R&D AND PATENTING ACTIVITY AND THE PROPENSITY TO ACQUIRE IN HIGH TECHNOLOGY INDUSTRIES

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Abstract

In this paper we investigate the incidence of high technology acquisitions using a large international sample of acquisitions by public high technology firms. Controlling for firms' financial characteristics, we examine the impact of the following innovation-related factors on the propensity to acquire: R&D-intensity as a proxy for R&D inputs; the citation-weighted patent-intensity as a proxy for R&D output; the stock of citation-weighted patents as a proxy for the accumulated stock of knowledge generated by past R&D efforts. The following conclusions can be drawn with respect to the characteristics of acquirers of non-public targets – mainly private firms and former subsidiaries. First, we find support for the view that the propensity to acquire new knowledge-related assets through acquisitions is driven by declining returns from the exploitation of a firm's existing knowledge base. Second, we find evidence in favour of the make-or-buy theory that acquisitions are a substitute for in-house R&D activity. Third, our results are in accordance with the theoretical argument that a large stock of accumulated knowledge enhances a firm's ability to absorb external knowledge through acquisitions. These results suggest that smaller acquisitions can be seen as part of an innovation strategy by acquiring firms with relatively low levels of internal R&D which seek to offset low R&D productivity by exploring a range of potential innovation trajectories in new and smaller business units. Interestingly, we find that these interpretations cannot be made for acquirers of the larger public companies.

JEL Codes: G34, O30, L20

Keywords: Mergers and acquisitions, acquisition likelihood, R&D, patents

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INTRODUCTION

Acquisition activity in the high technology industries[1] of the global economy rose dramatically in the last two decades of the 20th century. An impression of the order of the magnitude of this activity is provided by Inkpen et al. (2000), who report that acquisitions by firms in computer- and communication-related industries alone accounted for over one-fifth of all US acquisition activity by number, and two-fifths by value during the 1990s. They also report an accelerated trend towards such acquisitions, with their share the year-an-a-half since January 1998 accounting for nearly 57% of the $1.75 trillion in assets acquired in the US. Almost every multinational corporation engaged in some acquisition activity in recent years, with Siemens AG and General Electric Co acquiring more than 170 and 110 targets respectively during the eighteen year period from 1984 to 2001.

This wave of merger activity has been associated with an increased interest in the rationale of high technology acquisitions. The theories developed in the literature to explain the incidence of acquisitions in general, such as the realization of synergies arising from economies of scale and scope and market power or the elimination of inefficiencies in the market for corporate control and the stock market, are relevant to the high technology sector. They, however, do not deal directly with innovation-specific activities rooted in Research & Development (R&D) and patenting activity which impact in turn on growth and financial performance.

There is, moreover, a growing literature suggesting that firms use acquisitions, as well as other forms of corporate venturing, to learn from knowledge sources beyond the boundaries of the firm (Veugelers and Cassiman, 1998; Cassiman and Veugelers, 2002; Schildt et al., 2003). More fundamentally, Chesbrough (2003) argues that the evidence suggests that we are witnessing a "paradigm shift" in the way companies innovate new ideas and bring them to market from what he calls “closed innovation” towards “open innovation”. Although according to the former that successful innovation requires control, according to the latter companies can and should utilize both external and internal ideas and internal and external paths to market to create value. The seeds of these ideas date back to Williamson (1975), who proposed a systems approach of the innovation process, stressing the organizational limitations – essentially due to bureaucratization – of large firms. He claims that an efficient outcome can be achieved when small firms specialize at the initial development of innovative projects, and then large firms acquire these projects possibly through licensing or takeover.

To the best of our knowledge, this paper represents one of the most comprehensive large-sample studies on the impact of innovative activity on the acquisition likelihood. A major contribution of the study is that it tests empirically the view that acquisitions can serve as an alternative to in-house R&D, while it also specifies the conditions under which this is more likely to be the case by uncovering the particular characteristics of the acquiring firms. Furthermore, it accounts, to some extent, for the possibility that acquisitions as a whole may represent the aggregation of very different strategic activities (Bower, 2001). Because of an increased awareness that acquisitions of public versus private targets might represent a different phenomenon (Ang and Kohers, 2001; Fuller et al., 2002; Shen and Reuer, 2003; Conn et al, 2005), the analysis discriminates between acquisitions of large public firms and those of relatively smaller private firms and former subsidiary units, which, as we argue later, are likely to serve different needs for the acquiring firms. It appears that no previous empirical study specifically of R&D and innovative activity examines the characteristics of firms acquiring private targets and divested units, which actually account for the bulk of acquisition activity by numbers.

There are several approaches to R&D and patenting behavior which are relevant to our work. Our theoretical background is developed from three current perspectives. The first perspective is rooted in the distinction between explorative and exploitative learning. The former emphasizes experimentation with new alternatives, while the latter emphasizes the refinement and extension of existing competencies and technologies (March, 1991). It is argued that acquisitions can be used as an expansion method that enhances exploration and helps overcome the inertia and rigidity associated with an emphasis on the exploitation of a firm's existing knowledge base through greenfield investment (Vermeulen and Barkema, 2001). The second perspective is based on a particular interpretation of the make-or-buy approach, which views managers of high-tech firms as choosing between either investing in in-house R&D, or sourcing technological knowledge externally through the acquisition of innovative firms (Blonigen and Taylor, 2000). In this case, internal R&D is seen as an alternative to external acquisition of technology by takeover. The third perspective is based on the notion of absorptive capacity developed by Cohen and Levinthal (1989), which implies that in-house research activity enables the firm to develop and maintain its broader capabilities to identify, assimilate and exploit knowledge from the environment (Cohen and Levinthal, 1989). This line of argument suggests that the accumulated in-house research is likely to contribute to the internal knowledge capabilities that allow firms to effectively utilize foreign know-how (Arora and Gambardella, 1994), and enhances their ability to identify and absorb suitable acquisition targets.

On the basis of these arguments, three hypotheses about the innovative characteristics of acquiring firms are developed, with the innovative activity being measured using data on the inputs of the conduct of R&D (R&D expenditure) and its output in the form of intellectual property registered as patents.[2] By employing proxies based both on R&D expenditure and patents, the analysis accounts not only for the research effort made by firms but also its productivity. The hypotheses are tested using a unique dataset covering a maximum of 9,744 acquisitions mainly of public, private and former subsidiaries[3] by publicly traded firms in all the major industrial economies during the period 1984-2001. Controlling for the full range of financial variables which standard models of takeover behavior link to the propensity to acquire (Trahan and Shawky, 1992; Andrade and Stafford, 2000; Blonigen and Taylor, 2000; Gugler et al., 2004) we isolate the effect of R&D- and patent-based characteristics on the propensity to acquire in high technology industries.

This study has further distinctive characteristics compared with previous empirical work on acquiring companies. First, it focuses on high technology acquiring firms to ensure that innovation is an important element in corporate strategy. Using aggregate data from a wide cross-section of industries might mask a differing relationship between acquisitions and innovative activity that is likely to hold between high-tech and non-high-tech firms. Second, it employs a large sample of deals that are rich in geographical and industrial diversity, which compares favorably with the samples of previous studies.

The remainder of this paper is organized as follows. The next section develops our hypotheses. This is followed by a section describing the dataset and the methodology employed. Then, the empirical results from the analysis and their implications for the hypotheses are discussed. The final section presents the conclusions that can be drawn from the analysis of this paper.

THEORETICAL BACKGROUND AND HYPOTHESES

Explorative versus exploitative learning

This line of argument is anchored in the organizational learning literature. In a seminal paper, March (1991) argues that organizations in order to adapt and survive in a changing competitive environment need to allocate their limited resources so as to strike a balance between exploration of new alternatives and exploitation of existing competencies and technologies. An interesting argument is that, because of organizational factors, power-political incentives and the fact that the returns from exploitation tend to be relatively more proximate and predictable, organizations often prefer step-by-step local learning over the investigation and adoption of novel alternatives (Schildt et al., 2003; March, 1991). However, the on-going exploitation of the existing knowledge and capabilities, even those that make an organization successful in the short-run, after a point hampers the creation of new knowledge and eventually make the organization simple, rigid and unsuccessful (March, 1991; Vermeulen and Barkema, 2001). On the one hand, the ongoing exploitation of a firm's technology base is likely to lead to technological exhaustion because most of the possible relationships between a set of components have already been tried (Fleming, 2001; Kim and Kogut, 1996). On the other hand, the refinement and extension of existing competencies and technologies is likely to trap a firm in sub-optimal equilibria (March, 1991). For instance, successful innovators have often found themselves overhauled by challengers with disruptive technologies, which, although initially applied to small, emerging and low-growth markets, eventually become "mainstream" products (Christensen, 1997).

Along these lines Vermeulen and Barkema (2001) argue that acquisitions can be employed as a means of technological renewal and restoring technological diversity and of avoiding the inertia and simplicity that results from the repeated exploitation of a firm's knowledge base. In fact, there is evidence supporting the view that acquisitions are often associated with knowledge transfers and resource redeployment between the acquirer and the acquired firms (Capron and Mitchell, 1998; Bresman et al., 1999). Also, Capron and Mitchell find that a high degree of bilateral resource redeployment of the acquiring and acquired firms improves R&D skills, time to market, product quality, product cost and output flexibility.

Therefore we expect that, the likelihood of becoming an acquirer will be higher the lower the innovative output of firms relative to their asset base. This is consistent with an enhanced desire to acquire new technology and innovation-related assets driven by declining returns from the exploitation of the firm's existing asset base.

Hypothesis 1. Acquiring firms will have a lower innovative output from R&D given their asset base than other firms.

