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R&D ACTIVITY AND ACQUISITIONS IN HIGH TECHNOLOGY INDUSTRIES

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R&D Activity and Acquisitions in High Technology Industries

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Abstract: Economic analysis of high-technology industries often assumes that firms' abilities to survive in such an industry depend on their own internal R&D efforts We argue that high-technology firms may choose to specialize in either this internal growth (through R&D) strategy or an external growth strategy of acquiring other firms or firms' operations We use a panel of over 200 electronics firms over 10 years to test the relationship between R&D intensity and the probability of acquisition, controlling for traditional determinants of acquisition activity which include financial constraints Robust to a variety of dependent variable specifications, we find a strong and significant negative correlation, suggesting that electronics firms may be specializing in one activity or the other Our results also suggest that firms with greater intangible assets, higher profitability and lower debt to asset ratios are more likely to acquire Finally, statistical tests confirm that modeling unobservable firm-specific effects, as is possible with panel data, are important for explaining acquisition behavior This supports the notion that corporate/manager hubris plays a role in these acquisition markets

JEL Classification L21, O32, L63

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1. Introduction

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 A common feature of these models is often that firm survival may depend on a firm's ability to innovate, and if it cannot innovate, then its ability to imitate new products Thus, the implication of these papers is that firms must generate marketable products on their own or face exit [1] However, this ignores the possibility that firms may be able to obtain technology (or other assets) through an external acquisition market, rather than through their own internal efforts

Yet, anecdotal evidence suggests that firms may often turn to external acquisitions for marketable innovations in high technology industries, rather than through internal R&D effort A 1991 *Electronic Business* (January 7, 1991, pp 28-32) article 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 of 1989 Vishay Intertechnology, a manufacturer and distributor of electronic resistors, apparently decided on external over internal acquisition of technology in the late 1980s as well Again, an *Electronic Business* article reports that the CEO of Vishay 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 Mark Bailey, Vice President at Symantec Corporation, a software firm, writes in 1995 issue of *Mergers & Acquisitions*,

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[1] An exception to this is Katz and Shapiro (1986) who explore incentives of firms to license technology and other intangible assets

"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" (March/April issue, p 31)

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

Despite this, only a few papers have examined the possibility that merger and acquisition (M/A) activity in high technology industries is significantly motivated by technology considerations Granstrand and Sjölander (1990) present the hypothesis that M/A activity in high-technology industries concern large firms acquiring the technology generated by small firms They also present preliminary empirical evidence that it occurs with Swedish firms In essence, M/A activity is a mechanism for technology acquisition 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 M/A 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 M/A decisions by firms One empirical trend found by Hall does suggest a possible *ex ante* relationship between R&D and M/A activity -- Hall's analysis of over a thousand manufacturing firms from 1977-1987 shows acquiring firms tend to have lower R&D expenditures relative to the rest of their own industry This result has a number of explanations, but it may mean 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 M/A activity) at the firm level across a cross-section of industries They find that the greater the involvement of firms in joint venture activity, the lower the R&D expenditures, ceteris paribus, suggesting that joint venture activity may be an external substitute for 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 that have higher average R&D levels (i e , in high-technology industries), but have no satisfying explanation for why this may be occurring

This paper takes a closer look at the relationship between R&D expenditures and M/A motives in high technology industries in the United States We present and test two hypotheses regarding the relationship between R&D activity and the propensity to engage in M/As First, based on the discussion above, we argue that high-technology industries may have two types of firms those that pursue a strategy of internal growth through their own R&D activity, and those that choose a path of external growth and prosper by acquiring the technology form other firms We then develop a simple model where a firm may have different cost efficiencies in developing a marketable innovation through its own internal R&D process versus through an external acquisition In a cross-section of firms with differing relative abilities in generating marketable innovations through R&D versus acquisition, we expect firms to be at least partially specialized in one or the other, which would lead to finding a negative correlation between R&D intensity and M/A activity A second relationship may be posited between R&D expenditures and M/A activity due to a traditional synergy story which is common in the merger motive literature firms with a large absolute amount of R&D-related assets should be more likely to acquire due to greater possibilities for synergy gains with potential targets These R&D-related assets are not only innovations that potentially have complementarities with externally acquired assets, but also the specialized personnel, expertise and facilities that are connected with the internal R&D process 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 just as important for synergy motives as innovations [2]

It is important to note that these two hypotheses do not conflict, in the sense that the first hypothesis concerns R&D intensity of a firm, whereas the second hypothesis concerns the size of a firms' R&D operations For example, a firm may have large absolute R&D expenditures, yet low R&D intensity as measured by the R&D expenditures relative to sales Given our hypotheses, this is the type of firm that should have the greatest M/A activity, ceteris paribus

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[2]This is an important point given the work of Trajtenberg (1990) which creates some doubt as to the strength of the correlation between R&D expenditures and valuable innovations produced by a firm

