Volume Title: Corporate Takeovers: Causes and Consequences

Volume Author/Editor: Alan J. Auerbach, ed.

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-03211-6

Volume URL: http://www.nber.org/books/auer88-1

Publication Date: 1988

Chapter Title: The Effect of Takeover Activity on Corporate Research and Development

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Chapter URL: http://www.nber.org/chapters/c2053

Chapter pages in book: (p. 69 - 100)

3 The Effect of Takeover Activity on Corporate Research and Development

Bronwyn H. Hall

3.1 Introduction

Economists generally agree that research and development activity is an important factor in the long-term growth of the economy. The purpose of this paper is to explore the effects on corporate research and development of the recent increase in takeovers in the United States. R&D is interesting in this context because the firm's decision to invest in these activities is viewed as a long-term commitment. If a wave of mergers distracts managers from all but decisions for the near term, we might expect that R&D performance would cease to be optimal.

To shed some light on this question, this paper uses evidence on the characteristics of mergers that actually take place. To quantify the role of R&D in acquiring and acquired firms, I explore the factors that determine the probability of an acquisition as well as the valuation of these factors at the time of the takeover. The model of acquisition choice I have built for this purpose is tractable for estimation and allows for heterogeneity across firms and therefore unique synergies to a merger. In particular, different targets are worth different amounts to acquiring

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The author is grateful to Zvi Griliches and Timothy Bresnahan for ongoing discussions, to Alan Auerbach, Charles Brown, Lawrence Lau, Tom Macurdy, Ariel Pakes, and John Shoven for comments at various times during this research, and to Chris Hall for help with the data collection. Comments by seminar participants at Stanford University, the University of Santa Clara, Boston University, Harvard University, MIT, the University of Chicago, and the University of California, Berkeley, were also helpful in preparing this chapter. Some of this work was done while the author was a Sloan Dissertation Fellow and a John M. Olin graduate research fellow, and she thanks these foundations for their support. The data preparation was partially supported by a National Science Foundation Grant and by the National Bureau of Economic Research.

firms, and the highest valuer is the one most likely to make the acquisition.

The question whether increased merger activity is a good thing for the economy in general remains unresolved and unlikely to be resolved by focusing solely on the experience of the firms involved. Jensen (1986) and others have argued that mergers represent an unambiguously positive shifting of assets into their best use and provides the best mechanism for ensuring that managers act in the shareholders' interest. A more neutral view would be that the level of merger activity is just a by-product of this asset shuffling and has no particular externality; it fluctuates from time to time in just the same way as the number of shares traded on the stock market fluctuates from day to day. The negative view, associated with Scherer (Ravenscraft and Scherer 1986), sees acquired entities ("lines of business" in his empirical work) as almost always suffering declining profitability after merging, and Scherer inferred from this result the conclusion that increased acquisition activity is likely to be a wasteful thing for the economy as a whole.

Roll (1986) provided what is essentially an efficient financial markets explanation of the phenomenon observed by Scherer, although that was not his specific aim. He claimed that we see the transactions only where the managers of acquiring firms misperceive the value of the target firm as too low. Hence, according to Roll, even under efficient markets we find more negative surprises than positive ones. This picture of acquisitions implies that an increase in mergers is associated with an increase in corporate "hubris" (Roll's term), which is not good for the economy as a whole. But for this view to hold in the presence of efficient markets, the offer made by an acquiring firm should be associated with a drop in its share price, since shareholders should be capable of divining that the decision to buy is likely to be a bad one. The existing evidence on returns to the bidding firm does not seem consistent with this.

Is merger activity likely to have a negative effect on R&D performance? One reason it might is substitution. If firms with large amounts of cash would rather spend it than return it to shareholders in the form of dividends, we would expect R&D and acquisition to be substitutes for these firms. An increase in the attractiveness of acquisition opportunities would depress spending on internal investment, including R&D. Takeovers and R&D may be substitutes on the real side as well. There are two ways to acquire knowledge capital: either by investing within the firm (an R&D program), or by purchasing another firm after its R&D program has yielded successful results. The latter strategy has the advantage that more information is available about the output of the R&D, activities that tend to be highly uncertain. Under the two assumptions of no scale economies or diseconomies in R&D over the relevant range *and* perfect capital markets, the two strategies should, in fact, be perfect substitutes for the firm.

Alternatively, the view that some acquisitions are used as "cash cows" to service the debt incurred to finance them also implies a negative effect on R&D activity. An easy way to increase short-term cash flows at the expense of long-term profits is to cut spending on such things as R&D. Evidence that this indeed takes place is not, however, evidence that it is the wrong thing to do. The long-run profit rate may not have been high enough to justify the premerger R&D level of the acquired firm, and cutting back on R&D may be precisely what a now presumably better management should do.

Some evidence exists on a few of these questions. Using roughly the same data as mine, Addanki (1985) found no support for the hypothesis that firms with larger R&D programs were more attractive acquisition prospects. If anything, innovators were less likely to be acquired than other firms. A Securities and Exchange Commission study (1985) found that firms that were taken over invested less in R&D than other firms in their industry. The authors of the study did not control for size, however, which could account for some of the result. The same study produced a related piece of evidence on the market valuation of long-term investments such as R&D: The 20-day excess return for an announcement of an increased level of R&D was 1.8 percent, suggesting that the market placed a positive value on such announcements.

On the other hand, for a sample of 1,337 Industrial File firms in 1976, of which 301 were acquired by 1983, I found that once I had controlled for Tobin's q at the beginning of the period, the R&D-to-assets ratio was positively related to the probability of being acquired. The coefficient was consistent with a shadow price for the R&D capital stock of around 0.6 times that for the physical capital stock of the firm. In other words, firms for which the measured ratio of market value to book value was high because they also had intangible assets, such as a large R&D program, were more likely to exit from the sample by merger, *ceteris paribus*. In this version of the probability model I did control for size, so that the R&D effects would not be confounded by the negative correlation between the size of the firm and its R&D intensity. Nonetheless, the coefficient was rather imprecisely measured, and the results tended to be sensitive to the exact choice of sample (whether or not the sample included firms traded over the counter, for example).

In this chapter, I investigate these somewhat inconsistent results on the attractiveness of R&D-intensive firms as takeover candidates further, as well as some of the other issues related to R&D performance and takeover activity. To this end I have assembled a data set on all the publicly traded U.S. manufacturing firms that were acquired between the years 1976 and 1986 in order to examine the pattern of the acquisitions and mergers. In particular, were the acquired firms more or less R&D intensive than others in their industry? What were the characteristics of the acquiring firms, and what kinds of synergy favored the merger? What happened to R&D at the new, larger firm, and is there any evidence that the acquisitions took place partly to reduce R&D expenditures because of scale economies or other reasons? Finally, is there any evidence that R&D winners (successful innovators) were being singled out by the mergers and acquisitions process, suggesting that this is how successful innovators capture the appropriate rate of return?

3.2 Modeling the Acquisition Decision

In modeling takeover activity, I view it as a response to changes in states of the world (such as technology shocks) that make some assets less productive in their current use than they would be in some alternative use. Because of information lags, transaction costs, or whatever, these assets do not move continuously into their optimal use, and so the shocks induce a disequilibrium that is resolved by other firms' purchasing discrete bundles of the assets. In other words, merger activity is the result of a rearrangement of productive assets in response to changes in the available technology, or, in the case of the domestic manufacturing sector, to changes in the nature and level of competition from the rest of the world.[1]

I begin by denoting the value of the assets of a particular firm as $V(X) = V(X_1,X_2, \ldots)$, where X is a vector of the characteristics of the firm, such as its capital stock, R&D stock, industry, tax characteristics, and so forth. The value function V can be thought of as the present discounted value of the revenue streams that could be generated from these assets either alone or in combination with other assets. For the moment I do not necessarily identify $V(X_i)$ with the current stock market value of the firm, although in a world with fully informed, rational shareholders and efficient markets, $V(X_i)$ would of necessity be the price at which this bundle of assets traded. The reason I do not make this assumption here is the well-known fact that acquisitions take place at a significant positive premium over the preannouncement stock market value (Jensen and Ruback 1983, and the references therein). This fact implies that some agents place a higher value on X_i than the market does. Thus, it would be a mistake to impose at the outset a constraint that the market for corporate assets is in a fully informed equilibrium, since it is the disequilibria that drive the acquisition process. The implications of this assumption for the estimation strategy will be clarified after I present the model.