Make-or-buy

The task of defining the "efficient boundaries" of a firm and consequently which activities should be performed within- and which outside the firm has been largely investigated by the transaction cost approach (Williamson, 1975, 1979, 1981). In general, R&D activity has two of the characteristics in the presence of which the in-house making strategy is the most efficient option. First, the conduct of R&D involves a high degree of uncertainty with respect to the nature, the significance and the timing of the research outputs (Arrow, 1962). Second, it often requires transaction-specific investments in not easily redeployable assets (e.g. site-, physical- or human capital-specificity) which implies that market relationships are subject to the danger of opportunistic behavior by the parties involved. Under these conditions and the rather reasonable behavioral assumptions of bounded rationality for at least some of the agents, it is impossible, or prohibitively costly (particularly in terms of contract enforcement), to write a perfect contract. As a result, external or quasi-external (e.g. licensing or strategic alliances) sourcing of R&D is disfavoured.

However, the make-or-buy dilemma takes a different content once the possibility of sourcing technological knowledge through acquisitions of innovative firms is accounted for. Then, as Blonigen and Taylor (2000) put it, the make-or-buy theory views managers of high-tech firms as choosing between either organic growth with in-house R&D, or external growth through the acquisition of technological knowledge, either disembodied or embodied in other organizations' physical or human capital. This is an external sourcing strategy, but the transfer of ownership reduces the dangers of moral hazard once the acquisition has been completed. The acquisition of firms with an important innovative portfolio or some other external sourcing strategy often is a less risky and a faster way of exploiting commercially specific knowledge assets (Chakrabarti et al., 1994; Francis and Smith, 1995). Moreover in the case of publicly quoted acquisitions in particular, the acquired company has a track record to be analyzed and to make financial projections for future costs and expected performance (Hitt et al., 1996).

Although firms, particularly the large ones, are likely to follow a mixture of sourcing strategies and adopt a spectrum of activities (Veugelers and Cassiman, 1998; Brown and Eisenhardt, 1997), there are reasons to expect some kind of substitutability between in-house R&D and external sourcing of knowledge through acquisitions. First, it is argued that, because firms have a limited pool of financial resources available, a trade-off is likely to exist between investments in acquisitions and investments in other areas, such as R&D (Hitt et al., 1991). Second, because acquisitions require substantial financial resources, which are often covered by excessive amounts of debt, acquiring firms' financial risk increases (Hitt et al. 1990). As a result, managers themselves or risk-averse debt holders with an influence over the firm's management are then more likely to avoid risky investments with long-horizon payback periods, like R&D (Smith and Warner, 1979). Therefore, on the basis of this approach we expect that external acquisition of technology by takeover is a substitute for internal R&D. Since R&D is positively related to business size we express our hypothesis in size relative form.

Hypothesis 2. Acquiring firms will have a lower level of R&D inputs than other firms of a given size.

Absorptive capacity

According to Cohen and Levinthal (1989), R&D activity has a dual role. Firms invest in R&D not only in order to innovate, but also to develop and maintain their broader capabilities to identify, assimilate and use knowledge from the environment. In other words, one of the reasons that firms engage in R&D is to develop what Cohen and Levinthal call "absorptive capacity". In that sense, in-house research contributes to the internal knowledge capabilities that allow firms to effectively utilize external know-how (Arora and Gambardella, 1994). Similarly, Chesbrough (2003) stresses the importance of continued internal capacities and capabilities even while integrating external R&D. On this view, R&D and acquisitions of innovating firms can be viewed as complementary strategies, in the sense that the benefits from acquisitions of innovating firms are increased by the acquirer's own past research efforts. This line of reasoning also explains why some firms spend on basic research, which is unlikely to lead to directly commercially exploitable results. Thus, despite a trade-off for current expenditures between in-house activities and external acquisition, the likelihood of making acquisitions will be enhanced by past internal capacity development. This ensures that the acquired businesses will be effectively managed and their innovative potential fully utilized. Therefore, we expect that, controlling for current R&D, the likelihood of becoming an acquirer is positively associated with the stock of accumulated knowledge generated by past R&D efforts.

Hypothesis 3. Acquiring firms will tend to have a large stock of accumulated knowledge generated by past R&D efforts relative to other firms.

Public versus non-public targets

Although the empirical literature on mergers and acquisitions has until recently focused on acquisitions involving publicly traded firms, the volume of privately held targets and former subsidiary units acquired has surpassed that of publicly traded targets (Ang and Kohers, 2001). Acquisitions of public targets tend to be the deals with the largest transaction value and those that receive the most extensive coverage by the financial press. The largest domestic – but overall the second largest – high technology deal during the period 1984-2000, is the merger announced in 2000 between the US firms America Online Inc and Time Warner in a transaction valued at \$180.18 billion.[4] The largest high-tech deal during the period 1984-2001 – and actually the largest ever deal across all the industries – is the cross-border acquisition of the German firm Mannesmann AG by the UK-based firm Vodafone AirTouch PLC in a transaction valued at \$216.78 billion, which was announced in 2000. However, apart from a handful of mega-deals taking place every year, the vast majority of deals involve small, mostly private, firms. Our calculations based on the population of high-tech deals announced during the period 1984-2001 and reported by Thomson's Financial SDC, suggest that more than half of the deals have a value of less than \$25m, and only about 4% of all deals are between \$1 and \$10 billion, while just 0.5% of all the deals are valued at more than \$10 billion.

The inclusion of acquisitions of private targets and subsidiaries in the analysis of this paper is an important contribution to the literature. We suspect that the innovation-related hypotheses set out above are likely to hold more strongly for acquisitions of privately held targets and former subsidiaries divested by their previous parent compared to acquisitions of publicly traded targets. This is in accordance with Williamson (1975) who claims that no single size or form of organization has optimum properties with respect to all stages of the innovation process, from invention, to experimental development, to market testing, to commercial production and finally to distribution. The relative strengths of small firms are their behavioral characteristics, while those of large firms lie mostly in resources. He suggests that efficiency requires that the initial development and market testing to be performed by independent inventors and small firms (perhaps new entrants) in an industry, the successful developments then to be acquired, possibly through licensing or takeover, for subsequent marketing by a large multidivisional enterprise.

The best known and successful high-tech acquisition strategies in the decades covered by our sample involved persistent acquisitions of small highly innovative companies by Cisco Systems, a leader in the computer equipment market. These acquisitions were explicitly seen as primarily offering opportunities for access to new technologies, entry into new markets and growth (Holloway et al., 2004). Cisco's innovation strategy is often compared with that of its (approximate) competitor, Lucent Technologies (Chesbrough, 2003). The former did little internal research and put more effort in scanning the world of start-ups that were commercializing new products and services and either partnered with them or acquired. The latter, despite an acquisition activity that should not be disregarded, emphasized on in-house investments that were directed to exploring the world of new material, state-of-the-art components and systems, and it targeted at new fundamental discoveries.

As far as the acquired firms' incentives for sale are concerned, the evidence suggest that a high innovative and growth potential of small private firms is often under-utilized (Oakey, 1995; Hughes, 1998). This is due to market failures affecting their access to finance and limitations based on recruiting expanded managerial and directorial talent or a lack of some complementary assets and capabilities that play a crucial role in the innovative process or the successful commercialization of their products. Such factors can be continuous R&D, large-scale production, technological, market and product expertise, linkages with universities and research institutions, legal expertise in patent-related issues. In the case of acquisitions of subsidiaries, their previous parent firms often divest them if they require substantial R&D and capital investments that the parent firms are unable or unwilling to make, particularly when these units no longer fall inside their parent firm's core activities (Weston et al., 1998; Parhankangas and Arenius, 2003). Smaller acquisitions are therefore an obvious part of an innovation strategy for firms with relatively low levels of internal R&D which seek to offset low productivity in exploiting past R&D efforts by exploring a range of potential future innovation trajectories in new and smaller businesses.

In the case of larger public acquisitions other factors may come into play alongside the hypotheses we have set out in this section. These include broader strategies to rationalize and reorganize R&D investment programs by firms which are already highly R&D intensive and are related to gaining scale and scope economies in their innovation input activities, rather than a response to declining returns on past programs. We therefore carry out our analysis for our sample as a whole and disaggregated into public and non-public targets.

METHODS

The data

Acquisitions are defined as deals where the acquiring firm owns less than 50% of target's voting shares before the takeover and increases its ownership to at least 50% as a result of the takeover. Furthermore, high technology acquisitions are defined as those involving acquiring firms with some part of their activity in one of the high-tech industries specified by Hall and Vopel (1996), and whose primary activity[5] is in SIC 28 Chemicals and Allied Products, SIC 35 Industrial and Commercial Machinery and Computer Equipment, SIC 36 Electronics and Electrical Equipment, SIC 37 Transportation Equipment, SIC 38 Measuring, Analyzing and Controlling Instruments; Photographic, Medical and Optical Goods, SIC 48 Communications, SIC 73 Business Services, SIC 87 Engineering, Accounting, Research, Management, and Related Services.[6] We focus on acquisitions carried out by publicly traded firms and which involve firms operating in one of the ten most merger-active industrialized countries, namely Australia, Canada, France, Italy, Japan, the Netherlands, Sweden, Switzerland, the UK, and the US.[7] The population of acquisitions comes from Thomson Financial's SDC Platinum, which reports 14,016 completed deals announced during the period from January 1984 to June 2001. These deals are carried out by 3,544 public firms while no restriction is imposed on target public status.[8]

The innovative activity of firms is measured using data on the inputs of the conduct of R&D (R&D expenditure) and its output in the form of intellectual property registered as patents. However, because the distribution of the value of patented innovations is extremely skewed (Scherer 1997), we also consider for each patent the number of forward citations it receives by subsequent patents to approximate its value. A patent which is cited many times is more likely to be highly valued than a patent which is relatively rarely cited (Griliches, 1990).

Financial data and data on R&D expenditure for the period 1983-2001 were collected from Datastream, Compustat and Global Vantage. Data on patent counts and patent citations[9] were collected from the NBER dataset which includes all the utility patents granted by the US Patent and Trade Office (USPTO) with our series covering the period from 1983 until 1999 and 1997 respectively (Hall et al., 2001).[10] Moreover, because firms often register patents under their subsidiaries' names (Bloom and Van Reenen, 2000), we used Dun & Bradstreet's "Who owns whom" annual issues to obtain their detailed corporate structure and data were aggregated at the parent firm level. Combining these databases we construct a unique unbalanced panel dataset covering the period

1983-2001 which consists of financial and innovation-related variables on 13,075 firms, including both acquiring and non- acquiring firms.