We test both R&D-related hypotheses across a panel of 214 electronics firms from 1985 to 1994 Controlling for traditional merger motives, our empirical results provide strong evidence that high-technology firms do systematically differ in their "internal versus external growth" strategies Additionally, we find significant evidence that the synergy gain potential from R&D-related assets motivates M/A activity These results are robust to a wide variety of specifications and sensitivity analyses Our empirical results contribute to the merger motives literature in general as well Numerous studies have investigated merger motives with often surprisingly conflicting and insignificant results One potential explanation is the traditional practice of testing a sample of firms from a wide variety of industries without adequately controlling for industry-specific differences Exceptions include a study of merger motives in the beer industry by Tremblay and Tremblay (1988) and the banking industry by Hannan and Rhoades (1987), but no one to our knowledge has examined M/A motives in an industry such as electronics, where technology is of such significant importance In addition to our R&D related findings, we also find that a firm's debt and profitability significantly impact M/A activity in expected ways

Finally, given the panel nature of our data, we are able to test for the influence of corporate hubris in M/A activity Previous studies, beginning with Roll (1986), have looked at whether corporate hubris is important by analyzing whether managers may pay "too much" for target firms However, if managers may pay more than is warranted for a target firm, they also may decide to acquire when it is not warranted In particular, management's personal predilection for M/As may vary across firms, generating firm-specific effects that are essentially unobservable We find that modeling unobserved firm-specific effects in our panel data significantly affect our empirical estimates, lending support that corporate hubris is important in determining acquisition patterns Statistical tests reveal that this hubris may be correlated with other observable firm characteristics, suggesting that controlling for unobserved heterogeneity through fixed effects is preferred to random effects methods

The rest of the paper is organized as follows The next section develops a simple model to explain why we may expect negative correlation between R&D activity and acquisition activity The following section presents the econometric models and used to test our hypotheses and other merger motives in high-technology electronics We then present our empirical results and a final section concludes

2. A Simple Model of R&D and M/A Activity in High Technology Industries

The statements by CEOs of high technology firms presented in the introduction support the notion that firms are choosing between an internal growth strategy with relatively high R&D intensity versus an external growth strategy with acquisitions and relatively less R&D intensity To formalize this, we present a simple model which generates a negative correlation between R&D activity and the acquisition activity at the firm-level We focus on a representative firm and assume it generates a return, R, when it brings an innovation to the marketplace The firm has two avenues for developing an innovation internal R&D or acquiring R&D-related assets from another firm In both cases, we assume that acquiring a marketable innovation is not certain from the activity This assumption for internal R&D is fairly common, but may be justifiable for acquisitions as well For a wide range of assets, an acquiring firm will not have perfect information as to how well those assets/innovations will translate into market returns For example, the firm may not only have imperfect information on the asset it is acquiring, but such things as its own ability to successfully market the innovation and the plans of competing firms to market similar innovations which will affect the firms return on the innovation Thus, we assume that regardless of which combination of activities the firm chooses, there is an expected probability of generating a marketable innovation, $\Gamma(\,)$, which depends on both the firm's level of internal R&D and its acquisition activity For ease of analysis, we assume that these activities are perfect substitutes in increasing the expected probability of generating a marketable innovation, so that the probability is defined as $\Gamma(RI + ACQ)$ where RI is the level of internal R&D and ACQ is the level of acquisition activity We assume that $\Gamma(\,)$ is increasing in total innovation activity, but at a decreasing rate

At the same time, innovation activity is costly, but the costliness of internal R&D in comparison to acquisition activity may be different. In other words, a firm may be more efficient at producing internal R&D than acquisition activity To model this we assume that the cost function associated with internal R&D is C(RI), while the cost function for acquisition activity is α C(ACQ), where α is a given efficiency factor difference between the firm's two innovative activities We further assume that C is twice differentiable with C' > 0 and C" > 0

Given this situation, a firm maximizes expected profits by choosing the optimal level of acquisition activity and internal R&D. If the firm is risk neutral the objective function simplifies to the following

$$\underset{RI,\,ACQ}{\text{Max }\Pi} = R\,\Gamma(RI + ACQ) - C(RI) - \alpha C(ACQ)$$

The first order conditions to this problem are

$$\begin{array}{lll} RI & R\,\Gamma' - C' & = 0 \\ ACQ & R\,\Gamma' - \alpha C' & = 0 \end{array}$$

and it is simple to show that the second-order sufficient conditions for maximization are satisfied. Thus, one can derive the following comparative statics

$$\frac{\partial RI}{\partial \alpha} = \frac{-C' R\Gamma''}{D} > 0$$

$$\frac{\partial ACQ}{\partial \alpha} = \frac{-C'(R\Gamma'' - C'')}{D} < 0$$

where D is the determinant of the Hessian and is positive if the second-order sufficient conditions are satisfied. Thus, an increase in α, which represents a greater efficiency in producing a marketable innovation through internal R&D, naturally leads the firm to increase its internal R&D activity and lessen its acquisition activity

These results have straightforward empirical implications for a cross-section of high-technology firms. If α varies by firm and is distributed across n identical profit-maximizing firms, then we would expect to find that internal R&D activity is negatively correlated with acquisition activity across the sample This model helps to explain the empirical results below

