THE JOURNAL OF INDUSTRIAL ECONOMICS 0022-1821
Volume XLVIII March 2000 No. 1

R&D INTENSITY AND ACQUISITIONS IN HIGH-TECHNOLOGY INDUSTRIES: EVIDENCE FROM THE US ELECTRONIC AND ELECTRICAL EQUIPMENT INDUSTRIES*

Bruce A. Blonigen† and Christopher T. Taylor‡

Theory suggests R&D intensity and acquisition activity may be either directly or inversely related. However, we know relatively little about which firms are responsible for acquisition activity in high-technology industries, which are not only R&D-intensive, but also have substantial acquisition activity in the United States. Using a panel of 217 US electronic and electrical equipment firms from 1985–93 and limited dependent variable estimation techniques, we find a substantial negative correlation between R&D-intensity and a firm's propensity to acquire. This result is surprisingly robust to numerous sensitivity tests and is significant in both the 'within' and 'between' dimensions of our data.

I. INTRODUCTION

Research and development (R&D) activity and innovation have taken center stage in economic analysis of high-technology industries. A number of papers including Dasgupta and Stiglitz [1981], Reinganum [1985] and Jovanovic and MacDonald [1994a, 1994b] model and simulate industry evolution through patterns of innovation and imitation by firms.[1] Firm survival in these models depends on the ability to innovate or imitate new products, suggesting that firms must generate marketable products on their own or exit the market. However, these models do not consider that firms may obtain technology (or other assets) through acquisitions or licensing, which may be as important in determining firm survival and

* We thank Severin Borenstein, Lee Branstetter, Shane Greenstein, Bronwyn Hall, Carol Horton Tremblay, Wes Wilson, David Schimmelpfennig, Scott Stern, anonymous referees and participants at the NBER conference, *Competition and Organization in Technology-intensive Industries*, and Western Economic Association meetings for useful comments and suggestions. We would also like to thank James Mehring for valuable research assistance. The views expressed herein are those of the authors and do not represent the views of the Federal Trade Commission. Any errors or omissions are the responsibility of the authors.

† Department of Economics, 1285 University of Oregon, Eugene, OR 97403-1285, USA
email: bruceb@oregon.uoregon.edu (541) 346-4680

‡ Antitrust Division, Bureau of Economics, Federal Trade Commission, Washington, DC 20580, USA
email: ctaylor@ftc.gov (202) 326-2997

[1] In addition to the papers mentioned above, chapter ten of Tirole [1988] has a thorough overview of this literature.

TABLE I
ACQUISITION ACTIVITY IN SELECTED HIGH TECHNOLOGY US MANUFACTURING SECTORS

Sector	Sector's average annual domestic acquisitions, 1989–94	Sector's average share of domestic manufacturing acquisitions, 1989–94	Sector's share of total US firms in manufacturing (1992)	Sector's share of total US manufacturing shipments (1992)
Chemicals and Drugs	73.7	7.8%	4.6%	5.7%
Computer and Office Equipment	46.2	4.9%	0.6%	2.2%
Electronic and Electrical Equipment	84.3	8.9%	3.1%	4.5%
Measuring, Medical and Photographic Equipment	96.0	10.2%	2.2%	6.6%

Sources: Acquisition data for columns 1 and 2 come from the publication *Mergers and Acquisitions*, various issues. Data for columns 3 and 4 are from the US 1992 *Census of Manufactures*.
Notes: Chemicals and Drugs includes SIC 281, 283, 286, 287, and 289, Computer and Office Equipment is SIC 357, Electronic and Electrical Equipment is SIC 36, and Measuring Medical and Photographic Equipment is SIC 38. Acquisition classifications were by target firm and only those transactions of $1 million or greater are recorded by *Mergers and Acquisitions*.

growth as R&D. In contrast, papers such as Salant [1984], Gallini and Winter [1985], Katz and Shapiro [1986], and Gans and Stern [2000] show that licensing or acquisitions can alter firms' incentives to innovate. Thus, by allowing the firm with the highest-valued use to obtain an innovation, the acquisition market may play an important role in high-technology sectors.

Table I shows that acquisition activities are empirically important for high-technology industries.[2] The first two columns of Table I show annual average acquisitions and average annual share of all manufacturing acquisitions for some select high technology sectors in the United States from 1989–94.[3] For comparison, the third and fourth columns of Table I show each sector's share of total manufacturing firms and total manufacturing shipments, respectively. Table I demonstrates that acquisition activity in these high technology sectors is much larger than their share of total manufacturing firms or shipments. For example, computer and office equipment firms represent 0.6 percent of all manufacturing firms and account for 2.2 percent of all manufacturing shipments, but represents

[2] We focus on acquisition activity in this paper because of data availability and its relative importance for the firms we sample. The literature suggests that licensing arrangements seem most important for the pharmaceutical industry.

[3] Our choice and definition of high technology sectors was limited by the categories reported by *Mergers and Acquisitions*, our data source for the merger and acquisition data.

almost 5 percent of manufacturing acquisition activity. All four high-technology sectors in Table I display this same pattern.

Previous literature has examined the relationship between R&D intensity and acquisition activity. As will be discussed in the next section, theory argues that there may be either a direct or inverse relationship between R&D intensity and acquisition activity. The sparse empirical work on this issue finds mixed results. In addition, previous empirical work has typically examined firms across a wide cross-section of industries, yet the R&D process and technological innovation are much more important in certain sectors of the economy. Therefore, estimates from a sample of firms across a wide variety of industries may obscure a strong interaction between R&D intensity and acquisition activity in R&D-intensive sectors.

In response, this paper examines the empirical evidence on the relationship between R&D intensity and acquisition activity in the electronics and electrical equipment industry.[4] The question is which firms are acquiring assets in these industries? In particular, is it firms that are investing in R&D or not? Controlling for traditional merger motives, we explore whether high R&D intensity firms are more or less likely to make acquisitions using a sample of over 200 firms in the US electronic and electrical equipment industry from 1985 to 1993. Estimation is complicated by availability of only discrete counts of acquisitions (our dependent variable), potential issues of simultaneity, and dynamic considerations of the relationship between R&D intensity and acquisition activity over time.

Our results show a strong negative correlation between R&D intensity and acquisition activity; in other words, relatively low R&D firms in these industries are more likely to participate in the acquisition market. This result is surprisingly robust to a wide variety of specifications and sensitivity tests. The panel nature of our data also allows an analysis of the extent to which this R&D intensity/acquisition relationship stems from the 'between' dimension of our data (i.e., across firms) versus the 'within' dimension (i.e., over time within a firm). We find that there is a significant inverse relationship between R&D intensity and acquisition activity across *both* dimensions. In other words, not only are relatively low R&D-intensive firms more likely to acquire, but over time a firm is more likely to acquire during periods of lower R&D intensity.