The sample over which the financial characteristics and R&D-intensity of the acquiring firms are examined is reduced to 9,744 acquisitions (1,398 public and 8,346 non-public targets) initiated by 2,276 firms, after imposing the restriction that data are available for acquiring firms, at least on some key financial variables[11] in the last pre-merger year. The patent- and citation-weighted patent-based characteristics of acquiring firms can only be assessed on the basis of a sample of 6,413 and 5,064 acquisitions initiated by 1,166 and 1,074 acquiring firms, respectively. This is because, on the one hand, only a subset of acquirers is linked to patent assignees at the USPTO, and on the other hand, our patent and citation data end in 1999 and 1997, respectively.

The fall in the size of the sample of acquiring firms over which the pre-merger firm characteristics are assessed introduces some sample selection bias towards larger firms. While the overall median size (ln total assets measured in $1996 thousands) of all acquiring firms equals 12.32, the median size of the 9,744 acquiring firms over which the pre-merger financial characteristics and R&D-intensity are assessed equals 12.50. The bias is more serious for the sample of firms over which their patent-based characteristics are assessed, where the median size of the 6,413 acquiring firms equals 12.89. This larger size imbalance arises from the fact that the firms linked to patent assignees tend to be relatively larger compared with those not linked.

The model

The probability of making an acquisition is modeled as a function of key firm characteristics, using an unbalanced panel dataset which consists of financial and innovation-related variables on both acquiring and non-acquiring firms for which data are available in some years during the period 1983-2001.

We employ a logit and a negative binomial maximum likelihood model (See the Appendix) to estimate the acquisition probabilities, since the takeover incidence in a given year takes strictly non-negative values and hence the classical linear model is inadequate.[12] Similar estimation methods have been used in previous empirical work.[13] The logit model is very attractive due to its simplicity, but it has the drawback that, because it is a binary response model, it treats similarly firms that undertake a single or multiple acquisitions in a given year. The negative binomial maximum likelihood model tackles this drawback, where the dependent variable is the number of acquisitions made by each firm in a given year. For both models we assume that merger events are independent conditional on the regressors.[14]

Given the cross-section and time series nature of our dataset, panel data estimation methods have the advantage that they allow us to account for some unobserved heterogeneity across firms (Hsiao, 1986). With respect to the choice between fixed- and random-effects, we prefer the random effects approach because the number of firms over which the fixed-effects models is estimated is much lower. This is because the fixed-effects estimator procedure requires some variation in the outcome for each firm across time, and considers only firms for which data on regressors are available for more than a single year. We also employ the simple logit estimator that pools together observations across firms and years. It has the advantage of being simple to calculate, and it is expected to lead to comparable estimates to those of the random-effects estimator if the variance contributed by the panel-level component is small relative to the total variance. Robust standard errors to within-firm serial correlation are calculated for the simple logit estimates, since even if firm-specific effects are uncorrelated with the regressors, the composite errors might be serially correlated due to the presence of a firm-specific effect in each time period.

Independent variables and controls affecting the acquisition probability

Innovation-related characteristics

The innovative profile of firms is examined with respect to their R&D inputs, R&D output, and the stock of accumulated knowledge generated by past R&D efforts. Because of the large size differences across firms and the size difference caused by acquisitions, R&D inputs, proxied by R&D expenditure, and R&D output, proxied by the number of successful patent applications, are normalized by firm size (See, for example, Blonigen and Taylor, 2000; Hall, 1999; Hitt et al., 1991). Therefore, R&D inputs are defined as the ratio of R&D expenditure to total assets and we refer to this ratio as R&D-intensity.[15] R&D output is defined as the ratio of the number of successful patent applications to $million of total assets and we refer to this ratio as patent-intensity. The stock of accumulated knowledge generated by past R&D efforts is measured by the stock of patents[16], which is calculated by the standard perpetual inventory formula assuming a 15% depreciation rate per annum (See Hall, 1990). R&D output and the patent stock are also calculated using the number of normalized citations received by forward patents (instead of the raw patent count) to account not only for the quantity but also the quality of the patented inventions. The disadvantage of citation-weighted patent measures is that the citation data end in 1997.

Controlling for financial characteristics

Although the issue of primary interest is the innovative profile of merging firms, this is investigated in the light of their financial profile. This is because, financial variables are likely to influence both their innovative and acquisition activity. The initial set of characteristics that were considered as controls to model the acquisition probability consists of firm size, indicators of economic performance and of the availability of financial resources. The evidence from previous innovation-based studies is that the acquisition probability tends to be positively related to firm size, economic performance and internal financial resources (Hall, 1988, 1999; Blonigen and Taylor, 2000). All financial variables are expressed in constant 1996 prices using the US GDP deflator, which effectively averages how consumers, producers and the public sector experience inflation.

Firm size is proxied by the book value of total assets. We have chosen this specific size measure, because it has the best coverage among all the alternatives considered (sales, number of employees, net assets). Recent studies employing a similar size proxy include Powell (1997), Blonigen and Taylor (2000).

The economic performance is proxied by three variables. First, firm growth, which is calculated as the annual growth of total assets. Second, profitability, which is proxied by operating return and is calculated as the ratio of earnings before interest taxation, depreciation and amortization (EBITDA) to total assets. Third, Tobin's q, which we approximate by calculating the ratio of total assets plus the market value of common equity minus the book value of common equity to total assets (See Blanchard et al., 1994; Kaplan and Zingales, 1997; Andrade and Stafford, 2000) [17]. This performance measure has the advantage over the previous two accounting performance measures that, being a (quasi) market-based indicator, it is forward-looking in nature. According to the q-theory of investment, whenever the rate of return on a firm's current capital stock exceeds its cost of capital, q exceeds unity and the firm is expanding its capital stock (Gugler et al., 2004). Therefore, q can be viewed as an indicator of a firm's growth opportunities.

The financial status of firms is proxied by the cash flow ratio, leverage and liquidity. The cash flow ratio is employed to proxy for the amount of funds available to a firm for operations, investment and acquisitions. It might be an important determinant of the choice between internal R&D or acquisition of innovative firms, given the arguments that R&D is primarily financed by internally generated resources (Himmelberg and Petersen, 1994). It is defined as the ratio of income before extraordinary items plus depreciation and amortization to total assets. Leverage, which is employed as a proxy of a firm's capital structure, reflects the financial risk faced by a firm which might limit managers' ability to allocate adequate resources to R&D activity (Smith and Warner, 1979). It is calculated as the ratio of long-term debt to the book value of common equity. Finally, liquidity, which measures a firm's ability to meet its short-term obligations from its current assets, is calculated as the ratio of current assets to current liabilities.

Model specification

Table 1 provides descriptive statistics and correlations for all the variables.[18] It is interesting to notice that firm size and its stock of accumulated knowledge ((citation-weighted) patent stock) are not particularly correlated, and that there is a high correlation between operating return and the cash flow ratio. To avoid possible multicollinearity bias, the latter is excluded from the specifications estimated. The rather counterintuitive negative correlation coefficient between Tobin's q and operating returns is found to be due to the effect of some observations with negative operating return, and we actually obtain a positive correlation coefficient (0.39) for observations with non-negative operating return.

Table 1. Descriptive statistics & correlations, max 53,913 observations on 6,428 firms, 1983-2001

	Variable	Obs	Mean	Median	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Total Assets (ln)	53,913	11.637	11.547	2.240	5.114	17.529	**1.00**												
2	Total Assets Growth	53,913	0.359	0.055	1.488	-0.782	15.083	-0.04	**1.00**											
3	Operating Return	53,913	-0.021	0.085	0.488	-4.858	0.539	0.37	0.00	**1.00**										
4	Tobin's q (ln)	53,913	0.583	0.410	0.734	-0.853	3.779	-0.25	0.16	-0.31	**1.00**									
5	Cash Flow Ratio	53,708	-0.067	0.050	0.508	-5.211	0.387	0.36	0.01	**0.96**	-0.32	**1.00**								
6	Leverage	53,913	0.615	0.249	2.452	-14.957	22.605	0.14	-0.01	0.05	-0.10	0.05	**1.00**							
7	Liquidity	53,913	3.067	1.894	3.997	0.046	36.217	-0.18	0.26	-0.01	0.14	0.00	-0.09	**1.00**						
8	R&D-intensity (un-adjusted)	46,724	0.088	0.031	0.175	0.000	1.784	-0.36	-0.01	**-0.63**	0.40	**-0.62**	-0.10	0.10	**1.00**					
9	R&D-intensity	53,913	0.076	0.018	0.165	0.000	1.784	-0.32	-0.01	**-0.57**	0.38	**-0.56**	-0.09	0.10	**1.00**	**1.00**				
10	Patent Stock (ln)	18,755	0.378	1.486	4.617	-9.210	7.698	0.39	-0.06	0.04	0.01	0.04	-0.01	-0.07	0.02	0.04	**1.00**			
11	Cite-weighted Patent Stock (ln)	15,652	-0.113	1.507	5.153	-9.210	7.671	0.38	-0.06	0.06	0.00	0.06	-0.02	-0.07	0.01	0.03	**0.95**	**1.00**		
12	Patent-intensity	18,755	0.027	0.000	0.098	0.000	1.298	-0.23	0.06	-0.23	0.23	-0.20	-0.05	0.12	0.28	0.28	0.13	0.15	**1.00**	
13	Cite-weighted Patent-intensity	15,652	0.040	0.000	0.175	0.000	2.237	-0.20	0.07	-0.19	0.22	-0.18	-0.04	0.09	0.25	0.25	0.11	0.15	**0.73**	**1.00**

ln indicates the natural logarithm. Total Assets are measured in $1996 thousands. R&D-intensity is reported both un-adjusted and adjusted where missing observations are assumed to be zero if data on all the financial variables considered are available (this adjustment excludes German firms). Correlations with absolute value exceeding 0.50 are highlighted.