I assume that in each period (a year, in my data) the optimal configuration of corporate assets changes because of shocks to the economic environment. The acquiring firms are subscripted j, and the possible targets, which consist of my entire sample of firms, are subscripted i. Each firm in my sample can acquire any other firm; if it does so, the increment to the value of the acquiring firm j attributable to the new configuration of assets is denoted $V_j(X_i)$. If we assume for the moment that only one acquisition is possible in each period, firm j will buy firm i (that is, j and i will find it beneficial to combine) if

$$
(1) \qquad \begin{aligned} &V_j(X_i) - P_i > V_j(X_k) - P_k \qquad \forall\, k \in \text{Sample} \\ &V_j(X_i) - P_i \geq 0 \end{aligned}
$$

where P_i is the price j will have to pay for i's assets. The last conditions ensures that there is a positive gain from the acquisition; many potential acquirers will find that it holds for none of the targets and hence will acquire no firms during the period.

Equation (1) is similar to the equations that define product choice by a consumer in a random utility choice model (McFadden 1973; Manski and McFadden 1981; Train 1986; and references therein). To see this, think of the asset aggregation function (Vs) in this model as analogous to consumer utility expressed as a function of the underlying (Lancastrian) characteristics of the good. Thus, the market for acquisitions resembles the market for differentiated products, with one important difference. In the consumer demand literature, price enters the indirect utility function directly, since the consumers are assumed to be price-takers. In this market one cannot assume that the price firm j will pay for the assets is independent of j's attempt to purchase them. The empirical evidence is that by making a bid, firm j reveals something about the value of the assets that was not previously known and hence finds it necessary to bid above the current trading price. In a companion piece (Hall 1987b) I derive the equilibrium price in a market with a large finite number of unique, differentiated buyers and sellers and show that it will lie somewhere between the value of the good to the highest valuer and the value to the next highest valuer. In the econometric work here I assume that the price at which the potential acquirers will evaluate the purchase is not P_i, the current trading price of firm i's stock, but an unobservable $V(X_i)$, which is a function of the assets X_i.

The advantage of viewing the acquisition decision in this way is that there exists a large body of literature on which we can build to describe the types of mergers that take place and how the characteristics of targets are valued by different buyers. That is the literature on the econometric estimation of models of the demand for differentiated products. Although I frequently use the language of consumer demand to describe the acquisition decision throughout this paper, the reader should bear in mind that because price is not exogenous, what is actually being estimated can be interpreted as an equation determining the gains from particular mergers, ones in which the buyers and sellers are treated symmetrically, rather than as an equation describing the demand of an acquiring firm for a target.

An estimating equation is derived from the conditions in equation (1) by partitioning the gain to firm j from the acquisition into observable and unobservable components:

$$V_j(X_i) - P_i = f(X_i, X_j) + \epsilon_{ij} \quad (2)$$

and by letting ϵ_{ij} have an extreme value distribution. If the ϵ_{ij} terms are independently distributed across the alternatives, one obtains the usual multinominal logit probability that an acquisition will take place:

$$P(j \text{ buys } i|C) = \frac{exp[f(X_j, X_i)]}{\sum_{k\in} exp[f(X_j, X_k)]}, \quad (3)$$

where C is the entire pool of firms. The likelihood function is formed by multiplying these probabilities and conditioning on the observed characteristics of the acquirers and the potential targets.[2]

At this point the alert reader will notice that the choice set C is very large; it potentially includes any firm in or outside the United States. Even if I confine the choice set to my data set, it consists of more than 2,000 firms, which raises questions as to the feasibility of econometric estimation and the validity of the IIA assumption. Fortunately, McFadden (1978) has examined the large choice set problem and suggested two approaches for dealing with it. The first solution is to construct a nested logit model, which describes the choice from 2,000 alternatives as a hierarchical sequence of choices each of which considers vastly fewer alternatives. For example, I might hypothesize that firms first choose the industry in which they wish to make an acquisition and then choose among the firms in that industry. This solution requires more a priori information, but it has the advantage that it gets around the IIA problem somewhat. I have not chosen to use this model in my initial exploration of the data, however, because I wished to avoid imposing too much structure on the choice problem at the outset.

The second solution suggested by McFadden for the problem of very large choice sets is simpler to implement, though possibly not the most powerful or realistic in terms of its assumptions. One randomly samples from the unchosen alternatives and includes only a subset for each observation. McFadden showed that as long as the sampling algorithm has what he called the "uniform conditioning property," and the choice probabilities satisfy the IIA assumption, the estimates obtained using the subset of alternatives and a conventional multinomial logit program are consistent. The uniform conditioning property is defined as:

$$\text{(4)} \qquad \text{If } i,j \in D \subset C, \text{ then } \pi(D|i,z) = \pi(D|j,z),$$

where D is the subset of alternatives used, π is the probability distribution used to draw D from C, and the z terms are the exogenous variables of the model. The algorithm I used to generate my subsets D has this property, since my D consists of the chosen (numerator) alternative augmented by a random sample selected from the other alternatives. The size of the D I used was seven, but this is obviously an operation in which more experience and experimentation would be desirable.

For the econometric estimation of the model in equation (3) I need to specify a functional form for $f(X_i,X_j)$. The difficulty with this function as written is that the gains from different acquisitions are likely to have extremely heteroskedastic and possibly non-normal disturbances ϵ_{ij} because of the large size range of the firms in the data set.[3] I would like to choose a specification that mitigates this problem as much as possible, since the multinomial logit estimates will be biased in this case. My solution to the problem is to specify the acquisition choice problem in terms of rates of return to acquisitions rather than total gains. This specification implies a condition of the form:

$$\text{(5)} \qquad V_j(X_i)\,/P_i > V_j(X_k)/P_k$$

rather than equation (1). By using a multiplicative disturbance for the value functions and then taking logarithms, I arrive at the following estimating equation for the econometric model:

$$\text{(6)} \qquad P(j \text{ buys } i|C) = \frac{exp[v_j(X_i) \;-\; v(X_i)]}{\sum\limits_{k\in} exp[v_j(X_k) \;-\; v(X_k)]},$$

where the lowercase v denotes the measurable component of the logarithm of the valuation function. The subscripted v denotes the valuation from the perspective of the acquiring firm, whereas v without a subscript is the function describing the equilibrium price at which the firm's assets will trade.

For the econometric estimation I model the logarithm of V as a function of firm characteristics, including the logarithm of the capital stock, R&D intensity, and the two-digit industry. The exact functional form I use is motivated partly by a simple intertemporal optimizing model of a firm with a given stock of assets A and partly by a desire for the tractability and interpretability of the estimating equation. A Cobb-Douglas price-taking firm with one type of capital for which there are adjustment costs, and with all other inputs freely variable, has a value function

(7) $$V(A) = a_0 A^\sigma$$

as a result of maximizing the present discounted cash flow, where σ is a scale parameter equal to unity in the constant returns case (Lucas and Prescott 1971; Mussa 1974; Abel 1983,1985). In the absence of a good model for the value function of more than one kind of capital (see Wildasin 1984; Griliches 1981), I incorporate a second capital, knowledge capital K, by the simple expedient of aggregating it with A, but with a freely varying coefficient:

(8) $$V(A,K) = a_0 (A + \gamma K)^\sigma = a_0 A^\sigma [1 + \gamma(K/A)]^\sigma.$$

Taking logarithms,

(9) $$\begin{aligned} v(A,K) &\approx \sigma \log A + \sigma \log [1 + \gamma(K/A)] \\ &\approx \sigma \log A + \sigma\gamma \ (K/A). \end{aligned}$$

Thus, the coefficient of size in my estimating equation can be interpreted as a scale coefficient, and that of R&D intensity as representing a premium (or discount) the R&D capital receives in the market over that of ordinary capital. Of course, to interpret the R&D coefficient in this way, one must be careful to measure K and A in comparable stock units.