While our approach and data have the advantage of focusing on a specific set of relatively R&D-intensive industries, our data are poor at

[4] We note that there is substantial variation in R&D intensity across sectors in these industries as well. However, as we note below, our results are robust to eliminating observations of very low R&D or very high R&D intensity, or controlling for industry effects.

revealing characteristics of the targets.[5] However, we present some evidence that the majority of the targets in our sample are technologically important. To the extent this is true, our results have implications for the 'make or buy' literature. In particular, a finding that R&D intensity is inversely related to acquisition of technological assets may suggest that firms in the same industry are pursuing different strategies for growth and survival. That this relationship shows up over time within firms, suggests that this 'make or buy' strategy can change in the short-run, perhaps when the firm runs into trouble pursuing one particular strategy. Regardless, the strong inverse relationship between R&D intensity and acquisition activity is a puzzle that suggests necessary future work in this area.

The rest of the paper is organized as follows. The next section discusses in greater detail the potential for competing hypotheses on the relationship between R&D intensity and acquisition activity. The following sections present the data, our estimation methodology, and empirical results. A final section concludes.

II. R&D AND ACQUISITION ACTIVITY IN HIGH TECHNOLOGY INDUSTRIES

A traditional motive for acquisition activity is the potential for synergy gains. As formulated in Hall [1987], the acquisition market is a matching process. In this matching process a firm calculates the potential costs and synergy gains from an acquisition with all the possible target firms. A firm with more assets will have a greater potential for synergy with another firm's assets, ceteris paribus, and thus, is more likely to acquire. If firms with higher R&D intensity are generating more technological and innovative assets, one would expect R&D intensity to be positively correlated with acquisition activity. This assumes there is a strong correlation between R&D intensity and valuable innovations, which may not be true (Trajtenberg [1990]). However, Geroski *et al.* [1993] find that the process of innovation may be just as important to firm profitability as the product of innovation; thus, the assets connected with the R&D process may be as important for synergy motives as the innovations they may generate. This argument creates a credible case for a positive correlation between R&D intensity and acquisition activity.

Hall [1987] specifically explores the role of R&D activity in creating

[5] Hall [1987] is the only study of which we are aware that conducts a statistical investigation of acquisitions with data on both the acquiring firm and the target. However, to achieve this, Hall sampled all industrial firms in the Compustat data files and only looked at 'matches' between firms for which data were available on both. If we followed Hall's study, our sample size would have been reduced to only a handful of acquisition observations. Instead, we record all acquisitions by our firms, which yields 531 acquisitions across our sample of firms and years. However, these acquisition targets are often small firms or division of firms for which there are little or no associated financial data available.

the synergy gains that lead to acquisitions. She estimates a matching model of the acquisition decision by a firm. Conditional that a firm is in the acquisition market, the firm considers all other firms as potential targets and acquisitions occur when assets of the acquiring firm and target create synergy gains to yield a large enough return. The paper uses a large cross-industry sample constructed from all firms in the Compustat data files and focuses on synergy gains with respect to R&D assets and activity. The main finding with this matching model is that firms of like sizes and R&D intensity are more likely to merge. In addition, Hall [1987] finds that the shadow price of R&D intensity of the target firm increases in the acquiring firm's R&D intensity. These results suggest that R&D intensity may create important synergies that make a firm's valuation of a potential target greater. However, it should be noted that this result does not necessarily mean that R&D intensity is positively correlated with acquisition activity since it is conditional on the firm already having decided to acquire. In fact, when Hall [1987] explores determinants of the probability that a firm engages in acquisitions, R&D intensity is not a significant explanatory variable across the study's sample of years, 1976–86. However, for the subsample of years,1982–86, R&D intensity is *negatively* related to the probability of acquisition.

A negative correlation between R&D intensity and acquisition activity may occur because firms are choosing between an internal growth strategy with relatively high R&D intensity versus an external growth strategy with acquisitions. This is what is traditionally known as 'make or buy' strategy. Anecdotal evidence of managers using acquisitions for growth are common in high-technology industries. For example, a 1991 *Electronic Business* article (January 7, 1991, pp. 28–32) reports that the CEO of Seagate Technology, a manufacturer of disk drives, blamed financial losses in early fiscal 1989 for a slow down in R&D which then made Seagate tardy in bringing new innovations to the marketplace. As a result, Seagate acquired Imprimus Technology Inc., formerly a disk drive subsidiary of Control Data Corporation which claimed the fastest disk drive in the world at that time, in October 1989. In another example, Vishay Inter-technology, a manufacturer and distributor of electronic resistors, apparently decided on external acquisition of technology over internal development in the late 1980s as well. Again, an *Electronic Business* article reports that the CEO of Vishay, Felix Zandman, felt that 'Vishay could have grown either by developing new products or by acquiring companies in a related business. 'We decided to acquire,' he says' (*Electronic Business*, Jan. 7, 1991, p. 39). From November 1987 to October 1988, Vishay bought three resistor companies. A final example comes from the software industry. Mark Bailey, Vice President at Symantec Corporation, writes in an article for the March/April, 1995 issue of *Mergers & Acquisitions*,

> 'de novo innovations are becoming riskier, more expensive, and more time consuming in markets where survival depends on speed. Hence, high tech firms, as exemplified by software developer Symantec Corp., are going outside to get companies with talented people and proven products that can meet market demands and generate technological throw-offs for the future.' (p. 31)

The article notes that Symantec Corporation acquired 18 firms in its 12-year history.

Interestingly, these examples point out that acquisitions may be either a long-run strategy for growth or, in the case of Seagate, a response to difficulties in generating innovations and internal growth. If the latter case is the norm, it is not clear that there would be a negative relationship between R&D intensity and acquisition activity in general, as would be true with the former case. As Trajtenberg [1990] points out, while there is a strong relationship between R&D and patents, the relationship between R&D and valuable innovations is much weaker. Perhaps firms do not vary their R&D efforts, but use acquisitions in those periods when they have a below average realization of valuable innovations. In this case, one would not expect to find any correlation between R&D intensity and acquisition activity.

Francis and Smith [1995] suggest another important reason why some firms may choose to specifically focus on growth via acquisition rather than growth via internal R&D: the form of ownership in the firm. They argue management-owned firms are more likely to grow through internal R&D, while widely-held firms prefer acquisitions since it is a less risky and faster strategy. This provides an additional explanation for why firms may differ in their preference for R&D activity versus acquisition activity. However, it should be noted that their empirical results are quite mixed with respect to whether more diffusely-held firms prefer acquisitions to internal growth through the R&D process.

A recent paper by Gans and Stern [2000] in the patent race and innovation literature suggests that the relationship between R&D intensity and licensing/acquisition activity may be theoretically ambiguous. They begin with the standard model in this literature where an incumbent firm and entrant firm compete in a patent race. However, if the entrant wins the race, they do not assume the entrant will start production. Instead, the entrant may license the new technology to the incumbent (or equivalently the incumbent may acquire the potential entrant). They find that licensing/acquisition, rather than product market competition, is a unique equilibrium in their model when the entrant innovates before the incumbent. In particular, when the expected licensing fee (or acquisition cost) is small, the incumbent considers the entrant's research as an imperfect substitute for its own research; i.e. the incumbent's and entrant's research activities are strategic substitutes. In contrast, when the expected licensing fee is large, they are strategic complements, which is consistent with the traditional literature on patent races.