Because patent data are not available for a large number of firms, estimating a single regression, including all the independent variables, would introduce a serious bias against smaller firms and would lead to a dramatic reduction of firm-year observations. To overcome this problem, we adopted two complementary model specifications, and the robustness of our findings is examined by estimating a specification including all the independent variables together. The first one models the probability of making acquisitions as a function of some key financial characteristics (total assets, total asset growth, operating return, Tobin's q, leverage and liquidity) and R&D-intensity. The second one models the same probabilities as a function of a subset of financial characteristics (total assets, total asset growth and operating return), R&D-intensity, the stock of patents or citation-weighted patents, and patent-intensity or citation-weighted patent-intensity[19]. Although measures based on citation-weighted patent-intensity are likely to be better proxies of the importance of innovation output, we also consider measures based on raw patent counts, as this allows a larger sample size, since our citation data end in 1997.

The econometric models are estimated over the completed acquisitions during the period 1984-2002 that involve firms with the appropriate data. All covariates have been lagged by one year so as to avoid endogeneity problems and possible biases arising from different merger accounting methods and financial statement consolidation.[20] Country, industry and time dummy variables are included in the estimated specifications to account for the possibility of time or cross-sectional dependence of acquisitions.[21] Because we find evidence for the existence of some influential outliers, data are winsorized at 1% (0.5% from each side). To account for other idiosyncrasies (skewedness, missing observations, non-linearity) of some of the variables some additional adjustments have been adopted.[22] First, similar to Hall (1999), a dummy variable is employed for very negative operating returns, that is for EBITDA losses of more than half the firm's total assets, in which case the continuous variable is set to zero. Second, following the practice of previous studies (e.g. Hall, 1999) a dummy variable is employed for missing R&D values which equals one when R&D is missing and R&D-intensity is set equal to zero.[23] Third, a dummy is employed for firms with zero (citation-weighted) patent-intensity, to distinguish between firms with some versus no R&D output.[24]

RESULTS

Panel A of Table 2 provides the estimated coefficients for the simple logit, the random-effects logit and the random-effects negative binomial models. As can be seen from the random-effects logit and negative binomial models, the likelihood ratio test of the null hypothesis that the panel-level variance component[25] is unimportant is rejected at the 5% significance level.[26] Yet, the estimates and the corresponding standard errors from the three models are quite close. In all three models, the estimates are based on 53,913 observations of 6,428 firms and a total of 9,744 acquisitions by 2,276 acquiring firms. Let us start from the random-effects logit model. Employing the Wald test, we reject the null hypothesis that the slope parameters of the model are jointly zero. The coefficients of most of the year, country and industry dummies are individually significant, and together jointly significant according to a likelihood ratio test. In addition the hypothesis that the firm characteristics employed as regressors do not add anything to the explanatory power of our model over the year, country and industry dummies is rejected by a likelihood ratio test. The estimated coefficients suggest that the probability of making acquisitions is statistically significantly positively related to total assets, total asset growth, operating return, and Tobin's q, while it is significantly negatively related to R&D-intensity.

Table 2. Regressions for estimating the probability of making acquisitions
Panel A. Financial variables and R&D-intensity

Regressor	Logit	Logit Random Effects	Negative Binomial Random Effects
Constant	-11.190*	-12.540*	-8.785*
	(0.418)	(0.427)	(0.396)
Total Assets (ln)	0.396*	0.431*	0.346*
	(0.014)	(0.015)	(0.011)
Total Assets Growth	0.060*	0.049*	0.038*
	(0.009)	(0.011)	(0.008)
Op. Return	0.815*	1.180*	0.980*
	(0.141)	(0.147)	(0.117)
Dummy Op. Return Negative	0.143	0.080	0.038
	(0.103)	(0.110)	(0.093)
Tobin's q (ln)	0.350*	0.461*	0.397*
	(0.031)	(0.032)	(0.024)
Leverage	-0.001	-0.002	-0.002
	(0.006)	(0.007)	(0.005)
Liquidity	-0.004	0.004	0.006
	(0.005)	(0.006)	(0.005)
R&D-intensity	-0.725*	-0.743*	-0.638*
	(0.224)	(0.217)	(0.183)
Dummy No R&D	0.008	0.062	0.100**
	(0.073)	(0.076)	(0.059)
Country, Industry & Year dummies	Yes	Yes	Yes
No of Observations	53,913	53,913	53,913
No of Firms	6,428	6,428	6,428
No of Acquisitions	9,744	9,744	9,744
Wald Test	2,397.9	2,511.4	32,91.4
Degrees of Freedom	44	44	44
P-value	0.0	0.0	0.0
Log Likelihood	-15,275.7	-14,255.2	-20,101.3
Likelihood Ratio Test of Rho		2,041.0	2,573.2
P-value		0.0	0.0
Pseudo R-squared	0.18		

* (**) Indicates a significant coefficient at 5% (10%) level. Standard errors are in parentheses. Robust standard errors to within-firm serial correlation are reported for the logit model. ln indicates the natural logarithm. Total Assets are measured in $1996 thousands. The regressions include firms from Australia, Canada, France, Italy, Japan, the Netherlands, Sweden, and Switzerland, the UK and the US. The base country is the US, the base industry SIC 283 and the base year 2002.

Similar results are obtained by the negative binomial model. The only difference is that, in addition to the negative relationship between R&D-intensity and the takeover probability, we also obtain a significantly positive coefficient of the dummy for firms when R&D expenditure is not reported, which are expected to have zero or low R&D-intensity.

Panel B of Table 2 presents the results for the patent-based regressions (first three columns) and the citation-weighted patent-based regressions (last three columns). Again, the panel-level variation, for both the logit and the negative binomial models, is found to be important and hence the random-effects models are discussed.[27] With respect to the patent-based specifications, patent data availability restrictions lead to a total of 24,466 observations on 2,619 firms and 6,413 acquisitions by 1,166 acquiring firms. For both models, we find that the firm characteristics employed as regressors are jointly different from zero. Also, the country, industry and year dummies are jointly significant. As was the case with Panel A, we find that the acquisition probability is positively related to total assets, total asset growth, operating return, and negatively related to R&D-intensity. The acquisition probability is also positively related to the size of a firm's stock of accumulated knowledge (stock of patents), while we find a significantly negative coefficient of the dummy for zero patent-intensity for the negative binomial model.[28] Therefore, acquiring firms tend to have a rich record of accumulated knowledge and they are more likely to have non-zero R&D output in the year before acquisitions.

Table 2, Panel B. Financial variables, R&D-intensity and patent-related variables

	Patents			Citation-weighted Patents		
Regressor	Logit	Logit Random Effects	Negative Binomial Random Effects	Logit	Logit Random Effects	Negative Binomial Random Effects
Constant	-5.734*	-6.641*	-3.252*	-5.462*	-6.330*	-3.101*
	(0.306)	(0.315)	(0.247)	(0.326)	(0.324)	(0.269)
Total Assets (ln)	0.356*	0.395*	0.312*	0.340*	0.381*	0.309*
	(0.021)	(0.021)	(0.016)	(0.022)	(0.022)	(0.017)
Total Assets Growth	0.075*	0.058*	0.050*	0.076*	0.052*	0.041*
	(0.016)	(0.02)	(0.015)	(0.016)	(0.022)	(0.017)
Op. Return	1.724*	2.171*	1.776*	1.527*	1.972*	1.662*
	(0.202)	(0.2)	(0.153)	(0.218)	(0.221)	(0.174)
Dummy Op. Return Negative	0.011	-0.107	-0.124	0.145	0.028	-0.005
	(0.148)	(0.163)	(0.141)	(0.166)	(0.183)	(0.157)
R&D-intensity	-0.675*	-0.538**	-0.556*	-0.667**	-0.498	-0.464
	(0.316)	(0.295)	(0.248)	(0.345)	(0.341)	(0.284)
Dummy No R&D	-0.116	-0.158	-0.106	-0.061	-0.1	-0.054
	(0.109)	(0.111)	(0.084)	(0.116)	(0.118)	(0.09)
Patent Stock (ln)	0.038*	0.048*	0.035*			
	(0.01)	(0.01)	(0.007)			
Patent-intensity	-0.457	-0.135	-0.17			
	(0.346)	(0.356)	(0.31)			
Dummy Zero Patent-intensity	-0.165*	-0.08	-0.094**			
	(0.068)	(0.07)	(0.051)			
Citation-wtd Patent Stock (ln)				0.028*	0.034*	0.022*
				(0.01)	(0.009)	(0.007)
Citation-wtd Patent-intensity				-0.540*	-0.355	-0.324**
				(0.228)	(0.221)	(0.193)
Dummy Zero Cit.-wtd Patent-intensity				-0.230*	-0.162*	-0.147*
				(0.072)	(0.076)	(0.056)
Country, Industry &Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
No of Observations	24,466	24,466	24,466	20,940	20,940	20,940
No of Firms	2,619	2,619	2,619	2,462	2,462	2,462
No of Acquisitions	6,413	6,413	6,413	5,064	5,064	5,064
Wald Test	1,561.7	1,586.8	1,993.9	1,344.6	1,338.2	1,713.5
Degrees of Freedom	42	42	42	39	39	39
P-value	0.0	0.0	0.0	0.0	0.0	0.0
Log Likelihood	-8,509.4	-8,046.5	-11,834.8	-7,225.3	-6,848.8	-9,822.6
Likelihood Ratio Test of Rho		925.7	1,352.7		753.1	1,053.8
P-value		0.0	0.0		0.0	0.0
Pseudo R-squared	0.20			0.19		

In the patent-based regressions the base industry is SIC 283 and the base year is 2000. In the citation-weighted patent-based regressions the base industry is SIC 283 and the base year is 1998. In all the regressions the base country is the US. See notes to Panel A.