Using the basic underlying model for the valuation of the assets of the firms, I capture the synergy of combining the two firms in two different ways. The first models the gain from the acquisition $v_j(X_i) - v(X_i)$ as a linear function of the assets of the two firms and the distance between them in asset space, such that:

(10) $$v_j(X_i) - v(X_i) = X_j\beta_1 + X_i\beta_2 + |X_j - X_i|\beta_3,$$

where the X variables are the vector of variables describing the assets of the firm in question (for example, $\log A_i$ and $[K/A]_i$). Because of the form of the multinominal logit probability, the coefficients of the acquiring firm's characteristics, β_1, will not be estimable since they cancel from the numerator and denominator, so that only X_i and $|X_j X_i|$ will enter the logit equation in this case. In any case these coefficients will contain both terms from $v(X_i)$ and the linear terms from $v_j(X_i)$.

The second method for modeling the synergistic relationship between the two firms starts from the notion that each acquiring firm has a value $v_j(X_i)$ for the target firm i that is a different function of firm i's characteristics, so that:

(11) $$v_j(X_i) = \gamma_j X_i + \eta_{ij}.$$

I then model the "shadow prices" γ_j as linear functions of the characteristics of firm j. This will imply that cross-products of the variables for firm j and firm i enter the equation for the probability of a choice. The advantage of this formulation is that it allows us to place a valuation interpretation on the estimated coefficients; in other words, the γ_j estimates are hedonic prices of the characteristics X_i.

3.3 The Data and Sample Statistics

The data from which I draw my sample consist of 2,519 manufacturing firms that appeared at some time on the Industrial and Over-the-Counter Compustat tapes over the years 1976–85. The basic features of the 1976-based subset of this sample were described in Bound et al. (1984) and Cummins et al. (1986), and the construction of the whole sample is described in Hall (1987a; 1987c). The sample consists of a rolling panel of firms, with annual data available as far back as 1959 for some firms; all firms are followed as long as they remain publicly traded and therefore in the Compustat files, with the last year of coverage being 1985. The number of firms actually in the sample in any one year declined from a high of about 2,000 in 1976 to around 1,500 in 1985.

I used four sources of information to identify the reasons why 875 firms had exited the file as of 1985, as well as the name of the acquiring firm for all acquisitions: the Federal Trade Commission Merger Reports of 1977 through 1980; a list of around 400 acquisitions involving Compustat firms supplied to me by Auerbach and Reishus (for more detail see Auerbach and Reishus 1985; 1987); the 1986 Directory of Obsolete Securities; and Standard and Poors' Corporate Records, which provide news reports indexed by firm name every year for the entire period in question. This research yielded a nearly complete breakdown of the reasons for exit. Of the 875 firms that had left the sample by 1985, 601 had been acquired, 94 had gone bankrupt or had been liquidated, 115 had changed their name (and should have data for the new entity restored to the file), 45 had been reorganized (the capital structure was changed enough so that it was reported in the Directory of Obsolete Securities), and 20 exits remained unexplained.

After splicing in records for those firms whose names had changed (for example, U. S. Steel became USX Corp.), and also for those firms whose CUSIP numbers and symbols had changed because of reorganization, I updated this distribution of exits and searched out the remaining unexplained exits. The final tabulation is shown in table 3.1 by year of exit. The most striking fact in this table is the well-known one that the rate of acquisition rose between the late 1970s and the

Table 3.1 The Number and Employment of Firms Exiting from the Publicly Traded Manufacturing Sector, by Reason for Exit, 1976–86

Year	Total Exits		Acquisition by Public, Domestic Firm		Acquisition by Private, Domestic Firm		Acquisition by Foreign Firm		Liquidated or Bankrupt	
	N	E	N	E	N	E	N	E	N	E
1976	28	92	24	89	1	0	2	2	2	0
1977	55	256	35	165	5	6	11	81	2	2
1978	42	243	20	204	13	22	8	16	1	0
1979	33	131	23	80	5	14	2	7	1	14
1980	59	353	31	270	5	15	8	21	9	17
1981	81	323	35	220	22	58	6	18	11	16
1982	67	190	23	72	23	47	7	36	11	30
1983	71	249	27	102	21	66	3	1	10	16
1984	115	596	44	290	38	161	10	74	11	10
1985	111	823	43	552	36	138	7	78	19	11
1986	58	466	23	153	15	86	8	52	5	14
Total	704	3,721	332	2,195	199	615	72	385	101	132

Note: The employment columns (E) show the total employment, in thousands, in the firms during the year prior to their exit. The columns and rows do not sum because a few exits remain unidentified as to reason for or year of exit.

1980s (note that my numbers for 1986 are undoubtedly incomplete). In addition, a large part of the increase in the acquisition rate between the 1976–81 period and the 1982–86 period is due to the increase in acquisition activity by privately held and foreign firms. Weighted by employment, those acquisitions tripled, while the acquisitions by publicly traded firms increased by one-third. In this case acquisition by a "privately held" firm means acquisition by a firm that does not file 10-K forms with the Securities and Exchange Commission on a regular basis and therefore is not in the sample; some of these firms are leveraged buyouts by management or other investors (known as "taking the firm private").

Because the privately traded acquisitors perform roughly half the acquisitions, and these acquisitions are likely to be a nonrandom sample (for example, they are on average about 50 to 60 percent smaller), throughout the paper I will try to compare results for my subsample of acquisitions with those for the whole sample. Unfortunately, it is not in general possible to obtain data on the pre- and postacquisition experience of these buyers, which is a limitation of this study.

Some simple statistics on all the acquisitions are presented in table 3.2a, where I show the industrial breakdown for the firms in the manufacturing sector in 1976 and 1981 and for the subset of firms that were acquired between the two periods 1977–81 and 1982–86. To give an idea of the relative importance of acquisition activity by industry, I also report the total employment in these firms. Judging by the percentage of an industry's employees who were affected by acquisition during both periods, the industries with the greatest activity were food, textiles, and machinery. In fact, over a third of the employees in the manufacturing sector subject to takeover were in these three industries. The other industries with a substantial number of employees involved in acquisitions were rubber and plastics, fabricated metals, and machinery. There does not seem to be much of a pattern, except when we look at the second period. There, the industries with the largest acquisition share seem to be the older, somewhat technologically backward industries that are in the process of upgrading to meet foreign competition. Is the acquisition activity in these industries primarily oriented toward consolidation and shrinkage of the industry, or is there also an attempt to buy smaller firms in the industry that have been successful innovators? I will defer this question until we examine the R&D-to-sales ratios of the stayers and exiters.

Of the approximately 600 firms that were acquired, I was able to identify 342 that were acquired by firms in the Industrial or OTC Compustat files; of these, there are about 320 for which I have good data on both the buyer and the seller. This set excludes any firms that were acquired by foreign firms, as well as those acquired by privately held firms. It *does* include nonmanufacturing firms that acquired firms in the manufacturing sector. The characteristics of the subset for which I have data on the buyer are given in Table 3.2b. Although these data account for only half the acquisitions made during this period, they cover two-thirds of the employees involved in acquisitions (two million out of three million). The table also shows the industrial distribution of the firms doing the acquiring. There are fewer firms in this column since some made more than one acquisition during the period.

Table 3.2b demonstrates that there is no overwhelming pattern to the merger and acquisition activity; the distribution of buyers and sellers is quite different from industry to industry but not in a particularly meaningful way. The largest share of firms were taken over in the aircraft, machinery, and electrical machinery industries, while the aircraft, electrical machinery, and petroleum industries had the largest share of firms performing acquisitions. This last fact is a consequence of the fact that these industries are also the ones with the largest number of employees per firm on average.