Besides the papers mentioned above, a few other notable papers have empirically examined acquisition activity in high technology industries and its relationship to the R&D process. Granstrand and Sjölander [1990] suggests that acquisitions in high-technology industries involve large firms acquiring the technology generated by small firms. They also present preliminary empirical evidence that this phenomenon occurs with Swedish firms. Hall [1990] is the most comprehensive study to explore the general relationship between R&D intensity in an industry (as proxied by R&D expenditures as a percent of sales) and acquisition activity, however the study mainly focuses on the *ex post* intensity of R&D activity after a merger or acquisition takes place, rather than its potential role as a factor in acquisition decisions by firms. An empirical trend found by Hall suggests a possible *ex ante* relationship between R&D and acquisition activity. Hall's analysis of over a thousand manufacturing firms from 1977 to 1987 shows that acquiring firms tend to have lower R&D expenditures relative to the rest of their industry, possibly because some firms have chosen an external method of acquiring innovation or technology. Finally, Friedman *et al.* [1979] examine the relationship between R&D and joint venture activity (as opposed to acquisition activity) at the firm level across a cross-section of industries. They find the greater the involvement of firms in joint venture activity, the lower the R&D expenditures, suggesting joint venture activity may be a substitute for internal R&D activity. They also compare the degree of substitutability between R&D and joint ventures across industries and find higher degrees of substitution in industries with higher average R&D levels (i.e., in high-technology industries).

In summary, there are theoretical arguments for either a direct or inverse relationship between R&D intensity and acquisition activity. Empirical evidence, primarily from Hall's [1987; 1990] work, has been mixed, but examines data across a wide variety of industries. Finally, anecdotal evidence from electronic, electrical equipment, and software firms suggests that there are varying strategies for growth both across firms and within firms over time.

III. DATA

To construct our panel, we sample all electronic and electrical equipment firms listed in the Compustat database with primary Standard Industrial Classification (SIC) of 36 and 357 and with continuous financial data for the period from 1985 to 1993. Thus, any firm without complete coverage of standard financial statistics is eliminated.[6] This leaves 217 firms in our sample. The financial data collected correspond to a firm's fiscal year, which is not necessarily the calendar year.[7] We measure R&D intensity as the ratio of the firm's R&D expenditures to total assets.[8] Average R&D intensity for our sample firms is over nine percent, which is close to double the manufacturing average. At the same time, there is a wide degree of variability amongst firms and over time, as the standard deviation of R&D intensity for these firms is close to fifteen percentage points.

Measuring a firm's acquisition activity level in dollars is impossible since the terms of acquisition deals are often kept private. Therefore, we measure acquisition activity by observing the annual discrete counts of acquisitions by a firm reported in the publication, *Mergers & Acquisitions.* Acquisitions were defined broadly to include not only acquisitions of whole firms, but also partial acquisitions and equity increases of more than $1 million dollars in another firm. These modes of acquisitions often involve transfer of technological assets just like complete acquisitions. Because *Mergers and Acquisitions* reports on a quarterly basis we were able to match acquisitions closely to the period corresponding to the firm's fiscal year.

Table II shows annual acquisition activity and R&D intensity for our sample firms. The total number of annual acquisitions in the data set fluctuates from 40 to 80 over the nine years. The average yearly number of acquisitions by firms in our sample is considerably less than one, with zero acquisitions for well over half our annual firm-level observations and a maximum number of fourteen. The percentage of firms making at least one acquisition ranges between 13.8 and 19.8 percent, which differs from average yearly acquisitions because of the presence of multiple yearly acquisitions by firms. Average R&D intensity increases over the length of the data set. These 'yearly' observations should be treated with some caution, however: since firms' fiscal years vary, these yearly observations only roughly cover the calendar years indicated.

As a first look at the relationship between R&D intensity and acquisition activity across our sample, Table III matches observations in different R&D intensity ranges and the associated average annual

[6] We discuss our choice of regressors from these financial statistics below. A balanced panel is necessary for some of the statistical specifications we use below. In addition, we eliminated firms (less than five) that were completely acquired during this period and thus no longer reported financial characteristics.

[7] It is possible to construct (and Compustat reports) data for firms by calendar year, however, these are based on appropriately combining unaudited quarterly reports. We felt the audited fiscal year reports would reduce measurement error.

[8] We follow Hall [1987] in defining R&D intensity this way. As we note in the text below, our results are essentially identical if we use a firm's sales in the construction of R&D intensity, rather than total assets.

TABLE II
TIME SERIES DESCRIPTIVE STATISTICS FOR SAMPLE FIRMS

Year	Total Acquisitions	Average Firm Acquisitions by Year	Firms Acquiring (%)	Average R&D Intensity (%)
1985	40	0.184	14.8	8.6
1986	66	0.304	19.3	8.8
1987	60	0.277	19.3	8.4
1988	55	0.254	18.4	9.1
1989	60	0.277	19.4	10.5
1990	62	0.286	15.7	9.1
1991	46	0.212	13.8	9.5
1992	62	0.286	18.9	11.5
1993	80	0.369	19.8	12.0

Notes: All data pertain to the 217 electronic and electrical equipment firms sampled from the Compustat database. Total acquisitions are across all sample firms for the year. Average acquisitions is total acquisitions divided by number of firms (217), whereas firms acquiring gives the percentage of firms that made at least one acquisition during the year. The difference in these measures is due to the multiple acquisitions by firms in a year. Average R&D intensity is yearly cross-section averages for the ratio of a firm's R&D expenditures to total assets.

TABLE III
ACQUISITION ACTIVITY BY R&D INTENSITY RANGES ACROSS THE SAMPLE

R&D intensity range	Average annual acquisitions	Number of observations	Large representative firms in R&D intensity range
0.0–5.0%	0.39	653	Cobra Electronics Corp. Kuhlman Corp. Sheldahl Inc. Ametek Inc. Bell & Howell Co. International Rectifier Corp.
5.0–10.0%	0.25	639	Andrew Corp. General Instrument Corp. IBM Corp. ADC Telecommunications Inc. Storage Technology Corp. Texas Instruments Inc.
10.0–15.0%	0.24	369	General Datacomm Industries Hewlett-Packard Co. National Semiconductor Corp. Intel Corp. Tektronix Inc. Siliconix Inc.
15.0–20.0%	0.13	166	Advanced Micro Devices Inc. Analog Devices Inc. Cray Research Inc.
More than 20%	0.02	126	Evans & Sutherland Computer Corp. Xicor Inc.
Entire sample	0.27	1953	

Notes: Data on acquisitions come from the publication *Mergers and Acquisitions*, various issues. Data on R&D intensity (R&D expenditures to total assets) come from the Compustat database.

acquisition rate. It also lists relatively large representative firms in each R&D intensity range. A fairly substantial inverse relationship between R&D intensity and average annual acquisitions emerges, ranging from 0.39 acquisitions for very low R&D observations (R&D expenditures less than 5% of assets) to 0.02 acquisitions for very high R&D observations (R&D expenditures greater than 20% of assets). Even eliminating the extremes of the R&D intensity range, average annual acquisitions are almost two times higher for firms with R&D intensity between 5% and 10% of assets than firms with R&D intensity between 15% and 20% of assets. Of course, this does not control for other factors that may correlate with R&D intensity and determine acquisition activity, but it suggests a significant inverse relationship between R&D intensity and acquisition, especially across firms. We explore this further with a more formal empirical analysis below.