The above model is admittedly a simplified one, but it serves to illustrate the notion that high-technology firms may choose very different ways of obtaining marketable innovations, depending on relative strengths In other words, high-technology firms have the option between internal or external growth, and which path they choose depends on attributes of the specific firm We choose to show this by allowing these firm differences to show up in a firm's costs, but we could have just as easily allowed the expected probability of a marketable innovation through acquisition to vary from the expected probability of innovation through internal R&D across firms and obtained similar results
In addition, comments by the CEO of Seagate described in the introduction above suggest that financial constraints may play a role a firm choose one or the other Both forms of growth, but in particular, internal growth through R&D, involve a large amount of uncertainty, and hence, monitoring costs by external lenders. Thus, in a world of imperfect capital markets, firms may often be constrained in these activities by the extent of their own internal funds and cash flow To a large extent we have captured financial constraints through the convexity of our cost functions, and introducing financial constraints in a more formal manner would not affect the basic result [3] However, in the empirical results presented below, we find a negative relationship between R&D intensity and acquisitions despite controlling for the effect of financial constraints on the firm. On a final note, Francis and Smith (1995) suggest another important reason why some firms choose to focus on growth via acquisition rather than growth via internal R&D: the form of ownership in the firm They argue that management-owned firms are more like to

[3] Bernanke and Gertler (1989, 1990) are recent papers that build a model where imperfect capital markets can affect firm-level decision-making through financial constraints

grow through internal R&D, while diffusely-held firms will prefer acquisitions since it is a less risky and faster strategy. This provides an additional explanation for why firms may be differ in their preference for R&D activity versus acquisition activity.

The model and discussion above leads to the hypothesis that the lower the internal R&D activity for a firm, the greater its acquisition activity However, as mentioned in the introduction, traditional merger motive literature identifies a second potential relationship between R&D and acquisition activity -- synergy gains One could imagine a model where expected synergy gains from an acquisition comes from some sort of matching process between a potential acquiring firm's assets and the assets of a potential target firm. In this scenario, the more assets a firm, has the more potential for synergy with another firm's assets, ceteris paribus At any given time a firm is calculating the potential synergy gains and costs from an acquisition with all the possible firms it could merge with The higher the potential for synergy gains, then the greater the likelihood that these gains will outweigh the costs of acquisition and an acquisition will occur. If R&D expenditures sufficiently proxy as a measurement of a firm's stock of innovative personnel, expertise and facilities, then one may expect that the higher the internal R&D expenditures for a firm, the greater its acquisition activity

3. Methodology and Data

To test our hypotheses, we focus on the determinants of acquisition activity; i.e , we focus on explaining why a firm would acquire another firm or part of another firm's operations Measuring a firm's acquisition activity level (our dependent variable) is not straightforward because terms of acquisition deals are often kept private As is common, we measure acquisition activity by observing the discrete counts of acquisitions by a firm reported in the publication, *Mergers & Acquisitions* One common way to handle this discrete nature of the dependent variable is by using a probit model to test what factors determine the likelihood of any acquisition activity for firm i in period t[4] More formally, there is some level of acquisition activity chosen by the firm, ACQ*, which is unobservable, but a function of explanatory variables

$$ACQ_{it}^{*} = \beta' X_{it} + \epsilon_{it}$$

where X_{it} is a matrix of explanatory variables in for firm i in period t, β are coefficients to be estimated, and ϵ_{it} is the error term, where $\epsilon_{it} \sim N(0,1)$ ACQ* may include activity to identify possible targets, as well as activity surrounding an acquisition However, we only observe ACQ, which is a dummy variable that takes on a value of "1" if actual acquisition transactions occur in a period and "0" otherwise More formally,

$$ACQ_{it} = 1 \quad \text{if} \quad ACQ_{it}^{*} > 0 \quad \text{and} \quad ACQ_{it} = 0 \quad \text{if} \quad ACQ_{it}^{*} \leq 0$$

However, this 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. An alternative is the Poisson and negative binomial probability models which specifically handle the integer property of the dependent variable directly and include "0" observations as natural outcomes A Poisson distribution specifies that

$$\text{Prob}(Y = y_{it}) = \frac{e^{-\lambda_{it}} \lambda_{it}^{y_{it}}}{y_{it}!}, \quad y = 0, 1, \ , \quad \ln \lambda_{it} = \beta' X_{it}$$

where y_{it} is the number of acquisition by firm i in year t, and X_{it} are the explanatory variables that determine these occurrences Estimation of the parameters, β, follows by setting up the likelihood

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[4] Examples of other studies that have specified the dependent variable with either a probit or logit specification include Schwartz (1982), Harris et al (1982), Hannan and Rhoades (1987), and Tremblay and Tremblay (1988)

function and maximizing with respect to these parameters. However, the Poisson distribution has the often undesirable property that the mean and variance are specified to both equal the Poisson distribution parameter. Many data sets have overdispersion (i e the variance of the data is larger than the mean) and one way of modeling this is to specify a Poisson process which has a Poisson parameter, $\ln \lambda_{it} = \exp(\beta' X_{it}) + \epsilon$, where $\exp(\epsilon)$ has a gamma distribution with mean one and variance α This leads to the following negative binomial specification

$$\text{Prob}[Y = y_{it}] = \frac{\Gamma(\theta + y_{it})}{\Gamma(\theta)\Gamma(y_{it} + 1)} u_{it}^{\theta}(1 - u_{it})^{y_{it}}$$

where $u_{it} = \theta / (\theta + \lambda_{it})$ and $\theta = 1/\alpha$ If α is positive and statistically significant, overdispersion exists in the data and a negative binomial model is a better specification than the Poisson distribution
We rely primarily on the probit and negative binomial models for specification However, as reported below, our main results are qualitatively identical for a wide variety of specifications.