In tables 3.3a and 3.3b, I investigate the differences in R&D intensity between exiting firms and those remaining in the industry, and then between acquiring firms and those they acquired. Among those firms acquired by other firms in the publicly traded manufacturing sector,

Table 3.2a The Number and Employment of Manufacturing Firms Acquired, 1977–86

Industry	1976		1977–81		1981		1982–86	
	N of Firms	E (000)	% Firms	% E	N of Firms	E (000)	% Firms	% E
Food	158	1,753	19.0%	18.6%	120	1,771	25.0%	17.0%
Textiles	153	996	7.2	6.1	117	831	26.5	24.3
Chemicals	103	1,378	19.4	4.6	87	1,382	10.3	9.0
Pharmaceuticals	92	739	10.9	4.4	99	793	14.1	15.3
Petroleum	66	1,456	9.1	5.2	58	1,681	8.6	8.1
Rubber, plastics	76	708	9.2	1.0	61	545	23.0	22.3
Stone, clay, glass	58	373	17.2	8.2	47	342	23.4	13.4
Primary metals	87	771	11.5	8.0	76	796	15.8	18.0
Fabricated metals	136	565	13.2	5.2	115	576	21.7	18.9
Engines	59	592	10.2	9.6	53	570	5.7	1.5
Computers	113	1,107	12.4	3.0	130	1,566	3.8	0.6
Machinery	157	657	21.0	17.3	122	557	14.8	11.2
Electrical machinery	82	1,492	14.6	7.1	84	1,447	22.6	8.5
Electronics	192	2,000	8.3	2.6	198	2,376	7.6	5.6
Autos	77	1,357	14.3	4.6	62	1,041	19.4	10.3
Aircraft	40	823	12.5	1.7	37	984	21.6	9.4
Instruments	87	232	8.0	5.3	88	265	8.0	2.6
Lumber and wood	154	916	9.7	6.1	127	824	16.5	7.2
Misc. mfg.	166	957	11.4	5.0	150	1,091	18.0	10.0
Total Mfg.	2,056	18,874	12.8	6.6	1,831	19,436	15.6	10.4

Note: All employment figures include part-time and seasonal workers and exclude any contract employees or consultants. The first four columns refer to acquisitions made between 1977 and 1981 as a share of the industry as it existed in 1976. The next four columns show acquisitions made between 1982 and 1986 as a share of the industry in 1981. The number (N) of firms acquired and the employment (E) in those firms are shown as a percentage of the base-period number of firms and employment.

Table 3.2b **Characteristics of the Buyers and Sellers in 314 Manufacturing Acquisitions, 1977–86**

	1976		Firms Aquired, 1977–86				Acquiring Firms, 1977–86	
Industry	N of Firms	E (000)	N	%	E (000)	% E	N	%
Food	158	1,753	26	16.5%	541.5	30.9%	23	14.6%
Textiles	153	996	11	7.2	50.0	5.0	14	9.2
Chemicals	103	1,378	19	18.4	182.1	13.2	12	11.7
Pharmaceuticals	92	739	17	18.5	110.7	1.5	12	13.0
Petroleum	66	1,456	8	12.1	164.6	11.3	14	21.2
Rubber, plastics	76	708	11	14.5	8.2	1.1	9	11.5
Stone, clay, glass	58	373	10	17.2	31.3	8.3	8	13.8
Primary metals	87	771	12	13.8	161.3	20.9	5	5.7
Fabricated metals	136	566	25	18.4	45.7	8.1	16	11.8
Engines	59	592	6	10.2	44.3	7.4	3	5.1
Computers	113	1,107	18	15.9	53.4	4.8	10	8.8
Machinery	157	657	31	19.7	143.9	21.9	14	8.9
Electrical machinery	82	1,492	18	22.0	131.9	8.8	13	15.8
Electronics	192	2,000	27	14.1	173.0	8.9	16	8.3
Autos	77	1,357	6	7.8	21.0	1.5	11	14.3
Aircraft	40	823	10	25.0	89.3	10.8	6	15.0
Instruments	87	232	11	12.6	18.1	7.8	9	10.3
Lumber and wood	154	916	23	14.9	71.3	7.8	10	6.5
Misc. mfg.	166	957	25	15.1	47.1	4.9	11	6.6
Total Mfg.	2,056	18,874	314	15.3	2,088.7	11.1	216	10.5

Note: The sample consists of manufacturing acquisitions in which both the buyer and the seller appeared on the Compustat Files.

All employment figures include part-time and seasonal workers and exclude any contract employees or consultants. The first two columns are totals for the manufacturing sector in 1976. The next four columns are totals for the firms acquired between 1977 and 1986. The columns labeled % show those firms' share of the industry in 1976, both in number of firms and in employment. The last two columns tally the firms in the industry that made acquisitions of publicly traded manufacturing firms between 1977 and 1986.

the difference in R&D intensity between the acquiring firms and the acquired was insignificantly different from zero both in the entire manufacturing sector and in each industry taken separately. Only in primary and fabricated metals is there a suggestion that the acquired firms were doing slightly more R&D than those that remained. There is no evidence that the *dominant* pattern is either a weeding out of firms that are technologically backward or a culling of successful R&D projects.

The firms acquired by private companies or by foreign firms did, however, have significantly lower R&D intensity than those acquired by the manufacturing sector: 1 percent on average rather than 2 percent. This pattern persisted throughout the period; it was not a result of the rise in private buyouts in the latter part. It occurred partly because these acquisitions tend to take place in the less R&D-intensive, more slowly growing industries such as textiles. With only one exception, the petroleum industry, the industries with less than average R&D intensity were those in which private and foreign acquisitions were a larger than average share of all acquisitions. These industries, which contain half the firms in the sample, accounted for 70 percent of the acquisitions by private or foreign companies. This suggests that the recent increase in acquisition activity due to leveraged buyouts or other such private purchases is more or less orthogonal to the R&D activity in manufacturing. Even if all such purchases resulted in the complete cessation of R&D activity by the firm, this would amount to only around 500 million 1982 dollars annually compared to expenditures on R&D by the manufacturing sector of approximately 40 billion 1982 dollars annually.

R&D intensity does appear to have been lower in the acquiring firms than in the acquired ones; the firms sold had on average a higher R&D-to-sales ratio than those that bought them. But this finding is primarily due to the 38 takeovers of manufacturing firms by nonmanufacturing firms: here the firms were combined with an entity that probably did considerably less R&D in its nonmanufacturing lines of business. At the industrial level, it is difficult to draw any strong conclusions because of the relatively small samples.

The data in the columns labeled $\Delta R/S$ in tables 3.3a and 3.3b help answer the question of what happens to the R&D program of the combined firm after an acquisition has taken place. In table 3.3a the $\Delta R/S$ for nonacquired firms is the average two-year change in R&D intensity over the period for the firms in the industry. The $\Delta R/S$ for acquired firms is the two-year change in R&D intensity around the time of acquisition for the firms involved in the acquisition, classified by the acquired firm's industry. In table 3.3b the same quantity appears, classified by the acquiring firm's industry. The preacquisition R&D intensity is computed in the following way:

$$(R/S)_{pre} = (R_j + R_i)/(S_j + S_i), \tag{12}$$

where i and j index the two firms involved. The conclusions are not changed by restricting attention to those acquisitions in which both R_j and R_i are nonzero, so that the numbers presented are for all firms.

The individual industry data are difficult to interpret because of the imprecision with which they are estimated, but there did seem to be some significant increases in R&D around the time of acquisition, particularly in textiles, machinery, computers, and electronics. Viewed in the context of differing patterns of industry growth, this finding may have different meanings for different industries. In the textiles and machinery industries for example, two-thirds of the acquirers were outside the publicly traded manufacturing sector. The acquisitions here are therefore a special group and perhaps reflected the improved prospects for the remaining firms after the industry had shrunk. (See Schary 1986 for a more detailed study of the long-run reaction of firms in the textile industry to its declining profitability.) In computers and electronics, however, almost all the acquisitions were in the manufacturing sector, specifically in closely related industries, and the growth in R&D is perhaps another indicator that the firms engaged in acquisition activity need to invest more rather than less in R&D to exploit the value of their acquisitions.

Overall, however, there is little evidence of a significant difference in the mean growth rates of R&D intensity between firms involved in acquisitions and nonacquiring firms. Comparing the means is only part of the story, however. It is possible that R&D intensities change in different ways for different types of acquisitions in such a way as to leave the mean growth rate unchanged. Figure 3.1 plots the distribution of these changes for all firms in the manufacturing sector and for the acquisitions only. Figure 3.2 plots the same distribution but also includes the firms not engaging in R&D. These plots show some evidence that the variance of the changes in R&D intensities was somewhat higher for the acquisitions and that more of them experience a decline than the overall sample. Nonetheless, nonparametric tests[4] for the difference in the overall means of the $\Delta R/S$ data in tables 3.3a and 3.3b accept equality in almost all cases (whether or not publicly traded nonmanufacturing acquisitions are excluded and whether or not those firms doing no R&D are excluded). In only one case did a significant positive difference exist, that which included all publicly traded firms and firms that engaged in no R&D, and here that difference resulted