In relation to the citation-weighted patent-based models, data availability restrictions further reduce the sample size to 20,940 observations on 2,464 firms and 5,064 acquisitions by 1,074 acquiring firms. The financial characteristics of firms are similar to the ones described above, while the coefficient on R&D-intensity is still negative, but it becomes insignificant in the random effect models.[29] Apart from obtaining in both the random-effects logit and the negative binomial models a significantly positive coefficient for the citation-weighted patent stock and a significantly negative coefficient for zero citation-weighted patent-intensity, the results from the latter (and the simple logit) also suggest that acquiring firms are more likely to have significantly lower citation-weighted patent-intensity before acquisitions.

Taking these findings altogether, we conclude that acquiring firms tend to be relatively large and dynamic firms with high profitability and good growth prospects (Tobin's q). In relation to their innovative profile, they tend to have a large stock of accumulated knowledge and a rather low R&D-intensity. They are also more likely to be firms with at least some R&D output, but overall it seems that they are more likely to have a low R&D output (citation-weighted patent-intensity). Given that we have controlled for size and R&D-intensity, the low R&D output of acquiring firms is likely to reflect a low R&D productivity. Therefore, although acquiring firms have a large accumulated stock of patents, they appear to experience either a low number of patents generated per dollar expensed in R&D, and/or relatively low-valued patents in terms of the number of forward citations they receive before acquisitions.

Also in a separate analysis not tabulated here we investigate the importance of year, country and industry effects on the basis of the dummy variables from the random-effects logit model of Table 2, Panel A. The probability peaks in the mid-1980s, the late-1980s and the late-1990s.[30] Interestingly, these trends follow closely the world stock market fluctuations which were computed using a weighted stock price index from some 38 countries that is provided by Datastream. This suggests that the acquisition probability is correlated with stock market movements (See Nelson, 1959; Shleifer & Vishny, 2001). As far as the location of a firm is concerned, Canadian and British firms appear to be the most acquisition-intensive firms, after US firms, while Japanese firms are by far the least acquisition-intensive firms. These results are in accordance with the general distinction between firms in market-insider systems and market-outsider systems (See Franks and Mayer, 1995; Mayer, 1998). Finally, it appears that among the engineering firms (SIC 35, 36, 38, 48), those in SIC 36 are the most likely and those in SIC 37 the least likely to be active in acquisitions.[31]

Further Investigation

Given the remarkable diversity of acquiring firms and their targets, we investigate the robustness of the relationships established above. In particular, we suspect that there might exist significant differences between acquirers of public versus non-public[32] targets (See the theoretical section). If this is the case, pooling across public and non-public acquisitions might camouflage important differences in acquirers' characteristics. To investigate this dimension, we employ a multinomial logit model, which is a generalization of the logit model (See Greene, 1997, Chapter 19). The dependent variable takes on three different values, depending on whether a firm makes no acquisitions in a year, acquires at least one public target[33], or acquires non-public targets only. The results shown in Table 3 are reported in terms of marginal effects evaluated at the averages of the regressors, since in multinomial logit models the direction of the effect of each regressor cannot be assessed simply by the sign of its estimated coefficient (See Greene, 1997, Chapter 19).

We focus our attention on the regressions of Panels A and B including firms from all the countries.[34] The results suggest that both groups of acquiring firms tend to be relatively larger, more dynamic, to have higher q ratios, and probably higher profitability.[35] However, only the firms acquiring non-public targets seem to have a statistically significantly different innovative profile from non-acquiring firms. More precisely, they tend to have relatively lower R&D-intensity, a larger stock of accumulated citation-weighted patents, and although they tend to have non-zero R&D output (citation-weighted patent-intensity), they are more likely to have a relatively lower level of R&D output.

Table 3. Multinomial logit regressions: the probability of making acquisitions of public and non-public targets (marginal effects)

Panel A. Financial variables and R&D-intensity

	All		US		UK		Other	
Regressor	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Constant	-0.2968*	-0.1182*	-0.3139*	-0.1830*	-0.7355*	-2.13E-02*	-0.1148*	-1.40E-02*
	(0.0125)	(0.0059)	(0.0166)	(0.0088)	(0.0681)	(3.83E-03)	(0.0102)	(3.00E-03)
Total Assets (ln)	0.0031*	0.0051*	0.0029*	0.0081*	0.0092*	3.93E-04*	0.0019*	2.85E-04*
	(0.0002)	(0.0003)	(0.0002)	(0.0005)	(0.0014)	(7.78E-05)	(0.0002)	(5.79E-05)
Total Assets Growth	0.0005*	0.0005*	0.0006*	0.0007*	0.0007	6.60E-05*	0.0004*	5.16E-05*
	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0009)	(3.36E-05)	(0.0001)	(2.44E-05)
Op. Return	0.0083*	0.0032	0.0105*	0.0047	0.0062	3.34E-04	0.0034**	2.75E-04
	(0.0014)	(0.0022)	(0.0017)	(0.0038)	(0.0117)	(5.62E-04)	(0.0019)	(4.02E-04)
Dummy Op. Return Negative	0.0012	0.002	0.001	0.0032	-0.0052	-9.31E-05	0.0013	1.79E-04
	(0.001)	(0.0019)	(0.0012)	(0.0031)	(0.011)	(7.57E-04)	(0.0015)	(3.36E-04)
Tobin's q (ln)	0.0025*	0.0048*	0.0021*	0.0070*	0.0138*	6.69E-04*	0.0015*	1.67E-04*
	(0.0003)	(0.0005)	(0.0004)	(0.0008)	(0.0026)	(1.51E-04)	(0.0004)	(8.41E-05)
Leverage	3.14E-05	-0.0001	0.0001	-0.0001	-0.0007**	-1.28E-05	-0.0002*	-2.68E-05*
	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0004)	(3.45E-05)	(0.0001)	(1.02E-05)
Liquidity	-3.33E-05	-1.85E-05	-0.0001	-0.0001	-0.0001	-1.65E-05	2.40E-06	1.08E-05
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0008)	(3.63E-05)	(0.0001)	(9.05E-06)
R&D-intensity	-0.0079*	-0.0001	-0.0108*	-0.0008	-0.0009	5.15E-04	0.0031	-4.55E-04
	(0.0024)	(0.0027)	(0.0029)	(0.0045)	(0.0232)	(9.58E-04)	(0.0024)	(6.05E-04)
Dummy No R&D	0.0002	-0.0007	-0.0011	-0.0023	0.009	9.73E-04**	0.0015	-6.74E-06
	(0.0007)	(0.001)	(0.0008)	(0.0017)	(0.015)	(5.26E-04)	(0.0009)	(1.30E-04)
Country dummies	Yes		No		No		Yes	
Industry & Year dummies	Yes		Yes		Yes		Yes	
No of Observations	53,913		31,414		7,680		14,819	
No of Acquisitions	9,744		7,223		1,386		1,135	
Chi-squared	2,485.7		1,862.0		299.1		395.6	
Degrees of Freedom	86		68		68		82	
P-value	0.0		0.0		0.0		0.0	
Log Likelihood	-17,840.2		-12,484.9		-2,520.2		-2,585.0	
Pseudo R-squared	0.18		0.16		0.17		0.22	

(1) refers to the probability of acquiring non-public targets only, (2) refers to the probability of acquiring at least one public target. “Other” regression includes firms from Australia, Canada, France, Italy, Japan, the Netherlands, Sweden, and Switzerland. The base industry is SIC 283 and the base year is 2002. In the first two columns the base country is the US, and in the last two columns it is Canada. See notes to Table 2, Panel A.

Table 3, Panel B. Financial variables, R&D-intensity and patent-related variables

	All		US		UK		Other	
Regressor	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Constant	-0.3278*	-0.1020*	-0.3794*	-0.1340*	-0.6957*	-2.70E-07	-0.0795*	-1.89E-05*
	(0.0259)	(0.009)	(0.0318)	(0.0114)	(0.2809)	(2.43E-07)	(0.0162)	(7.49E-06)
Total Assets (ln)	0.0207*	0.0059*	0.0238*	0.0077*	0.0463*	1.71E-08	0.0052*	1.01E-06*
	(0.0017)	(0.0005)	(0.0021)	(0.0007)	(0.0185)	(1.76E-08)	(0.0012)	(4.04E-07)
Total Assets Growth	0.0043*	0.0010*	0.0048*	0.0013*	0.0186*	4.49E-09	0.0004	7.46E-08
	(0.0013)	(0.0003)	(0.0016)	(0.0005)	(0.0085)	(8.53E-09)	(0.0014)	(2.86E-07)
Op. Return	0.1033*	0.0216*	0.1335*	0.0299*	0.0954	-3.67E-08	0.0086	2.12E-06
	(0.0156)	(0.005)	(0.0196)	(0.0066)	(0.2184)	(1.69E-07)	(0.0111)	(3.78E-06)
Dummy Op. Return Negative	0.0114	0.0021	0.0079	0.0027	-3.4909*	-1.57E-06*	0.0074	-6.40E-05*
	(0.0118)	(0.0052)	(0.0149)	(0.007)	(0.641)	(6.18E-07)	(0.0096)	(2.11E-05)
R&D-intensity	-0.0882*	-0.0007	-0.1178*	-0.0004	-0.2572	-3.14E-08	0.0278	4.66E-06
	(0.0284)	(0.0069)	(0.0365)	(0.0093)	(0.5153)	(3.26E-07)	(0.0214)	(8.16E-06)
Dummy No R&D	-0.0015	-0.0033	-0.0050	-0.0040			0.0025	-1.65E-06
	(0.0083)	(0.0024)	(0.0104)	(0.0033)			(0.0068)	(1.53E-06)
Citation-wtd Patent Stock (ln)	0.0021*	0.0002	0.0017**	0.0003	0.0003	-5.25E-09	0.0019*	3.71E-08
	(0.0007)	(0.0002)	(0.0009)	(0.0003)	(0.0058)	(7.30E-09)	(0.0004)	(1.20E-07)
Citation-wtd Patent-intensity	-0.0386*	-0.0021	-0.0466*	-0.0033	0.2957	-1.26E-06	-0.0074	1.11E-06
	(0.0161)	(0.0063)	(0.02)	(0.0088)	(0.5618)	(1.99E-06)	(0.0092)	(1.47E-06)
Dummy Zero Cit.-wtd Patent-intensity	-0.0159*	-0.0019	-0.0194*	-0.0012	-0.0511	-1.29E-07*	0.0000	-1.48E-06
	(0.0052)	(0.0017)	(0.0069)	(0.0024)	(0.0465)	(4.68E-08)	(0.003)	(9.27E-07)
Country dummies	Yes		No		No		Yes	
Industry & Year dummies	Yes		Yes		Yes		Yes	
No of Observations	20,940		15,766		687		4,487	
No of Acquisitions	5,065		4,384		300		381	
Chi-squared	1,462.8		1,191.8		1,400.0		1,001.2	
Degrees of Freedom	80		62		55		76	
P-value	0.0		0.0		0.0		0.0	
Log Likelihood	-8,546.5		-7,279.0		-331.4		-817.0	
Pseudo R-squared	0.18		0.15		0.24		0.27	

(1) refers to the probability of acquiring non-public targets only, (2) refers to the probability of acquiring at least one public target. "Other" regression includes firms from Australia, Canada, France, Italy, Japan, the Netherlands, Sweden, and Switzerland. The base industry is SIC 283 and the base year is 1998. In the first two columns the base country is the US, and in the last two columns it is Canada. See notes to Table 2, Panel A.