Our choice of independent variables is based on our desire to test the R&D-related hypotheses concerning the relationship between R&D and acquisitions, while controlling for other firm-level variables that may affect a firm's acquisition activity. If our "internal versus external growth" hypothesis is correct, R&D intensity should be negatively correlated with acquisition activity across our panel of firms Thus, following Hall (1990), we use a firm's R&D expenditures per level of sales as a measure of the intensity of a firm's R&D intensity For similar reasons, we include sales of the firm as a regressor to "scale" the level of acquisition activity represented by the dependent variable In addition, previous studies have found that large firms acquire smaller firms, thus, firm sales proxies for "size" and we expect a positive coefficient To test our hypothesis regarding the effect of potential synergy gains from R&D assets on acquisition activity, we include R&D expenditures as a regressor and expect a positive coefficient Again, note that potential synergy gains come from the stock of R&D assets, not the intensity of R&D activity

In addition to the sales and R&D variables, we include a number of other explanatory variables as control variables, as well as to test for various M/A motives. The presence of control variables is important in testing our main hypotheses, since finding a negative correlation across a sample of firms in our model above is predicated on having "identical firms " Empirical studies of M/A motives have been preceded by a large theoretical literature on the subject As Jensen (1988, p 28) states, "more than a dozen separate forces drive takeover activity "[5] Some of the more common variables used (which will also be accounted for in our analysis) include the size of the firm, indebtedness, liquidity, and profitability[6] To take into account capital constraints, we include a firm's debt position and its current ratio, expecting a negative correlation between debt and acquisition activity and a positive coefficient on the current ratio Profitability of a firm may be important, since it is a signal that the firm is well managed If a firm is better managed than other firms, it will value target assets more highly than other firms, ceteris paribus, and thus be more likely to acquire Finally, a firm may be motivated by achieving synergy gains from other intangible assets beyond those related to the R&D process as discussed above. Thus, we include the unamortized value of a firm's intangible assets and expect a positive sign[7]

Table 1 shows the variables used in the analysis along with the sources, means and standard deviations. There are two alternative dependent variables ACQ_{it} is the number of firms acquired by firm i in year t, while $ACQP_{it}$ is a binary variable indicating whether firm i acquired one or more firms in year t The mean of ACQP shows that in 16.5 percent of the observations, which are a combination of one firm and one year, firms were acquired The mean of ACQ shows the average number of firms acquired by

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[5] Fairly comprehensive surveys of the merger motives literature include Hughes et al (1980), and Ruback (1983) and Scherer and Ross (1990)

[6] Mueller (1980), Schwartz (1982), and Harris et al (1982) are examples of studies that have used random samples of Fortune 500 companies to test M/A motives As mentioned earlier, Tremblay and Tremblay (1988) and Hannan and Rhoades (1987) are examples of studies that focused on individual industries

[7] As reported by the documentation accompanying COMPUSTAT, the intangible asset variable includes the value of a variety of things, including blueprints, copyrights, covenants not to compete, franchise rights, licenses, etc The value of patents is also included, thus this variable may partially represent the intangible assets connected with the *product* of R&D activity

firm i in year t. Both variables have standard deviations significantly larger than the mean and the difference in their means reflects that there are a substantial number of observations where acquisition activity involves more than one target firm There is a lot of variance in the financial variables in the data set as well. Most of the regressors have standard deviations as large or larger than their mean

A final issue with testing our hypotheses is endogeneity, which is difficult to control for in the limited dependent variable models we employ Following other studies on merger motives we treat our regressors as predetermined and lag them one period to avoid potential simultaneity This time inconsistency between acquisition activity and internal R&D is not modeled above, where the firm jointly chooses acquisition and internal R&D activity However, in reality obtaining a marketable innovation through internal R&D may take longer than obtaining through acquisition Thus, a firm may choose at first only an R&D strategy and then rely on a "quicker" acquisition strategy in the future if the R&D does not generate an innovation This fits closely to the empirical model we employ. Finally, to the extent that there is simultaneity between R&D intensity and acquisition activity, the bias would make our estimates less likely to find a negative correlation

We test our hypothesis on a panel data set of electronics-related high technology firms, which was constructed by first retrieving data on all firms in the COMPUSTAT database which list a Standard Industrial Classification (SIC) of 36 or 357. The time series dimension of our panel runs from 1985-94, since a substantial number of firms, especially computer firms (SIC 357), were not in the database before then. Finally, we eliminated any firms for which R&D expenditures (or any other variable used as a regressor) were not available continuously during our sample. This leaves 214 firms over 10 years. Data for each firm corresponds to its own fiscal year, which may not correspond to the calendar year However, transactions data on acquisition activity from *Mergers & Acquisitions* are dated, so that we were able to map counts of acquisitions to the individual firm's fiscal year. We define acquisitions broadly to include not only acquisitions of entire target firms, but also acquisitions of units of other firms, acquisitions of only certain assets of a target firm, or equity increases of more than $1 million dollars in another firm, as these modes of acquisitions often involve transfer of technological assets in a similar fashion to the acquisition of an target firm's entire operations