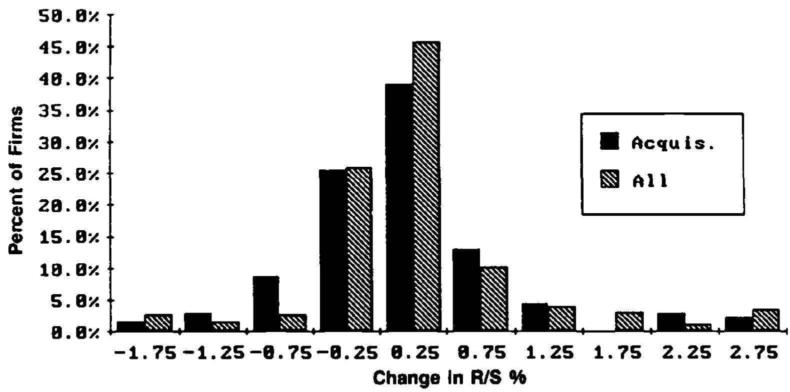

Fig. 3.1 Two-year change in R&D intensity at acquiring and nonacquiring firms in manufacturing, 1976–86

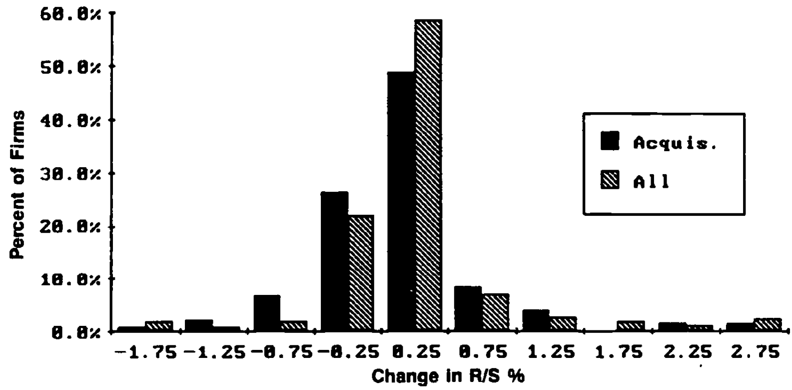

Fig. 3.2 Two-year change in R&D intensity, with data including firms not engaging in R&D, 1976–86

in only two of the four nonparametric tests. The same conclusion holds looking at three-year changes around the time of acquisition (not reported here). The conclusion is that there is no overwhelming evidence that acquiring firms experience a change in R&D behavior around the time of acquisition.

Because firm size is systematically related to both R&D intensity and the probability of being acquired, the data in the preceding tables are difficult to interpret in detail. In the next section I therefore attempt to quantify the determinants of acquisition further by estimating probability models with more than one explanatory variable.

3.4 Estimating the Probability of Entering the Acquisition Market

Before I present results for the full-blown multinomial logit model of acquisition matches, I present estimates of the "marginals" of such a model. These estimates are not marginals of the distribution of the multinomial logit model in the statistical sense, since they cannot be obtained by aggregating over the choice set,[5] but they summarize the data from the perspective of the acquiring and the acquired firms separately. They also provide an indication of the change in the sample when I restrict the data to the approximately 300 acquisitions for which I can observe both partners.

Assume that the reduced form for the probability of being acquired in any one year can be written as a logit function of various firm characteristics:

$$(13) \quad P(i \text{ acq. in year } t|X_{it},t) = exp(\beta X_{it} + \alpha_t)/[1 + exp(\beta X_{it} + \alpha_t)],$$

where X_{it} represents the characteristics of the firm. The estimates of β and α_t can then be obtained with a conventional maximum likelihood logit estimation. The same type of model can also be used to estimate the probability that firm j will make an acquisition in year t, conditional on the firm's characteristics X_{jt}.

The model of acquisition sketched in section 3.2 uses the assets of the firms to predict their valuation and, hence, the gain from merger. To keep things simple, I focus on two assets: capital stock (including all plant and equipment, inventories, and other investments), and the stock of knowledge capital. These two assets tend to be the most significant ones in a simple stock market value equation. For the buyers and sellers in 311 transactions that took place between 1977 and 1986, I have constructed estimates of the book value of the physical assets in current dollars and the R&D capital held by those firms one year before the acquisition, using the methodology described in Cummins et al. (1985). Adjustments for the effects of inflation on the book value of the physical assets have been applied, and R&D capital has been depreciated at a rate of 15 percent per year (see Griliches and Mairesse 1981, 1983). I then deflated these variables to be in 1982 dollars, using a fixed investment deflator and an R&D deflator (Cummins et al. 1985), respectively, since I would be pooling across years.

Table 3.3a **Comparison of R&D-to-Sales Ratios for Acquired and Nonacquired Firms, by the Acquired Firm's Industry, 1977–86**

		Acquired Firms		Nonaquired Firms		*R/S* Difference	
Industry	N of Firms	*R/S*	Δ *R/S*	*R/S*	Δ *R/S*	Avg.	*t*-Statistic
Food	26	.253%	.06%	.160%	.01%	−.093%	−1.5
Textiles	11	.158	.41	.169	.02	.012	0.1
Chemicals	19	1.79	−.21	1.80	−.35	.015	0.0
Pharmaceuticals	17	7.21	.23	4.87	.59	−2.34	−0.6
Petroleum	8	.322	.14	.337	.01	.016	0.1
Rubber, plastics	11	.573	−.04	.915	.06	.342	0.8
Stone, clay, glass	10	.411	.01	.372	.03	−.039	−0.2
Primary metals	12	.623	−.10	.269	−.01	−.354	−2.1
Fabricated metals	25	.986	.16	.563	.02	−.422	−2.3
Engines	6	.826	−.07	1.37	.11	.547	1.1
Computers	18	5.64	.48	5.32	.26	−.319	−0.1
Machinery	31	1.12	.40	1.58	.20	.455	0.7
Electrical machinery	18	3.51	−.13	4.40	.40	.893	0.3
Electronics	27	4.07	.88	3.44	.44	−.631	−0.3
Autos	6	.782	−.12	.766	−.18	−.016	−0.0
Aircraft	10	2.12	.09	2.02	.26	−.107	−0.1
Instruments	11	4.56	.35	4.10	.43	−.455	−0.2
Lumber and wood	23	.345	.03	.342	.32	−.004	−0.0
Misc. mfg.	25	.620	.04	.340	.02	−.028	−1.6
Total mfg.	314	1.97	.18	1.82	.16	−.154	−0.4
Acquisitions outside the sample	254	0.92		1.82		−0.90	−3.0

Note: *R/S* is the deflated R&D-to-sales ratio. The deflator for sales is the producer price index for finished goods (U.S. Bureau of Labor Statistics) and that for R&D is according to Griliches method, following Jaffe (see Cummins et al. 1985 for details). The columns labeled "acquired firms" show the average R&D-to-sales ratio for the 314 firms that were acquired by other firms in my sample, measured one year before the acquisition (*R/S*) and, for the combined firm, measured from one year before acquisition until one year later (Δ *R/S*). The columns labeled "nonacquired firms" show the average R&D-to-sales ratio and the change in that ratio for the firms that were not acquired, averaged over the 1977 to 1986 period. These data are based on several hundred observations per industry. The last two columns show the difference in *R/S* between the two groups of firms and the *t*-statistic for the hypothesis that the difference is zero.

Table 3.3b **Comparison of R&D-to-Sales Ratios for Acquired and Acquiring Firms, by the Acquiring Firm's Industry, 1977–86**

	N of Firms Acquired	Acquired Firms *R/S*	Acquiring Firms *R/S*	Acquiring Firms Δ *R/S*	*R/S* Difference Avg.	*R/S* Difference *t*-statistic
Food	30	.320%	.209%	.07%	−.111%	−1.1
Textiles	15	.276	.467	.49	.191	0.6
Chemicals	18	3.22	2.69	.18	−.532	−0.7
Pharmaceuticals	14	7.33	4.77	.31	−2.56	−0.9
Petroleum	11	.864	.383	−.06	−.481	−1.5
Rubber, plastics	11	.841	.921	.11	.080	0.2
Stone, clay, glass	9	1.11	1.10	.12	−.017	0.0
Primary metals	7	.084	.204	−.02	.120	1.0
Fabricated metals	28	.849	.649	−.12	−.199	−0.6
Engines	3	1.18	2.11	.06	.935	1.1
Computers	10	6.61	5.76	.46	−.854	−0.6
Machinery	21	1.08	1.24	.52	.161	0.4
Electrical machinery	23	3.34	2.00	.02	−1.34	−1.4
Electronics	17	3.92	4.07	1.88	.145	0.2
Autos	14	2.59	1.12	−.05	−1.47	−1.1
Aircraft	9	3.97	3.61	−.26	−.361	−0.3
Instruments	11	1.79	3.33	.12	1.54	1.9
Lumber and wood	10	.520	.304	.01	−.215	−0.6
Misc. mfg.	18	.656	.179	−.06	−.477	−1.3
Total mfg.	279	2.05	1.68	.22	−.369	−0.9
Nonmfg.	38	1.38	.168		−1.21	−3.4
Total	317	1.97 %	1.50 %		−.472%	−1.5

Note: The two columns labeled *R/S* give the average R&D-to-sales ratio for the acquiring firms and the firms they acquired. *R/S* is defined the same way as in table 3.3a. The column labeled Δ *R/S* is the average implied change in *R/S* around the time of acquisition for acquisitions by firms in that industry. The last two columns again test the difference between the two *R/S* ratios.