Before turning to our regression analysis, we discuss what we know about the acquisition targets in our sample. As mentioned in footnote 5, because we are observing all acquisitions by these firms (many of which are small firms or divisions of firms with no publically available financial data), the information we have on the targets is quite incomplete. However, *Mergers and Acquisitions* includes descriptions of the firms involved in each transaction, including purchase price when publically available. Using these descriptions, we can say the following about the over 500 targets in our sample. About one-third of our acquisition observations were partial acquisitions and most of the complete acquisitions were of quite small firms. For those acquisitions where a price was reported (approximately forty percent) the average price was slightly less than $150 million and the median price was just $17.5 million. When five transactions over a billion are removed, the average transaction drops to less than $75 million. In comparison, the average total assets for our sample of acquiring firms averages over $1 billion and the median firm has almost $500 million in total assets. Thus, these targets are generally much smaller than the acquiring firm, which is consistent with the findings of Granstand and Sjölander [1990] for their sample of Swedish firms.

There is also suggestive evidence that the target firms in our sample often possess important technological assets. The descriptions of the acquisitions in *Mergers and Acquisitions* for our sample often listed 'technological' assets as a motivation for the acquisition. Over sixty percent of the transactions listed items such as engineering services, computer programing services, radio frequency ID cards, or tantalum capacitors. Another six percent of the transactions involved software companies. The remaining observations (less than thirty percent) were in services, like financing or customer service or in low technology equipment and parts, such as fuses or wholesale electrical parts. Again, to the extent the data represent a sample of firms acquiring technology in the form of target firms, our results have relevance for the 'make or buy' hypothesis.

IV. METHODOLOGY

To explore the relationship between R&D intensity and acquisition activity further, we statistically estimate the determinants of acquisition activity by a firm, including its R&D intensity. We use the counts of acquisitions by firm and year discussed above as our dependent variable. Previous studies have often specified a probit analysis to model such a dependent variable. However, a probit model may suffer from specification bias, since it treats a firm with one acquisition in a period as observationally equivalent to a firm that has two or more acquisitions during the period. There are a fair number of multiple acquisition observations, so we model our dependent variable as following a negative binomial specification which specifically handles the integer property of the dependent variable directly and includes '0' observations as natural outcomes.[9] In particular, we specify our dependent variable (annual number of acquisitions) as following a Poisson process which has a Poisson parameter, λ_{it}, where i indexes firms and t indexes the year. Then we make the common assumption that this Poisson parameter is a function of regressors, X_{it}. We choose the particular relationship, $\ln \lambda_{it} = \exp(\beta' X_{it}) + \varepsilon$, where $\exp(\varepsilon)$ has a gamma distribution with mean one and variance α, and β is a vector of parameters to be estimated. This leads to the following negative binomial specification which we use for our initial analysis:

$$(1) \qquad \mathrm{Prob}[ACQ = ACQ_{it}] = \frac{\Gamma(\theta + ACQ_{it})}{\Gamma(\theta)\Gamma(ACQ_{it} + 1)} u_{it}^{\theta}(1 - u_{it})^{ACQ_{it}}$$

where ACQ denotes the number of acquisitions, $u_{it} = \theta/(\theta + \lambda_{it})$ and $\theta = 1/\alpha$.

Our choice of regressors includes R&D intensity as the focus of our analysis, as well as other firm-level variables that may affect acquisition activity. We rely on previous empirical studies of merger and acquisition motives for selection of other control variables.[10] Some of the more common variables used include the size of the firm, indebtedness, and

[9] We note that our results are qualitatively identical for a probit specification where the dependent variable is defined as whether there any acquisitions in a period or not.

[10] Comprehensive surveys of the merger motives literature include Hughes *et al.* [1980], Jensen and Ruback [1983] and Scherer and Ross [1990].

profitability.[11] The majority of studies in the merger and acquisitions literature (including Hall [1987], and Tremblay and Tremblay [1988]) control for the size of the firm, invariably finding a significant positive correlation between size and the probability of acquiring. Thus, we use the firm's total assets to proxy for size. To take into account capital constraints, we include a firm's debt ratio (total debt divided by total assets), expecting a negative correlation between debt position and acquisition activity. Jensen [1988] suggests that better performing firms will acquire and Tremblay and Tremblay [1988] find that 'more successful' firms in the beer industry (defined as output share of market during the previous two years) are more likely to acquire. Constructing a variable as in Tremblay and Tremblay [1988] is problematic for our sample, since they do not produce for similar output markets. However, profitability of a firm is likely an important signal that a firm is well managed and performing well. Therefore, we include a measure of the firm's income after expenses, before extraordinary items, and before provisions for common and preferred stock divided by sales. We refer to this variable as 'return to sales' and expect a positive correlation. Finally, in a related vein, we include a measurement of a firm's cash flow given Jensen's [1988] free cash flow hypothesis that suggests that better performing firms will also have higher cash flow and be more likely to acquire. We use a cash flow measurement reported by Compustat which is defined as a firm's income after expenses, before extraordinary items, and before provisions for common and preferred stock plus depreciation and amortization.

The timing of when a firm is choosing to acquire and when the acquisition is finalized is obviously important for our estimation. In other words, should we model the regressors as lagged or contemporaneous with the dependent variable? Lagging the regressors may be most appropriate even though our data are annual. It takes time to search and find an appropriate target firm, as well as to successfully finalize a deal. This may be particularly true if our sample is represented by firms that use acquisitions to acquire technology only when they have fallen behind, as is indicated by the anecdotal evidence we present on Seagate Technology above. On the other hand, if firms are constantly pursuing acquisitions and have a number of potential targets in mind each period, it may be that current financial position has a greater impact on acquisition activity provided deals can be finalized promptly. While we feel the lagged

[11] Schwartz [1982], and Harris *et al.* [1982] are examples of studies that have used random samples of Fortune 500 companies to test merger and acquisition motives. Tremblay and Tremblay [1988] and Hannan and Rhoades [1987] focus on individual industries. A large number of determinants have been examined across these studies. We use a fairly parsimonious specification, but note that our results of interest, the correlation between R&D intensity and acquisition activity, is quite robust to alternative regressor sets.

regressor specification may be closer to the true economic process generating the data, either way has the potential to mismatch the financial variables we use as regressors to the actual period the firm determines its acquisition activity.

There is an additional concern of simultaneity bias if the regressors are modeled as contemporaneous with the acquisition. Any acquisition will affect a firm's current period financial statement to some extent.[12] This introduces obvious bias, since we are trying to estimate which *ex ante* characteristics affect a firm's acquisition decision.[13] Given these issues, we use lagged regressors as our base case throughout the paper. However, we also present estimates from a model with contemporaneous regressors, as well as a GMM estimator recently suggested by Wooldridge [1997] which allows us to exploit the panel nature of the data to control for endogeneity. Estimates from both the lagged-regressors and GMM specification suggest that simultaneity effects work toward a downward bias of our coefficients when regressing with contemporaneous regressors.