Table 3 also reports the results from estimating the regressions after splitting firms into three geographical regions, the US, the UK and Other. As expected since more than four-fifths of firm-year observations involve US firms, the full sample results mainly reflect relationships that hold for US firms. In fact, the remarks made above apply with almost no exception to the US firms. Despite some differences, the financial profile of acquiring firms from the UK and "Other" countries in general accords with the above findings. However, the innovation-related characteristics of both groups of acquirers are not particularly different from those of non-acquiring firms. The only statistically significant coefficients are those of the stock of accumulated knowledge for acquiring firms from "Other" countries of non-public targets, and of the dummy for zero citation-weighted patent-intensity for UK firms acquiring public targets.[36]

We use a likelihood ratio test to test for coefficient equality for all the innovation-related variables between the two most heavily populated national groups of firms, namely the US and the UK. We find that the hypothesis of coefficient equality can be rejected only at a 10% level (p-value=0.07). The insignificant coefficients of the innovation-related variables for non-US firms do not necessarily have a zero effect on the acquisition probability, but their estimated values are likely to reflect relatively smaller sample sizes that produce statistically insignificant results. The results as a whole provide evidence to support the view that only US firms acquiring non-public targets have a distinctly different innovative profile from non-acquiring firms.[37]

Sensitivity checks

To check for the possibility that some kind of omitted variable bias has affected our results by estimating two complementary specifications, we estimate a specification for a sub-sample of 15,652 observations on 1,778 firms and 3,956 acquisitions by 835 acquiring firms where data on all financial, R&D and citation-weighted patent-related variables are available. The results presented in the first two columns of Table 4 are very similar to those presented in Table 3. The only differences are that for firms acquiring non-public targets we now find a significantly negative coefficient of liquidity at 10% significance level, and the coefficient of the dummy for zero citation-weighted patent-intensity becomes insignificant, although it is still negative. We also re-estimate the same specification but this time without normalizing R&D-intensity to zero when R&D expenditure is missing (the last two columns of Table 4). The results are similar to those obtained with the normalized R&D-intensity. Therefore, our results seem to be quite robust to variables omitted and to the R&D normalization adopted.

Table 4. Sensitivity checks: The probability of making acquisitions

	Multinomial logit regressions (marginal effects).		Multinomial logit regressions (marginal effects).	
	All independent variables		Observations with R&D data	
Regressor	(1)	(2)	(1)	(2)
Constant	-0.3578*	-0.1121*	-0.3558*	-0.1150*
	(0.0342)	(0.0107)	(0.0346)	(0.0111)
Total Assets (ln)	0.0221*	0.0063*	0.0216*	0.0066*
	(0.0022)	(0.0006)	(0.0022)	(0.0007)
Total Assets Growth	0.0041*	0.0009**	0.0033**	0.0004
	(0.0018)	(0.0005)	(0.0018)	(0.0005)
Op. Return	0.0762*	0.0166*	0.0704*	0.0148*
	(0.0192)	(0.0061)	(0.0195)	(0.0061)
Dummy Op. Return Negative	0.0189	0.0049	0.0183	0.0054
	(0.0139)	(0.0056)	(0.0143)	(0.0056)
Tobin's q (ln)	0.0131*	0.0041*	0.0133*	0.0046*
	(0.005)	(0.0015)	(0.005)	(0.0015)
Leverage	-0.0005	-0.0002	-0.0008	-0.0004
	(0.001)	(0.0004)	(0.001)	(0.0004)
Liquidity	-0.0012**	0.0001	-0.0009	0.0001
	(0.0007)	(0.0002)	(0.0007)	(0.0002)
R&D-intensity	-0.1170*	-0.0014	-0.1146*	-0.0009
	(0.0379)	(0.0081)	(0.0381)	(0.0079)
Dummy No R&D	0.0063	-0.0016		
	(0.0096)	(0.0029)		
Citation-wtd Patent Stock (ln)	0.0024*	0.0002	0.0026*	0.0001
	(0.0008)	(0.0002)	(0.0009)	(0.0002)
Citation-wtd Patent-intensity	-0.0510*	-0.0057	-0.0512*	-0.0039
	(0.0209)	(0.0086)	(0.0209)	(0.0077)
Dummy Zero Cit.-wtd Patent-intensity	-0.0103	-0.0016	-0.0082	-0.0014
	(0.0064)	(0.002)	(0.0067)	(0.002)
Country, Industry & Year dummies	Yes		Yes	
No of Observations	15,652		14,391	
No of Acquisitions	3,956		3,616	
Wald test				
Chi-squared	1,279.7		1,147.9	
Degrees of Freedom	86		84	
P-value	0.0		0.0	
Log Likelihood	-6,508.4		-5,895.4	
Pseudo R-squared	0.18		0.19	

(1) refers to the probability of acquiring non-public targets only, (2) refers to the probability of acquiring at least one public target. The base country is the US, the base industry is SIC 283 and the base year is 1998. See notes to Table 2, Panel A.

Finally, we investigate the possibility that the results are solely caused by an inability to empirically control for the underlying size effect, even after its inclusion in the set of regressors. It could be the case that the negative coefficients of R&D-intensity and patent-intensity are actually due to the presence of firm size in the denominator of the ratios, given that size and acquisition probability are positively related. For this purpose, we form ten size deciles so that the sizes of all firms in a decile are comparable and we re-run the multinomial logit regressions within each decile (Table 5).[38]

Although some result sensitivity emerges across size deciles, the sign pattern of the coefficients and their statistical significance are in accordance with our previous results. As far as the probability of acquiring non-public targets only is concerned, the coefficient of R&D-intensity continues to be significantly negative in three of the nine deciles and has the "correct" sign in 7 out of 9 deciles, whilst the coefficient of the citation-weighted patent-intensity continues to be significantly negative in two deciles and has the "correct" sign in 8 out of 9 deciles[39]. On the contrary, we find no comparable evidence for the corresponding coefficients when the effect on the probability of acquiring at least one public target is considered, which should be the case if the negative coefficients were merely caused by the higher likelihood of larger firms to act as acquirers. The results also provide some support for the finding that the firms acquiring non-public targets are likely to have a large stock of accumulated citation-weighted patents, while the results are inconclusive for the firms acquiring public targets.

Table 5. Sensitivity checks: Multinomial logit regressions (marginal effects) within deciles formed on firm size

Regressor	2	3	4	5	6	7	8	9	10
The probability of acquiring non-public targets only									
Constant	-7.2E-05	-1.9E-02*	6.4E-02	-1.9E-02*	-3.8E-05	-5.9E-02	-5.1E-01*	-9.6E-02	-1.1E+00*
Total Assets (ln)	-2.9E-05	1.6E-03**	-7.7E-03	1.4E-03*	2.4E-06	4.5E-03	3.6E-02*	5.0E-03	6.4E-02*
Total Assets Growth	7.5E-06	5.0E-05	9.5E-05	1.7E-04**	4.4E-06*	-4.9E-04	7.3E-04	-8.3E-03	2.9E-02
Op. Return	2.7E-04*	3.4E-03*	1.8E-02*	3.5E-03*	2.3E-05*	7.8E-03	5.3E-02	7.2E-02*	2.8E-01
Dummy Op. Return Negative	-1.5E-05	-2.4E-03**	5.0E-03	-2.2E-03			4.9E-02**		
Citation-wtd Patent Stock (ln)	1.5E-06	-1.8E-05	-4.9E-06	3.3E-05	2.3E-07	1.9E-04	1.9E-03	2.5E-03**	7.3E-03**
R&D-intensity	7.2E-06	-2.7E-03	-1.3E-02	2.3E-03	-6.9E-05*	-4.3E-02*	-8.9E-02	-1.4E-01**	-3.1E-01
Dummy No R&D	-1.1E-04	-2.5E-04	-5.3E-03	-5.1E-04	4.2E-06	-2.0E-03	3.2E-03	-6.7E-03	-4.8E-02
Cit.-wtd Patent-intensity	-2.4E-06	-1.2E-03	-4.3E-03	-4.2E-03*	-8.9E-06	-2.9E-02	-1.3E-01**	-7.0E-02	5.7E-01
Dummy Zero Cit.-wtd Pat-intensity	-4.1E-05	-4.4E-04	-1.5E-03	-4.7E-04	-4.3E-06**	-4.1E-04	-3.7E-03	-2.3E-02*	-5.3E-02
The probability of acquiring at least one public target									
Constant	2.1E-09	-1.8E-08	-1.3E-08	-7.9E-12	-4.0E-06	-6.7E-11	-4.7E-05	-5.8E-02	-4.2E-01
Total Assets (ln)	-3.1E-10*	1.2E-09	-4.7E-10	-5.7E-13	1.2E-07	4.3E-12	2.7E-06	2.8E-03	2.2E-02*
Total Assets Growth	-1.2E-10**	2.5E-11	1.3E-10	-2.7E-13	2.1E-07**	1.9E-13	2.6E-06*	5.1E-03*	2.5E-02
Op. Return	4.6E-10**	3.5E-09*	6.3E-09	1.8E-11*	1.1E-06	8.4E-12	1.1E-05**	2.0E-02*	1.6E-01*
Dummy Op. Return Negative	-3.8E-10	5.9E-10	1.7E-10	6.9E-12			-1.5E-04*		
Citation-wtd Patent Stock (ln)	2.1E-11*	-1.7E-11	-8.5E-10*	7.3E-14	7.1E-08**	-2.0E-13	9.3E-08	4.1E-04	2.2E-03
R&D-intensity	4.3E-11	1.0E-09	-6.4E-09	-3.2E-12	-4.2E-06	-9.7E-12	1.4E-05	7.9E-03	7.8E-03
Dummy No R&D	-2.6E-11	3.7E-10	-2.3E-07*	1.8E-12	-8.1E-07**	2.0E-13	3.3E-06	2.5E-04	-3.8E-02**
Cit.-wtd Patent-intensity	2.4E-10	9.6E-10	-9.6E-09	9.7E-12**	-3.2E-06	-4.2E-11	-1.6E-05	4.3E-03	9.0E-02
Dummy Zero Cit.-wtd Pat-intensity	3.5E-10	-1.6E-10	-4.4E-09	-8.1E-13	5.6E-08	-3.1E-12	-1.9E-06	6.3E-04	-1.7E-02
Country, Industry & Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	2094	2094	2094	2094	2094	2094	2141	2088	2053
No of Acquisitions	163	237	341	414	469	455	566	818	1525
Pseudo R2	0.14	0.12	0.12	0.13	0.19	0.22	0.25	0.20	0.17