I estimated equation (14) using, as regressors, size (the log of capital stock), the ratio of R&D stock to capital stock, and a trend variable. I also included a dummy variable for the more technologically oriented industries (those with *R/S* greater than 1 percent in table 3.3a) to check whether the R&D effects were in reality industry effects. Table 3.4 shows these estimates. The first column pertains to the complete sample of acquisitions for which data existed; the other columns are for two subsets: those firms acquired by private or foreign firms, and those firms acquired by the firms in my sample (mostly manufacturing, with a few nonmanufacturing firms).

The estimates for the two groups are quite different, confirming the findings in the simple statistics of table 3.3a. The privately traded acquisitions show a much steeper positive trend than the others, and all the other variables have predictive power. Size, R&D intensity, and whether the firm is in a science-based industry have a significant negative effect on the probability of its being acquired by a privately held or foreign firm. On the other hand, these variables have no effect on the probability of its being acquired by a publicly traded manufacturing

Table 3.4 **Maximum Likelihood Logit Estimates of the Probability of Acquisition (21,900 observations; heteroskedastic-consistent standard errors in parentheses)**

	Probability of Being Acquired		
	by All Firms	by Private or Foreign Firms	by Manufacturing Firms
N of Acquisitions	557	229	328
log *A*	−.042(.022)	−.166(.030)	.036(.028)
K/A	−.139(.144)	−.514(.314)	.058(.167)
D(*Tech*)	−.232(.097)	−.830(.175)	.146(.122)
Trend†	.125(.016)	.239(.028)	.054(.020)
$\chi^2(3)$ for *A*, *K*, *Tech*	12.0	60.2	3.4
	Probability of Making an Acquisition		
	1976–86	1976–81	1982–86
N of Acquisitions	319	167	152
log *A*	.432(.025)	.546(.036)	.320(.034)
K/A	−.314(.266)	.218(.340)	−.994(.385)
Trend†	.027(.023)	−.015(.049)	.264(.079)

log *K* = Log of deflated capital stock of the firm in the year before it acquired another firm or was itself acquired

K/A = ratio of R&D stock to assets in the same year

D(*Tech*) = dummy variable for the chemical, pharmaceutical, engine, computer, machinery, electrical machinery, electronics, aircraft, and instruments industries

†Includes a dummy variable for 1986 because the data for that year are incomplete

firm. Thus, it is likely that the private acquisition activity is targeted toward those industries and firms where the current management has already been perceived the growth opportunities as unprofitable. This could be construed as evidence that management has cut R&D spending in an effort to avert takeovers, but if so, they have not been successful. It seems more likely that this activity facilitates a needed shrinkage in the assets devoted to these particular activities. Without knowledge of subsequent events in these firms, it is difficult to be more precise about the reason for this finding. What can be said is that, in manufacturing, the acquisitions seem indistinguishable from the non-acquired firms.

The bottom part of table 3.4 shows the probability of making an acquisition for three different samples: acquisitions made during the full sample period, those made from 1976 to 1981, those made from 1982 to 1986. The results are unsurprising: Size is positively related to the probability of making an acquisition; that probability rose toward the end of the period; and R&D intensity is not important. When I focus on the two subperiods, a difference does emerge. In the 1980s the firms making the large acquisitions had a somewhat lower R&D intensity than the other manufacturing firms, suggesting some substitution between R&D performance and acquisition activity. I also included the *Tech* variable in these equations, but it was completely insignificant in all periods. This result is therefore not the result of a shift of acquisition activity toward low-technology industries.

3.5 Results for the Matching Model of Mergers

I now turn to estimates of the multinomial logit model of the match between the acquiring and the acquired firms. Here I confine my sample to the firms that made acquisitions; that is, the estimates are conditional on a firm having chosen to enter the takeover market, and they describe the choice made once the firm is in the market. A reasonable way to augment this model so that it also describes the decision to enter the market would be to build a nested logit model where the decision to make an acquisition is logically prior to the choice of target. The estimates obtained here are consistent for the lower branch of such a nested logit model (McFadden 1978,1984), although the interpretation of the coefficients would change. The upper branch would be somewhat similar to the logit model estimated in table 3.4, since it would describe the choice between making any acquisition or making none, but it would include an additional term corresponding to the "inclusive value" of the set of takeover candidates available. In other words, the characteristics of the available targets would enter in the form of a kind of index function along with the characteristics of the acquirer.

With this caveat in mind, I now describe the application of the random utility choice model to this problem. It is well known that when the unobserved part of the utility function has an extreme value distribution, the probability a particular choice will be made from a set of alternatives has the multinomial logit form (again, see McFadden 1973 and Manski and McFadden 1981). It is only slightly less well known that any model for choice probabilities can be written in the multinomial logit form, with the proviso that if the independence of irrelevant alternatives assumption does not hold, characteristics of the other choices may enter into the "utility" function associated with a particular choice. This statement should be kept in mind because it allows us to view the multinomial logit model estimated here as a descriptive summary of the data observed, even if the underlying interpretation of the V functions as determining the acquisition probability is suspect.

The results of estimation conditional on an acquisition's being made are shown in table 3.5.[6] These are estimates of the choice model given in equation (7), with the choice set consisting of the chosen alternative plus six others randomly selected from the firms in the sample that year. Model I, shown in the first two columns, captures the character of the match $v_j(X_i)$ very crudely with the absolute value of the difference in size and the difference in R&D intensity of the two firms. In addition, the size of the target and its R&D intensity enter the logit equation through $v(X_i)$. The second column includes a dummy variable for whether or not the firms are in the same industry; it improves the explanatory power ($\chi^2[1]$ = 183.), but it does not affect the other coefficients very much. The estimates imply that mergers between firms of very different sizes are less likely to take place, and that mergers between firms with differing R&D intensities are also less likely to happen. Thus, the evidence is fairly strong that mergers within the manufacturing sector tend to be between firms of like size and like R&D intensity.

The next set of estimates in table 3.5 are for the model (model II) suggested in equation (12). These provide a richer description of the matching taking place in the merger market. If the estimates in the last column are representative, they imply an equation for the incremental value of an acquisition to a firm of the following form:

$$(14) \qquad v_j(X_i) = \gamma_{0j} + \gamma_{1j}\log A_i + \gamma_{2j}(K/A)_i.$$

The term γ_{0j} is not identified in the conditional logit model because it cancels from the numerator and denominator of equation (6), but the other coefficients are the following:

$$(15) \qquad \gamma_{1j} = \gamma_{10} + 0.17 \log A_j - 0.18 \; (K/A)_j$$

$$\gamma_{2j} = \gamma_{20} + 0.32 \log A_j + 4.1 \; (K/A)_j.$$

In other words, the bidding firms value the size of the target at an increasing rate with respect to their own size, and at a decreasing rate

Table 3.5 Conditional Logit Estimates of Acquisition Choice, 1977–86 (311 acquisitions; standard errors in parentheses)

Variables	Coefficient Estimates			
	Model I		Model II	
$\Delta \log A$	−1.04(.15)	−1.00(.17)		
$\Delta(K/A)$	−4.05(.60)	−3.78(.66)		
$\log A_j \cdot \log A_i$			.17(.02)	.17(.02)
$(K/A)_j \cdot \log A_i$			−.31(.16)	−.18(.20)
$\log A_j \cdot (K/A)_i$			.28(.08)	.32(.08)
$(K/A)_j \cdot (K/A)_i$			3.82(.98)	4.05(1.09)
D(Same ind.)		2.34(.21)		2.41(.18)
$\log A_i$	−.72(.14)	−.73(.16)	−1.13(.13)	−1.21(.15)
$(K/A)_i$	3.30(.53)	3.09(.58)	−2.98(0.72)	−3.28(0.82)
log of likelihood	−502.3	−424.7	−557.8	−467.2

Note: The standard error estimates are robust heteroskedastic-consistent estimates; they differ from the conventional estimates by less than 10 percent in almost all cases.