4. Results

Table 2 shows the results of OLS, probit, Poisson and negative binomial regressions on the full data set [8] The probit regressions examine whether a firm acquired or not in a year (ACQP) and the OLS, Poisson and negative binomial regressions look at the number of acquisitions in a year (ACQ) In terms of signs and significance levels, the results are surprisingly robust across the alternative specifications In all cases, a log-likelihood ratio test rejects the hypothesis that the coefficients are jointly zero In general, OLS shows the least precision in point estimates, which is expected given that we argue above that limited dependent variable models such as probit and negative binomial should fit the data better Poisson and negative binomial estimates appear quite similar, but the statistically significant alpha parameter suggests that overdispersion in the data exist and hence, the negative binomial model is more appropriate Thus, for the remainder of the paper we focus mainly on the negative binomial specification

Both R&D-related variables have expected sign and are statistically significant at standard significance levels The R&D intensity variable (RDPER) is negatively related to acquisitions, suggesting that firms are partially specializing in either their own R&D or acquiring other firms Marginal effects of R&D intensity computed for the negative binomial model at the sample means shows that a firm with a 5 percentage point higher R&D intensity ratio (e g , from 7 percent of sales to 12 percent of sales) has an

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[8] Many firms report the dollar value of funds used for acquisitions separately in their financial reports which are then reported in the COMPUSTAT database However, there are a couple of serious concerns with these data. First, companies can carry over previous year expenses into current year figures, so that the data may not accurately reflect current period acquisition activity Second, firms still have the discretion to allocate acquisition costs to other accounts With this in mind, we did run a tobit specification for our sample using the reported acquisition costs as a dependent variable, which yielded qualitatively identical results to the specifications we report in the paper

approximately 25 percent lower yearly acquisition rate R&D expenditures have a positive relationship with the number of yearly acquisitions by a firm, suggesting that the potential for synergy gains from R&D-related assets is important in acquisition patterns in high-technology industries Our estimates suggest that at the means an extra $100 million in R&D expenditures increases yearly acquisitions by about 19 percent Another result concerning the relationship between acquisition behavior and the possibility for synergy gains involves the stock of intangible assets (INTAN) Our results find that the greater the firms stock of intangible assets, the more likely the firm is to be involved in acquiring a firm The stock of intangible assets could come from previous R&D and advertising spending or from previous acquisitions In either case, it is a measure of the importance of intangible assets to the firm, and hence, the potential for synergy gains This in conjunction with the R&D expenditures result, shows that acquiring firms have higher stocks of intangible assets, but are not necessarily obtaining these through a high intensity R&D program

Our results for the other determinants of acquisition activity are interesting as well As expected more profitable firms acquire more, while higher debt to asset ratios depress acquisition activity The latter result suggests that financial constraints play a role, however we find that a higher current ratio (CR) unexpectedly lowers acquisitions as well This unexpected coefficient on CR may reflect simultaneity bias (despite CR being lagged) if acquisition activity significantly lowers the CR. This simultaneity bias may affect the current ratio much more if firms use current debt or assets to finance acquisitions, rather than long-term debt At any rate, it is important to note that we have found an inverse relationship between R&D intensity and acquisition behavior despite controlling for possible financial restraints by the firm This suggest that the specialization across the industry in either R&D intensity or acquisitions is due to deliberate strategy decisions by firms rather than external financial constraints

Previous merger motive studies almost always find that size matters -- larger firms are more likely to acquire Our sample does not support this The coefficient on SALES is negative and, in the case of the negative binomial specification, insignificant as well One interpretation is that sales (or other size variables) used in previous studies merely proxy for the amount of intangible or firm-specific assets held by a firm These assets are precisely the ones that lead to the largest potential for synergy gains In this study, RDEX and INTAN have captured these effects to a large enough extent that SALES has no residual effect on acquisition behavior In our estimates, SALES has a statistically significant positive coefficient when RDEX is omitted as a regressor, but turns negative and is sometimes insignificant when RDEX is included At the same time, the coefficient on RDEX is not substantially affected by exclusion or inclusion of the SALES variable This provides some suggestive evidence for our interpretation above [9]

Given these initial estimates, we next run a number of sensitivity tests using the negative binomial specification and report three of these alternative specifications in table 3 First, 80 of the 214 firms had no acquisitions over the course of our sample If these firms' acquisition patterns systematically follow some other process, then our estimates may be biased However, as reported in column 1 of table 3, elimination of these firms leads to qualitatively identical results and the coefficients of interest (our R&D variables) are insignificantly affected A second concern may be that the SIC listed by COMPUSTAT may be misleading and including firms in our sample that may be distribution firms rather than high-technology electronics manufacturers [10] 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 If this is true, eliminating these firms may weaken our results To control for this, we eliminate all observations where RDPER was less than 5 percent This leaves 1280 observations which gives estimates that only strengthen our coefficients of interest As seen in column 2 of table 3, both R&D coefficients increase by about 50 percent and are strongly significant at the 1 percent significance level for this sample A third concern was

[9] Our finding that synergy gains are important for merger motives is consistent with McGuckin and Nguyen (1995) who find that acquired plants are on average the more productive ones, not poorly performing ones