The base industry is SIC 283, the base year is 1998 and the base country is the US. See notes to Table 2, Panel A. The ten deciles are formed on the basis of firm size (Total Assets). Firm size is increasing in successive deciles. The regression coefficients for firm-year observations in the first decile could not be estimated because the covariance matrix is not positive definite. See notes to Table 2, Panel A.

DISCUSSION

Let us summarize the main results from the analysis. Acquiring firms, in general, tend to be relatively larger, more dynamic and somewhat more profitable firms and they tend to have better growth prospects compared with non-acquiring firms. Although our initial analysis suggested that acquiring firms as a whole also tend to have a significantly different innovative profile from that of non-acquiring firms, it turned out when we split the sample accordingly that it is only the firms acquiring non-public targets (mainly private firms and subsidiaries) that do so. In particular, firms acquiring non-public targets have a significantly larger stock of citation-weighted patents, a lower R&D-intensity and, although they are more likely to have some R&D output, they tend to have a relatively lower citation-weighted patent-intensity. Accounting for firm size and R&D-intensity, we interpret this finding as an indication of some type of low R&D productivity of acquiring firms before they acquire non-public targets. These results hold mainly for US acquiring firms, which, however, account for the vast proportion of sample acquiring firms.

We conjecture that the inability to identify firms acquiring public targets on the basis of their innovation-related characteristics is due to the greater complexity of factors affecting large acquisitions which include multiple attempts, such as to rationalize costs and increase market power, which are not primarily relevant in relation to the much more numerous acquisitions of non-public targets.

The findings about the specific innovation-related characteristics of firms acquiring private targets and former subsidiaries have various implications for the hypotheses about the rationale of acquisitions set out in our theoretical section. The finding that the likelihood of becoming an acquirer is higher the lower the R&D output as proxied by the citation-weighted patent-intensity, after controlling for R&D-intensity, is in accordance with Hypothesis 1. We interpret this as suggesting that there exists an enhanced desire to acquire new technology and innovation-related assets driven by declining returns from the exploitation of the firms' existing knowledge base. This finding is along the same line as the conceptual argument supported by Vermeulen and Barkema (2001), Capron and Mitchell (1998) and others that acquisitions can be employed as a means of revitalizing a firm and enhancing its knowledge base.

We find supportive evidence for Hypothesis 2 which claims that, in accordance with the make-or-buy theory, internal R&D is an alternative to external acquisition of technology by takeover. Indeed, firms acquiring non-public targets tend to have significantly lower R&D-intensity, and this result was robust to alternative specifications and samples employed. Our finding that the make-or-buy theory seems to hold for US firms acquiring non-public targets is seemingly in agreement with Blonigen and Taylor (2000) who employ a sample of 531 acquisitions by US electronic and electrical equipment firms during the period 1985-93. However, the results from our analysis suggest that this hypothesis does not hold for acquirers of public targets. Therefore, we believe that Blonigen and Taylor's analysis[40] is likely to be subject to some sort of aggregation bias by not discriminating between acquisitions of public and non-public targets. As far as the "normal" R&D-intensity found for acquirers of public targets is concerned, it contradicts Hall's (1999) finding, based on a sample of 861 US manufacturing acquisitions from 1976 to 1995, that acquirers tend to have a low R&D-intensity. We suspect that the reason for this difference is that her sample extends across all the manufacturing industries, including the non-high-tech ones.

We also find evidence in favor of Hypothesis 3 that, controlling for current R&D, acquiring firms will tend to have a relatively large stock of accumulated knowledge generated by past R&D efforts. Therefore, the evidence seems to be in agreement with the theoretical argument that a large stock of accumulated knowledge is essential if the acquirer is to have the necessary absorptive capacity to identify the appropriate target and to fully exploit its innovative potential (Cohen and Levinthal, 1989; Chesbrough, 2003).

In effect we argue that smaller acquisitions are part of an innovation strategy for firms with relatively low levels of internal R&D which seek to offset low productivity in exploiting past R&D efforts by exploring a range of potential future innovation trajectories in new and smaller business units. Interestingly, these findings are broadly consistent with some of the findings of a number of empirical studies on the relationship between firm size and innovative activity.[41] Despite differences in measurement and methodology and disagreements in explanation, the very largest firms are often argued to have a lower R&D-intensity and R&D productivity than that of their large but somewhat smaller rivals, while the research conducted in most large industrial laboratories is found to generate predominantly minor improvement inventions rather than major new inventions.

Finally, the fact that only the acquirers of non-public targets that are incorporated in the US exhibit these distinctive innovative characteristics (particularly the low R&D-intensity) is interesting but hard to explain within the framework of this study. We suggest the possibility that the relatively large and long-established firms in the US have access to a relatively more developed market of high-tech start-ups and spin-offs which supplements other forms of technology markets and that they tend to adjust their R&D strategy accordingly. This view is in accordance with Williamson's (1975) systems approach to the innovation process, and of more recent explanations of "open innovation" strategies suggested by Chesbroough (2003) or the mechanism of trading technology through the trading of small firms described by Granstrand and Sjolander (1990) and others.

Although this study, focusing on the acquirers' side, provides support to the view that acquisitions are employed as an alternative to internal R&D activity in certain occasions, it also calls for further work on the supply side of the acquisition phenomenon. Uncovering the innovative characteristics of the firms acquired will enable a more comprehensive understanding of the role that acquisitions play in high technology firms' innovative strategy.

CONCLUSIONS

In this paper we investigate the incidence of high technology acquisitions using a unique dataset covering a maximum of 9,744 acquisitions of mainly public and private targets and former subsidiaries by high technology public firms in all the major industrial economies during the period from 1984 to 2001. Controlling for a full range of financial variables linked to the propensity to acquire, we develop alternative theories of the determinants of becoming an acquirer focusing in particular upon the impact of R&D-intensity as a proxy for R&D inputs, the citation-weighted patent-intensity as a proxy for R&D output and the stock of citation-weighted patents as a proxy for the accumulated stock of knowledge generated by past R&D efforts.

Our analysis shows that only the firms acquiring relatively small private targets and former subsidiaries (cf. acquirers of public targets) have a significantly different innovative profile compared with non-acquiring firms. The following conclusions can be drawn with respect to this type of acquisitions. First, we find support for the view that the propensity to acquire new knowledge-related assets through acquisitions is driven by declining returns from the on-going exploitation of a firm's existing knowledge base. Second, we find strong evidence in favor of the make-or-buy theory that acquisitions are employed by high technology firms as a means of sourcing knowledge externally as a substitute to in-house R&D activity. Third, our results are in accordance with the theoretical argument that a large stock of accumulated knowledge is essential if the acquirer is to have the necessary absorptive capacity to identify the appropriate target and to fully exploit its innovative potential.

These results suggest that smaller acquisitions can be seen as part of an innovation strategy for firms with relatively low levels of internal R&D which seek to offset low productivity in exploiting past R&D efforts by exploring a range of potential future innovation trajectories in new and smaller business units.

NOTES

[1] High technology industries are identified according to the classification suggested by Hall (1994), Chandler (1994) and Hall and Vopel (1996) on the basis of the industries' research-intensity and an informal assessment of those that are likely to have long horizons for project development and those that can move faster. Therefore, the high technology industries include Electronic Instruments & Communication Equipment, Biopharmaceuticals, Electrical Machinery, Computers & Computer Equipment, Transportation Equipment, Optical, Medical & Measuring Instruments.

[2] Strictly speaking, patents reflect inventions, i.e. "an idea, a sketch or a model for a new improved device, product, process, or system" rather than innovations, where an innovation "is accomplished only with the first commercial transaction involving the new product, process, system or device" (Freeman, 1982). However, because patents are found to be correlated with innovations (Comanor and Scherer, 1969; Griliches, 1990), they can be used as proxies for innovative activity.

[3] The 9,744 acquisitions involve 1,398 (14.3%) publicly traded firms, 4,850 (49.8%) privately held firms, 3,363 (34.5%) former subsidiary units, and 133 (1.4%) units that are reported by Thomson Financial's SDC either as joint ventures or their public status is unknown.