Before reporting results, Table IV reports descriptive statistics and sources for all variables used in the empirical analysis. Table IV also shows that lagged R&D intensity is quite high across these firms and time periods, averaging 9.4 percent of total assets. One concern is that there are a number of observations with very high R&D intensity. Below we examine sensitivity of our results to these potential outliers in R&D intensity, as well as with respect to other regressors we use, since there is substantial variability in these control regressors too. However, as we discuss below, our results are not driven by outliers in these variables.

[12] For acquisitions involving a firm obtaining a 50 percent or higher share in the target firm, end-of-period financial statements are consolidated line by line. Line-by line consolidation also occurs when there is an acquisition of assets that does not involve ownership stocks. For acquisitions involving stock, where the acquiring firm purchases a 20–50 percent share, there is no line-by-line consolidation. Instead, the purchase is recorded as an investment and asset on the acquiring firm's balance sheet, and the acquiring firm's share of the target's net income (based on its equity share in the target firm) is recorded as net income on the acquiring firm's income statement. For acquisitions involving stock with a purchase of less than 20 percent share of the target, the purchase is recorded as an investment and asset on the acquiring firm's balance sheet, but only dividend income from the target firm is recorded on the acquiring firm's income statement.

[13] With respect to R&D intensity, Hall's [1990] analysis suggests endogeneity bias contributes to finding a negative coefficient on R&D intensity in our estimates, since her time series analysis shows that firms typically reduce R&D intensity after an acquisition or merger. On the other hand, there may be reasons to expect the bias to work the other way. For example, a third factor, capital constraints, may be positively correlated with both acquisitions and R&D intensity. Himmelberg and Petersen [1994] find evidence that capital market imperfections may substantially affect R&D activity because it means the firms must rely on internal financing. These same considerations may similarly affect acquisition activity and lead to both activities moving together, depending on the firm's finances, and biasing the R&D intensity coefficient in a positive direction. In the end, these considerations are substantial and could lead to an estimate on R&D intensity that has substantial bias in either direction.

TABLE IV
DESCRIPTIVE STATISTICS OF VARIABLES

Variable	Mean	Standard Deviation	Min	Median	Max
Number of yearly acquisitions	0.272	0.862	0	0	14.000
R&D intensity (R&D expenditures divided by total assets)	0.094	0.147	0	0.073	3.755
Total assets (in billions)	1.226	9.342	0	0.049	192.880
Return to sales (income before extraordinary items divided by sales)	−0.013	0.214	−3.321	0.031	1.036
Debt ratio (total debt divided by total assets)	0.022	0.032	0	0.017	0.687
Cash flow (in billions)	0.108	0.690	−1.578	0.003	10.237

Notes: There are 1953 observations for each variable from a balanced panel of 217 firms over nine years. The acquisition data cover the period from 1986–1994, while all other variables are lagged one year and span the 1985–1993 period. The data on acquisitions come from the publication *Mergers and Acquisitions*, various issues. All other data are from the Compustat database.

V. RESULTS

The first column of Table V shows the results of a negative binomial maximum likelihood estimation on the pooled data set. A log-likelihood ratio test rejects the hypothesis that the coefficients are jointly zero for the specification. R&D intensity shows a negative sign and is statistically significant at standard significance levels. The marginal effect of R&D intensity on a firm's acquisition activity is quite substantial. At the sample mean, our estimates suggest a firm with a 5 percentage point higher R&D intensity ratio (e.g., from 7 percent of assets to 12 percent of assets) has an approximately 26 percent lower yearly acquisition rate.

The other explanatory variables have expected signs as well, with statistically significant point estimates for total assets, return to sales and cash flow. A variety of other specifications were estimated as sensitivity checks, including estimation of OLS, probit, and Poisson models, as well as a variety of alternative explanatory variable matrices.[14,15] While the

[14] Alternative regressors included other measures of firm profitability, such as return-on-equity and return-on-investment measures. These generally yielded similar, but noisier estimates relative to our return-to-sales variable. We also tried alternative measures for a firm's liquidity to test the free cash flow effect on the probability of acquisition, including a firm's current ratio and quick ratio. These generally yielded noisy point estimates and quantitatively similar coefficients on other regressors, including R&D intensity. We also estimated various functional forms of the dependent variables with similar effects.

[15] Please see the supplementary material on the *Journal*'s editorial web page for further detail on these sensitivity checks, or any empirical results referred to below, but not reported in the paper.

TABLE V
DETERMINANTS OF FIRM-LEVEL ACQUISITION ACTIVITY IN US ELECTRONIC AND ELECTRICAL EQUIPMENT MANUFACTURERS, 1985–93

	Full Sample			Sample Without Outliers	
Regressor	Negative Binomial/ Lagged Regressors	Negative Binomial/ Contemp. Regressors	GMM Estimation	Negative Binomial/ Lagged Regressors	GMM Estimation
Constant	−1.091***	−1.027***		−1.170***	
	(0.166)	(0.176)		(0.167)	
R&D Intensity	−5.208***	−5.675***	−9.190***	−4.825***	−8.520**
	(1.281)	(1.338)	(1.638)	(1.304)	(3.538)
Total Assets	0.016*	0.024***	0.006***	0.080***	0.069***
	(0.010)	(0.005)	(0.000)	(0.021)	(0.004)
Return to Sales	2.872***	2.110***	0.959	3.274***	1.157
	(0.669)	(0.768)	(0.638)	(0.675)	(0.906)
Debt Ratio	−4.929	−3.870	−6.611***	−3.416	−8.665
	(4.504)	(4.452)	(1.561)	(4.582)	(12.341)
Cash Flow	0.321***	0.146*	−0.075***	−0.238	−0.041***
	(0.124)	(0.085)	(0.016)	(0.190)	(0.013)
Alpha	2.179***	2.193***		2.238***	
	(0.322)	(0.329)		(0.346)	
Log-Likelihood	−1131.75	−1135.66		−1090.87	
Likelihood-ratio Test (p-value)	181.79 (0.000)	175.51 (0.000)		143.52 (0.000)	
Sample Size	1953	1953	1953	1917	1917

Notes: The dependent variable is the number of acquisitions for a firm during a fiscal year. Likelihood-ratio test is of the null hypothesis that slopes (excluding constant) are jointly zero and is distributed $\chi^2(5)$. Standard errors are in parentheses, except for the likelihood-ratio test which reports p-value of test in parentheses.

point estimates on some of the explanatory variables are sensitive to choice of specification, the coefficient on R&D intensity is quite insensitive to these alternative specifications, both in terms of sign and magnitude. In addition, using a firm's sales as a proxy for size rather than total assets and/or defining R&D intensity as the ratio of R&D expenditures to sales yields qualitatively identical results.

One concern with our estimates is that we are not controlling for time effects. As Table II shows, there is some variability in total acquisitions occurring across our sample of firms. Controlling for these effects is complicated by the fact that our sample firms vary in the time period covered by their fiscal years and hence in the period covered by their annual observation in our data, as discussed above. To address this we created annual calendar year time dummies where we allocated the share of the dummy effect according to how the firm's fiscal year overlapped with the calendar year. We could not reject the hypothesis that these time dummies are jointly insignificant at the 5 percent significance level and they had little impact on our other estimated coefficients. We also constructed a variable of total US domestic acquisition activity (excluding the electronic and electrical equipment industries to avoid endogeneity) that corresponded to each firm's fiscal year.[16] Including this variable does not significantly alter any of our coefficient signs and was typically insignificant in most specifications we tried.