[10] 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 the manufacturing as its primary SIC

that approximately 35 percent of the acquisitions in our sample were of firms or assets in industries other than electronics-related ones [11] While firms could acquire marketable innovations or products from other industries, acquisitions by firms outside their industry may be motivated by quite different factors To test the impact of these non-industry acquisitions, we used *Mergers & Acquisitions* to classify our acquistions into industry and non-industry and then obtain negative binomial estimates using industry acquisitions as our dependent variable Not surprisingly, our coefficients of interest (reported in column 3 of table 3) are stronger when focusing solely on acquisitions within electronics-related industries

Firm-specific effects and the role of corporate hubris

The above results looked at 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 Not controlling for these unobserved effects may bias our coefficients Roll's (1986) hubris hypothesis provides one compelling reason to expect that there are unobservable firm-specific effects that are important in explaining acquisition patterns in our data Roll suggests that hubris on the part of managers of bidding firms may mean that some firms pay more than is warranted for a target firm [12] However, if this is true then a potential implication is that these managers are also acquiring more often than they should based on observables This implication follows if there are other potential bidders for the target firm which would have won the bid if hubris had not made the firm bid more than was warranted

To analyze the importance of firm-specific effects in both our probit and negative binomial specifications, we estimate the random effects probit model presented in Butler and Moffitt (1982) and

[11] We defined electronics-related industries as SIC 357, 36, and 38

[12] In a related vein, Morck et al (1990) find that personal managerial objectives can often explain acquisitions that perform badly in increasing shareholders' profits

estimated with the LIMDEP software package and the fixed effects and random effects negative binomial models derived by Hausman et al (1984) and estimated via maximum likelihood using Gauss software Appendix A gives a brief description of the fixed effects and random effects negative binomial models Both random effects specifications include additional parameters to be estimated which determine the structure of the random effects In the random effects probit, the correlation (rho) between successive disturbances for the same firm must be estimated In the random effects negative binomial model the random effects are assumed to follow a beta distribution with shape parameters (a and b), which are estimated

Table 4 reports results from these maximum likelihood estimations Qualitatively, results are quite similar to the probit and negative binomial coefficient estimates However, there are significant differences in the magnitude of the coefficient estimates and statistical tests confirm that it is inappropriate to ignore the firm-specific effects With respect to the random effects probit, the correlation parameter, rho, is positive and statistically significant at the 99 percent confidence level In addition, a Hausman test between the probit and random effects probit ($\chi^2(7)$ = 12 63) rejects the null hypothesis of homogeneous firm-specific effects at the 90 percent confidence level Likewise, a Hausman test for the negative binomial versus the fixed effects ($\chi^2(7)$ = 49 56) and random effects negative binomial models ($\chi^2(7)$ = 15 48) provide even stronger support for modeling firm-specific effects Thus, robust to alternative specifications, there is support for important firm-level hetereogeneity in acquisition patterns across high-technology electronics firms due to unobservable factors, which may come from differing corporate hubris

Hausman et al (1984) point out that modeling of firm-specific random effects can lead to inconsistent estimates if the random effects are correlated with the regressors If the firm-specific random effects are due to corporate hubris, then this would mean that if hubris depends on our regressors, such as the firm's profitability, current ratio, etc , then the random effects negative binomial estimates (and potentially the random effects probit) are inconsistent One would guess that this is likely, since managers may view the health or success of the firm (as indicated by the firm-level financial data we use as regressors) as a signal of how much hubris (or confidence) they can employ in their acquisition decisions A Hausman test on the fixed effects versus random effects negative binomial estimates can be used to test this Under the null hypothesis, there is no correlation between the random effects and the regressors, and both sets of estimates should be consistent The Hausman test yields a chi-squared statistic of 31 10, which supports at the 1 percent confidence level that there is correlation between the random effects and the regressors and suggests that the random effects estimates are inconsistent Given our arguments above, we would guess that this issue is an important concern for any estimation of panel data that analyzes firm-level behavior Because of the likelihood of correlation between random effects capturing unobserved manager heterogeneity and firm-level variables, fixed effects methods may be more appropriate for obtaining consistent estimates

5. Conclusion

This paper has provided evidence for a significant relationship between R&D activity and patterns of acquisitions in a high technology industry Robust to a variety of alternative specifications and sensitivity tests, we find that R&D intensity and acquisition activity substitute for each other across a panel of electronics firms This supports the notion that firms in high-technology industries may have different comparative advantages, leading to at least partial specialization across the industry into one of these two modes for generating marketable products Our results also suggest that the potential for synergy gains plays a large role in these industries as well, both with respect to R&D-related assets, as well as other intangible assets Unlike many previous studies, we find statistically significant results with respect to a number of other merger motives as well, including the positive effect of firm profitability and the negative effect of a high debt to asset ratio on acquisitions The precision of the estimates may be due, in part, to sampling from a specific industry rather than analyzing merger motives of firms from a cross-section of diverse industries as done by many studies in the past Finally, we find that modeling unobserved firm-specific hetereogeneity in acquisition patterns is appropriate and important This supports the notion that corporate/manager hubris plays a role in these acquisition markets