$\log A$ = log of deflated assets in the year before the acquisition, where assets equal the sum of capital stock, inventories, and other investments

(K/A) = ratio of R&D stock to assets in the year before the acquisition

$\Delta \log A = |\log A_j - \log A_i|$

$\Delta(K/A) = |(K/A)_j - (K/A)_i|$

D(Same ind.) = 1, if the acquiring and the acquired firms are in the same two-digit industry

The subscript j indexes the acquiring firms, and i indexes target firms. The coefficient estimates are for the probability that firm j chooses firm i when it makes an acquisition. Models I and II are described more completely in the text.

with respect to their R&D intensity. More interesting, the shadow price for the R&D intensity of the target is an increasing function of the size and the R&D intensity of the bidding firm. This finding may arise partly because of management's preference to acquire firms similar to those in their own industry. Nevertheless, the simple correction of controlling for the match being in the same industry had very little effect on the magnitude of the estimates, although it did reduce the R&D match coefficient somewhat, as expected. Further investigation of this finding, particularily within and across industries, seems warranted.

What do these estimates tell us about the valuation of the R&D stock of the firm at the time of acquisition? Unfortunately, we cannot say very much about this without making strong assumptions about the way in which $v(X_i)$, the price paid for the acquisition, is determined, since the estimated coefficients of the target firm's characteristics will contain terms from both the $v_j(X_i)$ (for example, γ_{10}) and the $v(X_i)$ equation.[7] This problem limits our ability to interpret equations (15) beyond pointing out that the shadow value placed on R&D capital is steeply rising with the acquiring firms' R&D intensity.

On the other hand, it is possible to know something about the price actually paid for the assets of the firms that were acquired and to compare this amount to the preacquisition value of these assets. I collected such data for 271 of the 311 acquisitions in the sample, namely, the value of debt plus equity in the year before the acquisition serves as the preacquisition market value of the firm (see Cummins et al. 1985 for details). I then collected data on the price paid to each holder of a share of common stock in the acquired firm at the time of acquisition and used the rate of return thus earned by holders of the common stock between the year before acquisition and the time of acquisition to update the value of debt plus equity (assuming that the total value of the firm was increasing along with the value of the common stock). This procedure is necessary because of the difficulty of valuing the claims of all stock and bond holders at the time of acquisition.

Using these numbers, I estimated a valuation equation for the 271 firms in the year before acquisition and at acquisition time. The results were:

$$\log V(A,K) = \alpha_t + \underset{(0.02)}{0.96} \log A + \underset{(0.12)}{0.49} (K/A) \tag{16}$$

$$\log V(A,K) = \alpha_t + \underset{(0.03)}{0.95} \log A + \underset{(0.14)}{0.65} (K/A), \tag{17}$$

where α_t denotes a dummy variable for the year in question. These equations suggest that a firm's R&D stock is valued at a slight premium over its value in the stock market when the firm is a candidate for takeover. This finding is strikingly consistent with Addanki's (1985) findings using some of the same data but a different model, and it deserves to be investigated further by integrating these equations into the full multinomial logit model of acquisition choice.

The analysis in this section has yielded two findings that bear on the role of R&D in acquisition activity. First, the takeover premium is positively related to the amount of R&D capital the acquired firm possesses. Second, some sort of matching does seem to be at work in the merger market: Firms prefer to acquire other firms that are similar to themselves, especially with respect to R&D intensity. This result is not one that is easily determined from the aggregate (marginal) patterns of merger estimated in table 3.4, suggesting that the full matching model I tried for the first time here may yield more information about the merger market than we have hitherto been able to obtain. Further research is needed to verify this result with additional information about the other firm characteristics that prompt takeover activity.

3.6 Conclusions

I began this paper with some questions about the costs and benefits of increased merger activity in the United States and suggested that exploring the role of research and development activity might shed some light on whether at least the firms involved have benefited from the increase. I also cited some previous and rather inconsistent evidence on the attractiveness of R&D in the takeover market. With respect to this last point, a richer model of acquisition, one that attempts to match buyers and sellers, seems to provide an explanation for some of the earlier results. Although on average acquired firms invested the same amount or slightly less in R&D as the industry norm, the R&D they engaged in was valued more highly at the margin by the firms that took them over. This result at least hints that successful innovators are being taken over. In addition, the evidence suggests that larger gains are generated by acquisitions where both firms involved have high R&D intensity.

I also found evidence that much of the acquisition activity by private and foreign firms in the domestic market was directed toward firms and industries that were relatively less R&D intensive and had a weaker technological base, so that this kind of acquisition activity cannot be a major factor in causing a shift in focus away from innovation activity, unless we take the view that managers in these industries saw themselves as threatened with takeover far in advance and cut R&D spending in anticipation of a takeover. But given the nature of the industries involved, this view seems somewhat unlikely. Explaining this result will require further investigation into the motives for private acquisitions.

Finally, the existing data (through 1985) provide very little evidence that acquisitions cause a reduction in R&D spending. In the aggregate the firms involved in mergers were in no way different in their pre- and postmerger R&D performance from those not so involved. At the individual industry level the results were too imprecisely measured to draw solid conclusions.

Many questions remain deserving of further attention. First, at the level of econometric specification, what are the optimal regressors and the optimal sampling for the choice set in the model I employed, and how do the results change when a nested logit model is used to estimate the probability of acquisition and the probability of the choice made? Second, can we learn more about the precise valuation of this part of the returns to R&D by incorporating takeover prices directly into the model of acquisition probability? Finally, is there more information about the relative importance of other reasons for merger to be gained from a more complete model of the acquisitions market using this framework? These questions await further research.

Notes

1. An additional reason for changes in merger activity might be changes in the transactions or other costs associated with buying another firm. For example, Jensen (1986) has suggested that the innovation of junk bonds facilitates the takeover of large firms by small ones, which would not have taken place previously. In my investigation here, I am abstracting somewhat from the changes in takeover "technology" that have occurred in recent years because they primarily affect factors in a time-series analysis and my focus is on cross-sectional differences and similarities in takeovers.

2. As was suggested by Ariel Pakes, one of the discussants of this paper, it is possible to reverse this model by viewing the decision from the perspective of the potential target. In this case the coefficients of the gain function are estimated from a comparison of the actual acquirer and those firms that might have acquired the target. If the specification is correct, and the ϵ_{ij} terms are truly independent, both methods should give the same estimates of the structural parameters. A full exploration of the econometric specification of such a model, though interesting, is beyond the scope of this paper. Work now under way on this topic suggests that differential propensities to be acquired or to acquire (that is, a lack of independence of the alternatives) may have a role here.

3. In data of this kind, with a skewed size distribution, the functional form typically having disturbances that are normally distributed is the log-log. For example, consider the form

$$\log V = \beta_0 + \beta_1 \log X + \epsilon, \quad \epsilon \sim (0,\sigma^2).$$

If we choose instead to estimate using V, we obtain

$$V = e^{\beta_0} X^{\beta_1} e^{\epsilon} \approx A_0 X^{\beta_1} (1 + \epsilon e^{\epsilon})$$

by a first order Taylor-series expansion. This disturbance is obviously very heteroskedastic (and skewed).

4. I used the Wilcoxon rank sum test (which is best for the logistic distribution), the median score test (best for double exponential), the Van der Waeden test (best for normal), and the Savage test (best for exponential).

5. In the special case where there are no synergies in acquisition (the gain is additively separable in the characteristics of i and j), these are the true marginal probabilities of acquiring and being acquired, but it seems unlikely that this particular model holds for these data. Simple significance tests on the interaction terms confirm this.

6. All the logit estimates in the table were obtained with the logit procedure TSP Version 4.1 (Hall, Cummins, and Schnake 1986).

7. I am grateful to Charles Brown, one of the commentators, for pointing out that the identifying assumption used in the first version of this paper, $\gamma_{10}=0$, is not very reasonable.