[4] Values are reported in 1996 constant prices using the US GDP deflator.

[5] This is to avoid the inclusion of large conglomerate companies which are primarily active in non-high-tech industries with just a tiny proportion of their sales in a high-tech industry.

[6] These eight 2-digit SIC codes are the ones defined by Hall and Vopel (1996) as high-tech industries with the addition of SIC 73 and 87. SIC 73 is added to the set of high-tech SICs because many of the firms active in 357 *Computer And Office Equipment* are often classified as software companies with primary activity in SIC 737 *Computer Programming& Data Processing*. SIC 87 is added to the set of high-tech SICs, as a large number of the companies selected based on Hall and Vopel classification had their primary activity in SIC 873 *Research, Development, And Testing Services*. Notice that "purely" software

firms are excluded from the sample in the first instance, because intellectual property rights tend to be relatively more frequently secured by copyrights rather than by patents.

[7] German acquiring firms were initially included in the sample but they were eventually dropped because of lack of data (in particular, R&D expenditures were missing for the population of German firms).

[8] With 1,947 of these deals involving public targets, while the majority of them involves private firms and subsidiary units.

[9] The citations series is subject to some truncation bias, i.e. patents applied for closer to the right-end of our dataset will have a smaller "opportunity" to be cited in subsequent patents. To control for this source of bias, citations are normalised using the "fixed-effects" approach described in Hall et al. (2001).

[10] Our study is not the first one to employ US patent data for both US and non-US firms (See Bloom and Van Reenen, 2001; Geroski, Van Reenen and Samiei, 1996). Our analysis controls for the possibility of some "home advantage" bias, since US firms will tend to have a higher propensity to patent in their home-country patent office compared to non-US firms (the latter might tend to register relatively more important inventions to the USPTO).

[11] These variables include total assets, total asset growth, operating return, Tobin's q, leverage and liquidity.

[12] The main problems are heteroscedastic residuals and predicted probabilities often exceeding unity.

[13] Among others, Palepu (1986), Hall (1988, 1999), Powell (1997) employ a logit model, while Blonigen and Taylor (2000) employ a negative binomial maximum likelihood model.

[14] The independence assumption of acquisitions is often questioned by the argument that they tend to be clustered by time, country and industry (Andrade and Stafford, 2000). In that case, the estimated parameters are still consistent but their standard errors are incorrect (Poirier and Ruud, 1988). We adopt a remedy which is similar to that suggested by Beck et al. (1997), by adding to the set of regressors time, country and industry dummies to account for the possibility of time and cross-sectional interdependence.

[15] Some studies calculate R&D-intensity as the ratio of R&D-expenditure to sales. Since we proxy firm size by total assets, we use the same variable in the denominator of the ratio for consistency reasons.

[16] We choose to proxy for the stock of accumulated knowledge using the stock of (citation-weighted) patents rather than of R&D expenditure, because the

patent series do not suffer from the time discontinuities present in the R&D expenditure series.

[17] This approximation has the advantage over the alternative measures that we considered (e.g. Bosworth et al., 2000; Hall, 2000; Blundell et al., 1992) that it is easy to calculate and it has better sample coverage than the alternatives. It has shortcomings (Andrade and Stafford (2000)). It assumes that the replacement cost of assets and liabilities is well proxied by their book value, it assumes that the average and the marginal q are the same, and it ignores tax effects. The conceptually correct measure comparing replacement costs to market values requires data which is frequently missing in financial datasets, and considerable imputation, which made it impractical in this study spanning many countries. For a recent discussion of alternative 'q' estimators see Lee (1999).

[18] Recall that total assets, Tobin's q and the stocks of (citation-weighted) patents are transformed using the natural logarithm. The discussion that follows refers to the transformed variables.

[19] It is possible that Tobin's q will tend to be correlated with left out intangibles including R&D, so that firms with more R&D or patents will have higher q. Given measurement error this implies a downward bias in estimating the coefficient on R&D intensity and patent intensity. Estimating our second model serves a test for this possible impact by excluding 'q'. We find little evidence in the results below that this downward bias is present.

[20] We are aware, however, that even lagging regressors in a panel dataset does not necessarily control for all sources of endogeneity (Wooldridge, 1997). Notice that this adjustment implies that comparisons between firms active in acquisitions with those not active are drawn with respect to the last pre-merger year. Similar methods have been widely used in the literature (Blonigen and Taylor, 2000; Hall, 1999).

[21] Industry groups are defined at the 2-digit SIC level, with the exception of firms in SIC 283 which are distinguished from those in SIC 28 (excluding 283), since they are likely to have distinct characteristics, such as a significantly higher R&D-intensity.

[22] We actually find, based on likelihood ratio tests, that such adjustments improve the fit of the models.

[23] We assume that R&D-intensity is immaterial whenever R&D-expenditure is not reported but data on most of the economic variables are available. In the analysis that follows, we check for the robustness of our findings to this normalisation.

[24] Notice that the patent-based regressions include only firms which have been linked to USPTO patent assignees, which may not, however, produce any patentable invention in some or all the years.

[25] The likelihood ratio test tests that the proportion of the total variance contributed by the panel-level variance component equals zero and hence that the panel estimator is not different from the pooled estimator.

[26] Statistical significance in the subsequent analysis will be assessed at the 5% or 10% level.

[27] Yet, again the pooled and the random-effects logit models predict similar relationships.

[28] This dummy is equal to unity for about a third of the acquirers.

[29] Only in the simple logit model the coefficient of R&D-intensity remains negative and significant.

[30] The effects of the last two years (2001-2) are biased from the fact that our acquisition data include (successfully completed) deals announced until June 2001.

[31] We do not put much weight on the marginal effects of the industrial activity for firms primarily active in SIC 28 (excluding 283), 73 and 87, as the estimated effects are likely to reflect the selection criteria for acquiring firms described in the third Section.

[32] These include mainly privately held firms and subsidiaries, as well as some former joint ventures and some firms of which the public status is unknown. We have adopted this dichotomous classification of acquisitions into those involving public and non-public targets, since this classification captures a significant difference: the median acquisition of a public target has almost ten times the value of the median acquisition of a non-public target ($133.1 million versus $13.6 million).

[33] This group also includes firm-year observations where, apart from acquisitions of public firms, possibly non-public targets are acquired. We assume that acquisitions of public targets are likely to dominate in significance acquisitions of non-public firms, in the same logic explained in footnote 32. We also discriminated between observations in which the acquiring firm acquires public targets only and both public and non-public targets, but we found that these two groups of acquiring firms have similar characteristics.

[34] In Panel A (B) there are 1,221 (567) observations where firms acquire at least one public target, and 4,703 (2,592) observations where firms acquire non-public targets only.

[35] For acquirers of public targets, we get an insignificantly positive coefficient of operating return in Panel A, but a significantly positive one in Panel B.

[36] The statistically significant dummy for missing R&D in the UK regression for the probability of acquiring public targets in Panel A, which equals unity for only 1% of UK acquiring firms, becomes insignificant in Panel B.

[37] Possible explanations behind the difference between US and non-US acquiring firms are discussed in the discussion section.

[38] Results are reported for all, but the smallest size decile for which the regression coefficients could not be estimated because the covariance matrix is not positive definite. The loss in information content is small since firms in that decile make only 77 of the 5,065 acquisitions.

[39] If there was no relation between the variables we might expect an equally number of positive and negative coefficients across deciles. A binomial probability test reveals that we can reject the hypothesis of no relation at the 5% level when 8 out of 9 signs are the same.

[40] Their sample includes acquisitions which are part of our sample, and we find that our results continue to hold for the subsample of US firms active in electronic and electrical equipment.

[41] For a review see Williamson (1975), Cohen and Levin (1989), Symeonidis (1996).

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APPENDIX

The logit model

Assume that the probability, P_{it}, for firm i to belong to a binary outcome y (y=0,1), here to make acquisitions in year t, can be written as a logit function of some vector of various firm characteristics included in matrix X, with i=1,…,N, and t=1,…,T. Then, the probability is given by the following cumulative distribution

$$\Pr ob(y_{it} = 1) = P_{it} = \frac{\exp(\underline{\beta' X_{it}} + v_i)}{1 + \exp(\underline{\beta' X_{it}} + v_i)}$$

where β is a vector of parameters to be estimated and v_i is a firm-specific residual constant across time. The maximum likelihood estimates are derived by maximizing the log-likelihood function with respect to the unknown parameters (See Wooldridge 2002, Chapter 15, p. 483). A positive sign on a parameter indicates that an increase in the corresponding variable increases the likelihood of a takeover, and vice versa.

The negative binomial maximum likelihood model

Let y_{it} be the number of acquisitions firm i makes during year t. We assume that y_{it} is distributed as Poisson(γ_{it}), which seems a natural first assumption for many counting problems in econometrics (See Hausman et al., 1984). The Poisson parameter γ_{it} follows a Gamma distribution with shape parameters (λ_{it},1/δ_i), where λ_{it} is parameterized as $\lambda_{it} = \exp(\underline{\beta' X_{it-1}})$ and δ_i is the dispersion parameter. For the random-effects estimator we assume that the dispersion is the same for all elements in the same firm (1+δ_i) but δ_i varies randomly from firm to firm, and that 1/(1+δ_i) is distributed as a Beta random variable with shape parameters (r,s), where r and s need to be estimated in addition to the vector of parameters β. The negative binomial model is given by

$$\Pr ob(Y_{it} = y_{it} \mid \delta_i) = \frac{\Gamma(\lambda_{it} + y_{it})}{\Gamma(y_{it} + 1)\Gamma(\lambda_{it})} \left(\frac{1}{1+\delta_i} \right)^{\lambda_{it}} \left(\frac{\delta_i}{1+\delta_i} \right)^{y_{it}}$$

Then, the joint probability for counts and the consequent log-likelihood function are derived, with the latter being estimated using standard maximum likelihood techniques (See Hausman et al., 1984).