We foresee future work in this area along a number of lines First, while our results show that firms may take substantially different paths toward growth and survival, our results do not address whether firms pursuing one strategy or the other tend to be more successful in terms of profitability or other measures of firm success This may be an important issue in that the average return to sales across our panel is approximately zero with a relatively large standard deviation A second issue worthy of pursuit may be examining the role of manager hubris more closely We have controlled for firm-specific effects, which prove important, but these firm-specific effects may not be constant if there is turnover in management In other words, we controlled for corporate hubris, not necessarily manager hubris Finally, these two issues may be related

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APPENDIX
Fixed Effects and Random Effects Negative Binomial Models

This appendix briefly describes the fixed effects and random effects negative binomial models developed by Hausman et al. (1984) and used for estimation in this paper Beginning with a simple Poisson distribution, Hausman et al. first assume that the Poisson parameter, λ_{it}, follows a gamma distribution with shape parameters, (γ,δ). As is standard, we can parameterize γ to be an exponential function of the independent variables, X_{it}, such that $\gamma_{it} = \exp(X_{it}\beta)$ where X_{it} is the regressor matrix and β the associated parameter vector. Initially, δ is a common parameter across firms and time The resulting compound distribution is a negative binomial model. Hausman et al then derive a fixed effects negative binomial distribution by assuming that $(\gamma_{it},\delta_i) = (e^{X_{it}\beta},\phi_i/e^{\mu_i})$, with both ρ_i and μ_i allowed to vary across industries and account for firm-specific effects. Thus, this model specification allows for firm-specific effects (since each firm has its own δ_i), as well as overdispersion However, simply giving each firm its own δ_i (here $\delta_i = \rho_i/e^{\mu_i}$), and estimating it with maximum likelihood incurs a problem. with fixed T and large N, we have the incidental parameter problem and maximum likelihood estimation need not be consistent Thus they employ a conditional maximum likelihood approach Since the negative binomial distribution is a member of the exponential family, a sufficient statistic for $T\lambda_i$ $(= \Sigma_t\lambda_{it})$ is $\Sigma_t y_{it}$. Thus, by conditioning each observation on the sum of acquisitions that occur across the years in the panel for that firm the observation belongs to, the model accounts for firm-specific effects in a similar way to how dummy variables function in the linear fixed effects model. Observing that if y_{it} follows a negative binomial distribution with underlying parameters (γ_{it},δ), then Σy_{it} is distributed negative binomial with underlying parameters $(\Sigma_t\gamma_{it},\delta)$, they find the resulting joint probability of firm i's acquisitions conditioned on its total acquisitions over the years in the panel to be

$$pr(y_{i1}, \; y_{iT} | \sum_t y_{it}) = \left(\prod_t \frac{\Gamma(\gamma_{it}+y_{it})}{\Gamma(\gamma_{it})\Gamma(y_{it}+1)} \right) \left(\frac{\Gamma(\sum_t \gamma_{it})\Gamma(\sum_t y_{it}+1)}{\Gamma(\sum_t \gamma_{it} + \sum_t y_{it})} \right) \qquad \textbf{(A1)}$$

where y_{it} is the number of acquisitions by firm i in year t By conditioning on the sum of acquisitions, the firm-specific parameters, ρ_i and μ_i, do not appear in equation (A1) and the incidental parameter problem is avoided. With the joint probability of acquisition for each industry specified in equation (A1), we can construct an appropriate log-likelihood function for our entire panel

To develop a random effects negative binomial model, Hausman et al (1984) start with the negative binomial model described above and introduce variation across firms by assuming that each firm i has its own δ_i, which are randomly distributed across the i firms To accomplish this, Hausman et al assume that the ratio $\delta_i/(1+\delta_i)$ is distributed as a beta random variable with shape parameters (a,b). Using this beta density they derive the joint probability of an firm's acquisitions over the panel years to be

$$pr(y_{i1}, \; ,y_{iT} | X_{i1}, \; ,X_{iT}) = \frac{\Gamma(a+b)\Gamma(a+\sum\gamma_{it})\Gamma(b+\sum y_{it})}{\Gamma(a)\Gamma(b)\Gamma(a+b+\sum_i\gamma_{it}+\sum y_{it})} \left(\prod_t \frac{\Gamma(\gamma_{it}+y_{it})}{\Gamma(\gamma_{it})\Gamma(y_{it}+1)} \right) \qquad \textbf{(A2)}$$

where y_{it} denotes the dependent variable The random effects negative binomial model thus has two "shape" parameters, a and b, to estimate, in addition to our coefficient vector, β

TABLE 1
Descriptive statistics of variables

Variable	Description	Source	Mean	Standard Deviation
ACQ_{it}	Number of firms acquired by firm i in year t	M & A	0 245	0 663
$ACQP_{it}$	Binary version of ACQ_{it}	M & A	0 165	0 372
$RDPER_{it}$	R&D expenditures divided by sales	Compustat	0 076	0 075
$RDEX_{it}$	R&D expenditures in millions	Compustat	62 720	336 153
$SALES_{it}$	Sales in millions	Compustat	796 457	4307 779
$RETSALE_{it}$	Income before extraordinary items divided by sales	Compustat	- 0 017	0 223
$INTAN_{it}$	Unamortized value of intangible assets in millions	Compustat	25 650	170 973
DAT_{it}	Debt to total assets ratio	Compustat	0 229	0 417
CR_{it}	Current ratio	Compustat	3 154	2 946