As mentioned above, another concern is timing. If firms can find targets and finalize deals quickly, the model may be better specified with contemporaneous regressors. However, contemporaneous regressors also introduce endogeneity concerns from consolidation of financial statements, as well as the possibility that reorganization can impact the R&D intensity of a firm (Hall [1990]). The second column of Table V reports estimates from a model with contemporaneous regressors. The results are very similar to the estimates when regressors are lagged. The coefficient on R&D intensity gets larger which is consistent with the expected endogeneity bias, but statistically the bias is small since we cannot reject the null that the coefficient on R&D intensity is identical across the lagged and contemporaneous specifications.

However, it is clear that lagging regressors is not an ideal method of addressing endogeneity concerns, and there may be more endogeneity bias present than that suggested by the difference in the lagged versus contemporaneous regressor models. Wooldridge [1997] points out that even lagging regressors in a panel data set does not control for all sources of endogeneity if current values of the dependent variable affect future values of the regressors. In our case, this means that our estimates may be inconsistent if current acquisition activity affects future R&D intensity, profitability and other financial characteristics we include as controls.

Until recently it was difficult, if not impossible, to address these issues in the nonlinear count/panel data framework we employ in this paper. However, Wooldridge [1997] develops a generalized method of moments (GMM) estimation approach that corrects for these endogeneity concerns in a panel and count data model. Wooldridge's paper suggests a forward-difference transformation that leads to appropriate orthogonal moment conditions when simultaneity or feedback over time from the dependent variable are possible in a multiplicative panel data set. Following Wooldridge, define a transformation function

[16] This variable was constructed from *Mergers and Acquisitions* as well, which lists acquisitions by quarters. Thus, for example, if a firm's fiscal year end is March 31, this variable is US domestic acquisitions for quarters 2, 3, and 4 of the previous year and quarter 1 of the current year.

$$(2) \qquad r_{it}(\beta) = ACQ_{it} - ACQ_{i,t+1}[\mu_{it}(\beta)/\mu_{i,t+1}(\beta)], \quad t = 1, \ldots, T-1,$$

where T is the number of periods in our panel and β is the vector of coefficients. We define $\mu_{it}(\beta) = \exp(x_{it}\beta)$, where x_{it} is the matrix of regressors, which is the common functional form used to represent the mean in a count data model, such as Poisson or negative binomial. Given an appropriate instrument matrix, w_{it}, Wooldridge shows that

$$(3) \qquad E[w'_{it}r_{it}(\beta)] = 0, \quad t = 1, \ldots, T-1.$$

The orthogonality conditions represented in (3) allow us to obtain consistent GMM estimates. We use contemporaneous and one-period lagged values of regressors for instruments, as well as an additional variable and its one-period lag: patents per assets.[17] The latter is used as an additional instrument for our variable of interest, R&D intensity. Previous studies have demonstrated a strong correlation between R&D expenditures and patents (e.g., Trajtenberg [1990]), but it is unlikely that acquisition activity affects current-period patents, since patents are generated through an often lengthy R&D process. We provide further details of the GMM estimation procedure we use on the *Journal's* editorial web page.

Besides addressing endogeneity concerns, the GMM estimation procedure also controls for fixed effects across the panel. The results to this point examine pooled data across all firms in our sample. While we find a number of firm-level variables with substantial explanatory power, there may be sources of unobserved heterogeneity in firms' acquisition patterns. By accounting for firm-specific effects, we are assured that more broadly classified fixed effects, such as industry-specific effects, are not driving the inverse relationship between R&D intensity and acquisition activity.[18] We note that by controlling for firm-specific effects we are getting identification from variation within our firms, which will affect how we interpret the coefficient on R&D intensity.[19]

The third column of coefficients in Table V give results from our GMM estimation. We use a fixed effects Poisson model (as suggested by Wooldridge [1997]) as our starting values for the coefficients. The GMM

[17] With the forward difference transformation used for this estimator, this means that contemporaneous regressors are predetermined and thus appropriate as instruments. Firm-level patent data were retrieved from the US Patent and Trademark Office CD-ROM, CASSIS (Classification and Search Support Information System).

[18] Including 4-digit industry effects in the negative binomial specification, both with and without lagged regressors, yields very similar results to the GMM estimates that control for fixed-effects below.

[19] Controlling for firm-specific effects can also substantially reduce apparent serial correlation. Taking into account the time series properties of the data in these count data/panel data models is relatively undeveloped in the literature. A GMM specification which included a lagged dependent variable found a very small correlation between current and lagged acquisition activity, which had virtually no impact on the other estimated coefficients. See the *Journal*'s editorial web page for those results.

over-identification statistic ($\chi^2(99) = 109.7$) with p-value 0.22) fails to reject the null hypothesis, which suggests that our instruments are appropriately orthogonal to $\mu_{it}(\beta)$. Controlling for endogeneity and fixed effects significantly increases the size of the coefficient on R&D intensity. However, this difference is due to controlling for fixed effects, as the fixed-effect Poisson starting value for R&D intensity in the GMM estimation (before controlling for endogeneity) is 9.333. Thus, the endogeneity bias works toward reducing the coefficient some, which is consistent with the difference between the negative binomial and lagged regressor negative binomial specification (in the first and second columns of Table V). The other control variables have identical signs to the negative binomial specification with the exception of cash flow, though return to sales is statistically insignificant while debt ratio is now significant with the GMM specification. In summary, the GMM estimator suggests that the endogeneity bias is fairly small, which is consistent with the evidence we present that many of these acquisitions are small in terms of size. However, in controlling for fixed effects, the estimator presents a further puzzle—not only do the data show a robust inverse relationship between R&D intensity and acquisition activity, but this relationship is stronger when identifying the relationship only within our cross-sectional units. After presenting further sensitivity checks of our main results in the next section, we return to this issue and compare differences in a 'between' and 'within' estimator.

V(i). *Further Sensitivity Checks*

Although we have discussed numerous sensitivity analyses as we presented results above, in this section we examine sensitivity to potential outliers and issues surrounding the sample of firms in our data. Examining the descriptive statistics in Table IV, there is a high degree of variance among most of the variables. In our data, one firm (General Electric) is an order of magnitude larger (in terms of assets) than virtually all the firms in our sample and is responsible for a proportionally large percent of each year's acquisitions. Additionally, three firms (Computer Automation, Power Designs and Dian Controls) have annual observations where R&D intensity is 100 percent of total assets or larger. These firms are quite small and account for only one acquisition between them in our data. Whether these 'outliers' are driving the negative correlation between R&D intensity and acquisition activity is an important question.

