventures

Positive: Cree Research and Philips sign joint agreement; new laser diodes will increase optical storage capacity; ARPA provides $4 million funding
Negative: Hitachi, GE dissolve lighting joint venture.

New Funds

Positive: Intel To Invest $100 Million In Hitachi, Ltd.'s Join Venture Elpida Memory Inc.-DJ
Negative: Storage Technology loses loan.

New Prototypes

Positive: IBM Says It Set Record For Bits of Data on Disk
Negative: Gentex delays new LED technology.

New Patents

Positive: Universal Display Corporation Announces Issuance of the Fourteenth Patent in the Organic Light Emitter Project
Negative: Seagate Files Patent Infringement Lawsuit Against Storage Computer Corp.

Pre-announcements

Positive: Sony Corp of Japan said on Tuesday it will launch a home-use optical-type videodisc player, "Laser Max", on April 21.
Negative: Sony to delay mass production of digital audio tape (DAT) heads.

Product Launch

Positive: Sony Expands 5.25-Inch Magneto Optical Library Line to Include Permanent WORM Configurations
Negative: Sony to delay mass production of digital audio tape (DAT) heads.

Quality Awards

Positive: EPA Names Lexmark International "Energy Star Printer Partner of the Year"

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