TABLE 2
Determinants of firm-level acquisition activity in U S electronics, 1985-94
Results from alternative specifications

Regressors	OLS	Probit	Poisson	Negative Binomial
Constant	0 258	- 0 557	- 0 755	- 0 793
	(0 000)	(0 000)	(0 000)	(0 000)
RDPER	- 0 442	- 2 933	- 5 216	- 5 051
	(0 037)	(0 000)	(0 000)	(0 000)
RDEX	0 709	1 777	2 119	1 874
	(0 007)	(0 003)	(0 000)	(0 063)
SALES	- 0 013	- 0 108	- 0 127	- 0 101
	(0 531)	(0 022)	(0 000)	(0 204)
RETSALE	0 168	2 134	2 807	3 654
	(0 029)	(0 000)	(0 000)	(0 000)
INTAN	0 716	0 782	1 037	1 180
	(0 000)	(0 000)	(0 000)	(0 003)
DAT	- 0 003	- 0 481	- 0 708	- 0 755
	(0 943)	(0 026)	(0 015)	(0 058)
CR	- 0 009	- 0 074	- 0 131	- 0 134
	(0 060)	(0 000)	(0 000)	(0 002)
Alpha				1 777
				(0 000)
Log-Likelihood	- 1983 55	- 883 07	- 1262 43	- 1200 47
Likelihood Ratio Test	344 72	153 65	304 99	123 92
	(0 000)	(0 000)	(0 000)	(0 000)
Sample Size	2140	2140	2140	2140

NOTES The dependent variable for the probit regressions is a binary variable identifying whether a firm acquired or not in a year (ACQP) and the dependent variable for the OLS, Poisson and negative binomial specifications is the number of acquisitions in a year (ACQ) Likelihood ratio test is of the null hypothesis that slopes (excluding constant) are jointly zero and is distributed $\chi^2(7)$ P-values for slopes and likelihood ratio test are in parentheses

TABLE 3

Determinants of firm-level acquisition activity in U S electronics, 1985-94

Sensitivity analysis with negative binomial estimates

Regressors	Alternative sample Only firms with acquisitions	Alternative sample Only observations with RDPER > 0 05	Alternative dependent variable Number of electronics acquisitions
Constant	- 0 589 (0 001)	- 0 243 (0 331)	- 1 322 (0 000)
RDPER	- 5 166 (0 000)	- 8 251 (0 000)	- 5 566 (0 002)
RDEX	1 556 (0 038)	2 683 (0 000)	2 520 (0 065)
SALES	- 0 086 (0 137)	- 0 163 (0 006)	- 0 183 (0 122)
RETSALE	2 579 (0 000)	2 397 (0 003)	4 503 (0 000)
INTAN	0 877 (0 003)	3 242 (0 490)	1 309 (0 014)
DAT	- 0 562 (0 152)	- 1 242 (0 019)	- 0 593 (0 226)
CR	- 0 054 (0 225)	- 0 171 (0 001)	- 0 083 (0 076)
Alpha	0 932 (0 000)	0 617 (0 004)	2 093 (0 000)
Log-Likelihood	- 1045 92	- 657 25	- 930 01
Likelihood Ratio Test	62 29 (0 000)	39 66 (0 000)	73 42 (0 000)
Sample Size	1340	1280	2140

NOTES The dependent variable is the number of acquisitions in a year (ACQ) Likelihood ratio test is of the null hypothesis that slopes (excluding constant) are jointly zero and is distributed $\chi^2(7)$ P-values for slopes and likelihood ratio test are in parentheses

TABLE 4
Determinants of firm-level acquisition activity in U S electronics, 1985-94
Regressions controlling for firm-specific effects

Regressors	Random Effects Probit	Fixed Effects Negative Binomial	Random Effects Negative Binomial
Constant	- 0 778 (0 000)		- 0 142 (0 347)
RDPER	- 3 409 (0 011)	- 5 480 (0 000)	- 4 610 (0 001)
RDEX	1 717 (0 079)	1 640 (0 058)	2 263 (0 001)
SALES	- 0 092 (0 286)	- 0 060 (0 266)	- 0 139 (0 001)
RETSALE	2 013 (0 000)	3 794 (0 000)	3 131 (0 000)
INTAN	0 537 (0 325)	0 980 (0 002)	1 047 (0 000)
DAT	- 0 582 (0 084)	- 1 066 (0 003)	- 0 688 (0 083)
CR	- 0 046 (0 066)	- 0 148 (0 000)	- 0 124 (0 006)
Rho	0 281 (0 000)		
a			35 859 (0 273)
b			18 046 (0 280)
Log-Likelihood	- 838 63	- 780 77	- 1200 45
Likelihood Ratio Test	88 87 (0 000)	244 32 (0 000)	362 96 (0 000)
Sample Size	2140	2140	2140

NOTES The dependent variable is the number of acquisitions in a year (ACQ) Likelihood ratio test is of the null hypothesis that slopes (excluding constant) are jointly zero and is distributed $\chi^2(7)$ P-values for slopes and likelihood ratio test are in parentheses