Table VI displays descriptive statistics of the data when these four firms are eliminated from the sample. Elimination of these firms has a significant impact on the descriptive statistics for a number of the variables. We next reestimate our empirical model with this reduced sample. The fourth and fifth columns of Table V report results from a negative binomial with

TABLE VI
DESCRIPTIVE STATISTICS OF VARIABLES FOR SAMPLE WITHOUT OUTLIERS

Variable	Mean	Standard Deviation	Min	Median	Max
Number of annual acquisitions	0.241	0.654	0	0	7.000
R&D intensity (R&D expenditures divided by total assets)	0.087	0.073	0	0.073	0.856
Total assets (in billions)	0.790	5.113	0	0.050	92.473
Return to sales (income before extraordinary items divided by sales)	−0.007	0.190	−3.321	0.031	0.355
Debt ratio (total debt divided by total assets)	0.021	0.026	0	0.017	0.617
Cash flow (in billions)	0.086	0.589	–1.578	0.003	10.237

Notes: There are 1917 observations for each variable from a balanced panel of 213 firms over nine years. The acquisition data cover the period from 1986–1994, while all other variables are lagged one year and span the 1985–1993 period. The data on acquisitions come from the publication *Mergers and Acquisitions*, various issues. All other data are from the Compustat database.

lagged regressors and the GMM specification on the new data sample. Interestingly, most of the estimated coefficients and their associated marginal effects at the means are quite similar, suggesting that the outlying firms were not driving the estimated relationships. This is particularly true of the relationship between R&D intensity and acquisition activity. The only exception to this is total assets for which the coefficient increases by an order of magnitude.

Other sensitivity tests included eliminating firms with no acquisition activity in the data set. One might be concerned that these firms' acquisition decisions follow a completely different specification than firms that acquire. However, there was virtually no impact on our estimated coefficients. Another concern may be that the SIC listed by Compustat may be misleading and we are including firms that may be distribution firms rather than high-technology electronics manufacturers.[20] Distribution firms would have negligible R&D expenditures and our results on R&D intensity may just be suggesting that distribution firms acquire more than manufacturing firms. We ran a sample which excludes observations where R&D intensity is less than 2.5 percent, leading to qualitatively identical results to those estimated using the full sample.

[20] Firms often have interests in a number of industries and must choose one 'primary' SIC to report. Thus, for example, a firm could have 33 percent of its operations in wholesale distribution, 33 percent in retail, and 34 percent in electronics manufacturing and would report manufacturing as its primary SIC.

V(ii). *Comparing 'Between' Versus 'Within' Estimates*

Given the panel nature of our data and the GMM 'fixed effects' estimates, a natural question to ask is whether the inverse relationship between R&D intensity and acquisition activity is coming primarily from the 'between' or from the 'within' dimension of the data. To the extent that firms in our sample are choosing a long-run strategy of either 'making' technology assets through their own R&D investment or 'buying' these assets, we would expect the inverse relationship between R&D intensity and acquisitions in our sample to come from the between dimension; i.e., the relationship that exists across firms in the sample. In contrast, the Seagate Technology example suggests that firms may be changing their 'make or buy' decision internally over time, and thus, there should be an inverse relationship within as well. Decomposing panel estimates into between and within estimates is straightforward in a linear context. In this limited dependent variable framework it is much more difficult. However, Hausman *et al.* [1984] develops within estimators (a fixed- and a random-effects estimator) and a between estimator for the negative binomial model, which we employ here. We further describe construction of the random-effects and 'between' estimator we use below on the *Journal's* editorial web page. It should be noted that both of these estimators introduce additional parameters that are estimated, which we report as 'a' and 'b.'

Table VII presents estimates from the pooled, between, and random effects negative binomial models using lagged regressors. Before discussing these results, we note two important points about these estimates. First, the cash flow variable was eliminated from these regressions because of collinearity problems with total assets. The pairwise correlation between cash flow and total assets is 0.8 in the pooled sample, but rises to 0.94 if one uses data on cross-sectional means from which the between estimator is getting identification. This led to sign reversals and statistical insignificance on total assets and cash flow with the between estimator when cash flow was included. Since cash flow had little explanatory power in previous estimates and its inclusion has little impact on the coefficient on R&D intensity, we chose to eliminate it (see the *Journal's* editorial webpage for point estimates from the between estimator with cash flow included).

Second, there may be a concern that there is sufficient variation in R&D intensity within our cross-sectional units for the nine years to get credible within estimates. The difference on the R&D intensity coefficient between the lagged and contemporaneous specifications is not large, suggesting substantial persistence over time in R&D intensity. The simple correlation between contemporaneous R&D intensity and one-period lagged R&D intensity is 0.56 and statistically significant at the 1% level.

TABLE VII
POOLED, BETWEEN EFFECTS AND RANDOM FIXED (WITHIN) EFFECTS NEGATIVE BINOMIAL ESTIMATES FOR SAMPLE OF US ELECTRONIC AND ELECTRICAL EQUIPMENT MANUFACTURERS, 1985–93: LAGGED REGRESSORS

	Full Sample		
Regressor	Pooled Negative Binomial	'Between' Negative Binomial	'Within' Negative Binomial
Constant	−1.067*** (0.163)		1.200*** (0.366)
R&D Intensity	−5.225*** (1.127)	−4.973** (2.248)	−6.374*** (1.950)
Total Assets	0.038*** (0.006)	0.030*** (0.009)	0.011** (0.005)
Return to Sales	3.077*** (0.663)	3.226 (1.972)	2.665*** (0.660)
Debt Ratio	−5.489 (4.460)	−1.028 (7.544)	−9.862* (5.559)
Alpha	2.222*** (0.330)		
a		4.787*** (1.217)	6.938*** (1.993)
b		1.142*** (0.249)	0.782*** (0.134)
Log-Likelihood	−1134.01	−398.02	−1058.34
Likelihood-ratio Test (p-value)	193.86 (0.000)	360.75 (0.000)	372.94 (0.000)
Sample Size	1953	1953	1953

Note: The dependent variable is the number of acquisitions for a firm during a fiscal year. Likelihood-ratio test is of the null hypothesis that slopes (excluding constant) are jointly zero and is distributed $\chi^2(4)$. Standard errors are in parentheses, except for the likelihood-ratio test which reports p-value of test in parentheses.

However, taking the standard deviation of R&D intensity within each cross-sectional unit and then averaging across all cross-sectional units yields 0.042, which is substantial given that the average R&D intensity in our sample is 0.094. This suggests to us that there is sufficient variation in R&D intensity within the cross-sectional units.

Table VII presents evidence for a significant inverse relationship between R&D intensity and acquisition activity for *both* the between and within dimensions. The coefficient on R&D intensity is higher for the within dimension than for the between dimension, as the coefficient on R&D intensity in the within specification is over 20% larger than for the pooled sample. However, the standard deviation of R&D intensity is substantially smaller in the within dimension: the average one-standard-deviation change in R&D intensity in the within dimension is only about 30% as large as in the pooled dimension (0.042 versus 0.147). This still suggests that the within result is not only statistically significant, but economically meaningful as well.[21] While the between coefficient on R&D intensity is below the pooled estimate, it is quite close to the pooled estimate and statistically significant at the 5 percent significance level. In a linear context, the pooled estimates necessarily lie between the within and between estimator and is a weighted average of the two estimates. In addition, we would be able to conclude that most of the variation in the data with respect to the R&D intensity relationship is in the between dimension because the coefficient for the pooled estimates is closer to the between than the within estimator. While we stress that these properties do not technically hold in this nonlinear setting, these observations seem sensible for the sample of firms we have and other results presented in the paper.