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Comment Charles Brown

Hall's paper presents needed evidence on the relationship between corporate takeovers and R&D activity. It actually provides a broader picture than its title promises, since it analyzes both the changes in R&D activity following mergers and the impact of R&D activity on acquisitions.

The introduction of the paper poses several possible relationships between merger activity and R&D spending. These follow from conjectures about discretionary managerial behavior, not derived as the "optimal" behavior of managers with particular objectives and constraints. It is not obvious to me, however, that the picture would be sharpened by such an effort.

For the most part, the managerial behavior discussed has to do with investment in general rather than R&D in particular. It would be interesting to undertake a parallel analysis, for the same firms, of whether investment in physical capital is changed by corporate takeovers.

The model of merger partners allows one to raise interesting questions, but two things are, in a sense, missing. First, j acquires i when it is profitable for j to do so (as Hall emphasizes) but only when it is not more profitable for some other firm k to acquire i. It is true that competition for i among potential suitors would raise the price of i, and when the dust clears the acquisition is profitable for only one firm. Yet the information that it was not profitable in the end for the other firms to acquire i is not explicitly included in the estimation. Second, the price that j will ultimately pay for i is taken as a function of i's characteristics and not identified with the preannouncement value of

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i, because "by making a bid, firm j reveals something about the value of the assets that was not previously known and hence finds it necessary to bid above the trading price." If so, the potential acquisition price might depend on j's characteristics, and the distinction between the v_j and v functions is blurred.

Assembling the data for this study (Hall was part of the team that did so) was a sizable task, and it would be bad form to overemphasize the potential for omitted-variable bias in the "lean, mean" empirical specification that data limitations impose. Constructively, a quick survey of the determinants of R&D and the determinants of merger activity found in previous studies might give one a better feel for the direction any such bias is likely to take.

Hall presents several interesting results, whose full explanation will provide a likely topic for future work. Some of the conclusions will benefit if a few years of "merger mania" expand the sample to be studied. There is surely room for disagreement about one's favorites; mine are the very different pattern of acquisitions between manufacturing firms and firms that are not publicly traded (table 3.3) and the premium placed on the stock of R&D by potential acquirers (table 3.6, model II).

Comment Ariel Pakes

There are two parts to Hall's paper. The first documents the characteristics of an extensive data base on mergers and acquisitions that Bronwyn has put together. The second suggests a framework for the econometric analysis of merger activity and then presents some preliminary estimates. I am going to focus my comments on the second part of the paper (since this is where my own value added is likely to be highest). There is no doubt, however, that the first part of the paper makes a substantive contribution to the literature on mergers and acquisitions. Hall has produced both a valuable data set and an apt characterization of the trends in merger activity over a ten-year period (broken down by industry and type of buyer). This information should prove extremely valuable in considering the possible causes and effects of merger activity.

Finding a sensible framework for a detailed econometric analysis of merger activity is not a simple task. The spectrum of forces that the literature refers to as motivating mergers is large and depends on many

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factors that are difficult to quantify. The best we can do is look for a way to summarize the data that makes some "reduced form" sense, and then be very careful in the way we interpret the estimates.

Hall's framework consists of three main equations. If we let $V_j(X_i)$ be the increment in firm j's value that results from the purchase of firms i's assets (X_i), then Hall assumes firm j purchases firm i if

(a) $V_j(X_i) - P_i \geq V_j(X_k) - P_k$, for all possible firms k, and

(b) $V_j(X_i) - P_i \geq 0$,

with

(c) $$P_i = V(X_i),$$

where P_i is the price of firm i. The logic underlying equations (a) and (b) is that if firm j purchases firm i, the increment in firm j's value from this coupling, or "match," must be both greater than the increment from any other possible match j could make and greater than zero. Equation (c) states that the price of firm i depends only on its own assets. Note that P_i is observable so that (with some additional functional form assumptions) equation (c) could be estimated.

I think that this form of a "matching" model is not appropriate for the merger problem. If we take (c) as given, (a) and (b) are likely to be satisfied for a large number of potential acquisitors simultaneously, and only one coupling will actually take place. Moreover, the price of firm i is unlikely to depend only on firms i's own assets. Simple economics tells us that the price firm i sells for must be between the values assigned to firm i by the potential purchasers with the first and second highest evaluations of firm i's assets. Since these evaluations are likely to depend on the characteristics of these two potential buyers, so will P_i. What is lacking in this system of equations is some allowance for the workings of the market as a whole.

An alternative to the matching model is the look for "equilibrium" conditions and estimate from them. We might, for example, consider replacing (a), (b) and (c) with

(a′) $$V_j(X_i) = max_k V_k(X_i)$$

(b′) $$V_j(X_i) \geq P_i \geq V_r(X_i),$$

with

(c′) $$V_r(X_i) = max_{(k \neq j)} V_k(X_i),$$

where *max* refers to the operation of taking the maximum. Equation (a′) states that if j purchases i, the value of i to j must be at least as great as the value of i to any other potential buyer (or else the other acquiror would make the purchase; note that $V_j[X_i]$ must also be greater than $V_i[X_i]$ which is the value of i as an independent entity). Equations (b′) and (c′) filter in the price of acquisition by insuring that it lies between the values assigned to i by the two potential buyers with the highest evaluations of i.

There are also problems with the kind of frictionless, complete-information, equilibrium approach embodied in (a′), (b′), and (c′). For example, this model is not complete without an additional rule specifying the set of potential buyers, or the set over which the maximum is taken (this problem also plagues Hall's framework). Still, I think it is useful to begin with a set of equations that have some simple economic justification and then try to build in the appropriate complexities as best we can. Note that the difference between (a) and (a′) is in the comparison set. Statement (a) compares $V_j(X_i)$ to other purchases firm j could make; (a′) compares it to the values attached to i by other potential buyers. If we were to use the type of logit specification Hall implements, it would be just as easy to estimate one version as the other.

The "equilibrium" strategy can be pushed further than this. Statements (a′), (b′), and (c′) use only the equilibrium conditions in the current period. There are also equilibrium conditions in prior periods. Since in period $t-1$, firm i existed as a separate entity, it should be the case that $max_k V_k^{t-1}(X_i^{t-1}) \leq V_i^{t-1}(X_i^{t-1}) = P_i^{t-1}$, where the subscript $t-1$ denotes evaluations made in the period prior to the merger, so that P_i^{t-1} is the observed value of the ith firm in period $t-1$. Thus, if we let t be the merger period, putting together the equilibrium conditions from the period prior to merger with the period after the merger gives us the statements

$$V_j^t(X_i^t) - V_j^{t-1}(X_i^{t-1}) \geq P_i^t - P_i^{t-1}$$

if j actually makes the acquisition, and

$$V_k^t(X_i^t) - V_k^{t-1}(X_i^{t-1}) \leq P_i^t - P_i^{t-1}$$

if k does not.

Although combining information from different periods should provide us with more precise estimators if the assumptions of the model are correct, it also places a heavy burden on the (clearly inappropriate) assumption that every possible buyer evaluates all possible purchases in every period. In fact, evaluating potential acquirees is a costly and time-consuming task. An alternative strategy would be to provide a model of when an evaluation process is initiated. A model of when the costs of acquisition are actually incurred could also provide us with a formal way of determining the set of potential buyers (and this, in turn, would do away with the need to invoke the independence-of-irrelevant-alternatives assumption that is now being used to constrain the number of potential buyers in the estimation algorithm).

Once Hall moves on to her choice of functional forms for $V_j(X_i)$, I am much happier with her assumptions. She assumes $V_j(X_i) = \Sigma\alpha_{jk}X_{ik} + \epsilon_{ij}$, where $\alpha_{jk} = \Sigma z_{jr}\delta_{kr}$. Here firm j's evaluation (α_{jk}) of firm i's assets (X_{ik}) depends on firm j's characteristics (z_{jr}). I think this is an intuitive way of looking at the reduced form relationships between the characteristics of the acquiring firm and those of the acquired firm. My only recommendation would be to try to augment the list of characteristics (the X_k and the z_r) and to allow for a disturbance term in the equation determining the α_{jk} (it is difficult to quantify all the factors that make firm i's assets attractive to firm j). It would be particularly useful if we could find and use variables that might capture the effects of some of the alternative explanations of merger activity. I imagine that all these tasks are in Hall's list of things to do.