VI. CONCLUSION

This paper has provided evidence for a significant relationship between R&D intensity and patterns of acquisitions in high technology industries. Robust to a variety of alternative specifications and sensitivity tests, we find a substantial inverse relationship between R&D intensity and acquisition activity among electronic and electrical equipment firms. In particular, our base result suggests that a firm with a 5 percentage point higher R&D intensity (e.g., from 7 percent of assets to 12 percent of assets) has an approximately 26 percent lower yearly acquisition rate. These results contrast with previous mixed empirical evidence that sampled a broader cross-section of manufacturing firms. In other words, our focus on high-technology industries seems to sharpen the inverse relationship between R&D intensity and acquisition activity. Further, we find that this inverse relationship is significant for both the within and between dimensions of our data.

These results present puzzles that we cannot fully resolve in this paper. If one assumes that the targets of the acquisitions we observe in our sample are technology-intensive (as opposed to acquisitions of production or distribution facilities), our results may have important implications for the 'make or buy' hypothesis. The inverse relationship between R&D intensity and acquisition activity in the between dimension supports the notion that firms in high-technology industries may have different

[21] Unfortunately, because of the way these estimators are constructed, it is impossible to technically compute marginal effects from the coefficients. For example, the random-effects estimator conditions out the firm-specific effects to generate a distribution to model the data—this means there is no specific formula for the marginal effects.

strategies by at least partially specializing in one of these two modes, internal R&D or acquisitions, for survival and growth. The significant relationship we find in the within dimension suggests that an individual firm's strategy can change over time as well.[22] However, these implications are conditioned on firms targeting technology with their acquisitions. While we present some evidence this may be true, we stress that data availability limit what we know about our targets in this study. Future work to uncover more information on targets will be important to fully interpret the findings of this paper.

ACCEPTED JUNE 1999

REFERENCES

Dasgupta, P. and Stiglitz, J., 1981, 'Entry, Innovation, Exit: Towards a Dynamic Theory of Oligopolistic Structure', *European Economic Review*, 15, pp. 137–158.

Francis, J. and Smith, A., 1995, 'Agency Costs and Innovation: Some Empirical Evidence', *Journal of Accounting and Economics*, 19, pp. 383–409.

Friedman, P., Berg, S. V. and Duncan, J., 1979, 'External vs. Internal Knowledge Acquisition: Joint Venture Activity and R&D Intensity', *Journal of Economics and Business*, 31, pp. 103–110.

Gallini, N. T. and Winter, R. A., 1985, 'Licensing in the Theory of Innovation', *Rand Journal of Economics*, 16, pp. 237–252.

Gans, J. S. and Stern, S., 2000, 'Incumbency and R&D Incentives: Licensing the Gale of Creative Destruction', *Journal of Economics and Management Strategy*, forthcoming.

Geroski, P., Machin, S. and Van Reenen, J., 1993, 'The Profitability of Innovating Firms', *Rand Journal of Economics*, 24, pp. 198–211.

Granstrand, O. and Sjölander, S., 1990, 'The Acquisition of Technology and Small Firms by Large Firms', *Journal of Economic Behavior and Organization*, 13, pp. 367–386.

Hall, B. H., 1987, 'The Effect of Takeover Activity on Corporate Research and Development', in Auerbach, Alan, J. (ed.), *Corporate Takeovers: Causes and Consequences* (University of Chicago Press for NBER, Chicago).

Hall, B. H., 1990, 'The Impact of Corporate Restructuring on Industrial Research and Development', *Brookings Papers of Economic Activity: Microeconomics 1990*, pp. 85–124.

Hannan, T. H. and Rhoades, S. A., 1987, 'Acquisition Targets and Motives: The Case of the Banking Industry', *Review of Economics and Statistics*, 69, pp. 67–74.

[22] Our results are potentially relevant for the Gans and Stern [2000] paper as well. The inverse relationship is consistent with a market where expected acquisition costs for incumbents are low enough that acquiring incumbent firms R&D activity may be a strategic substitutes for R&D. In fact, the internal/external growth story and the results of Gans and Stern complement each other to the extent that a substitute relationship between R&D and acquisition activity is possible only if there is an efficient acquisition market. In that sense, our paper suggests that a well-functioning acquisition market plays an important role in determining the structure of an industry.

Harris, R. S., Stewart, J. F., Guilkey, D. K. and Carlton, W. T., 1982, 'Characteristics of Acquired Firms: Fixed and Random Coefficients Probit Analyses', *Southern Economic Review*, 49, pp. 164–184.

Hausman, J., Hall, B. H. and Griliches, Z., 1984, 'Econometric Models for Count Data with an Application to the Patents-R&D Relationship', *Econometrica*, 52, pp. 909–938.

Himmelberg, C. P. and Peterson, B. C., 1994, 'R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries', *Review of Economics and Statistics,* 76, pp. 38–51.

Hughes, A., Mueller, D. C. and Singh, A., 1980, 'Hypotheses About Mergers', in Mueller, D. C. (ed.), *The Determinants and Effects of Mergers* (Oelgeschlager, Gunn & Hain, Cambridge, MA).

Jensen, M. C. and Ruback, R. S., 1983, 'The Market for Corporate Control: The Scientific Evidence', *Journal of Financial Economics*, 11, pp. 5–50.

Jensen, M. C., 1988, 'Takeovers: Their Causes and Consequences.', *Journal of Economic Perspectives*, 2, pp. 21–48.

Jovanovic, B. and MacDonald, G. M., 1994a, 'Competitive Diffusion', *Journal of Political Economy*, 102, pp. 24–52.

Jovanovic, B. and MacDonald, G. M., 1994b, 'The Life Cycle of a Competitive Industry', *Journal of Political Economy*, 102, pp. 322–347.

Katz, M. L. and Shapiro, C., 1986, 'How to License Intangible Property', *Quarterly Journal of Economics*, 101, pp. 567–590.

Reinganum, J., 1985, Innovation and Industry Evolution', *Quarterly Journal of Economics*, 100, pp. 81–100.

Salant, S. W., 1984, 'Preemptive Patenting and the Persistence of Monopoly: Comment', *American Economic Review*, 74, pp. 247–253.

Scherer F. M. and Ross, D., 1990, *Industrial Market Structure and Economic Performance* (Houghlin Mifflin, Boston).

Schwartz, S., 1982, 'Factors Affecting the Probability of Being Acquired: Evidence for the United States', *Economic Journal*, 92, pp. 391–398.

Tirole, J., 1988, *The Theory of Industrial Organization* (MIT Press, Cambridge, MA).

Trajtenberg, M., 1990, 'A Penny for Your Quotes: Patent Citations and the Value of Innovations', *Rand Journal of Economics*, 21, pp. 172–187.

Tremblay, V. J. and Tremblay, C. H., 1988, 'The Determinants of Horizontal Acquisitions: Evidence from the U.S. Brewing Industry', *Journal of Industrial Economics*, 37, pp. 21–45.

Wooldridge, J. M., 1997, 'Multiplicative Panel Data Models Without the Strict Exogeneity Assumption', *Econometric Theory*, 13, pp. 667–678.