THE REVEALED PREFERENCES OF HIGH TECHNOLOGY ACQUIRERS: AN ANALYSIS OF THE CHARACTERISTICS OF THEIR TARGETS

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Abstract
In this paper we investigate the motives of high-tech acquirers by analysing their revealed preferences in terms of the high-tech companies they acquire. Using a large sample of acquisitions involving publicly traded firms from various countries we ask whether high technology acquisitions are best understood in terms of acquirers seeking to source externally special innovation-related assets by acquiring firms with "superior" innovative performance; or acquirers seeking to acquire firms with "inferior" innovative performance in order to turn them around. We find evidence that acquisition is a very noisy phenomenon and that economic and innovation related variables explain only a modest part of the probability of becoming a target. We do however find that, compared to non-acquired firms, high-tech targets tend to be somewhat larger, to have poorer profitability, lower Tobin's q and liquidity. In relation to their innovative profile, targets, in general, seem to have a relatively larger stock of accumulated knowledge (stock of citation-weighted patents), relatively higher R&D inputs (R&D-intensity), but they are more likely to generate no R&D output (citation-weighted patent-intensity) before they are acquired. We conclude that high technology acquisitions reflect a process which is primarily driven by acquirers wishing to exploit the potential for turning around firms which, despite a good past record, appear to be innovatively and economically inefficient before they are acquired.

Keywords: G34, O30, L20

JEL Classification: Mergers and acquisitions, acquisition likelihood, R&D, patents

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INTRODUCTION

Preferences and motives driving actions are not frequently directly observable. Researchers can however attempt to elicit them from observing the behaviour of the organizations in which they are formed. In this paper we investigate the motives of high technology acquirers of public high technology targets by analysing their revealed preferences in terms of the companies they acquire. The majority of the existing empirical literature has concentrated on the financial characteristics of the acquired firms (Mueller, 1980; Palepu, 1986; Morck et al, 1988; Ambrose and Megginson, 1992; Powell, 1997; Dickerson et al., 1998). However, in a high technology context, where the innovative activity of firms is a crucial determinant of economic performance (Franko, 1989; Amendola et al., 1993; Geroski et al., 1993; Cosh et al., 1996), the role of the effort devoted to the R&D process and its output is of special interest when modelling the takeover likelihood.

Along these lines, two recent studies that examine the relationship between R&D and acquisition activity on the acquirer's side, stress the importance of work to uncover targets' innovative characteristics to fully understand their findings (Blonigen and Taylor, 2000; Dessyllas and Hughes, 2005). Blonigen and Taylor (2000), using a sample of 531 acquisitions by US electronic and electrical equipment firms during the period 1985-93, find that acquisitions are used as a substitute for in-house R&D activity. This result is verified by Dessyllas and Hughes (2005) for acquirers of private targets and subsidiaries but not for public targets in an international sample of a 9,744 public and private acquisitions during the period 1984-2001.[i] They argue that, although 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, there is little to be said on acquisitions of the normally larger public targets.

This study fills this void in the empirical literature by investigating the innovative characteristics of public targets in order to cast some light upon the *rationale* of high technology acquisitions involving public firms. The resources devoted by acquirers to purchases of public targets account for the vast proportion of all acquisition expenditures (e.g. Fuller et al., 2002). In particular, acquisitions involving public high technology firms operating in ten of the largest industrial economies accounted for over 74% of the $2.7 trillion of their total acquisition activity during the period 1984-2001.[ii]

Although we recognise that, in practice, the thousands of deals that take place may represent the aggregation of very different activities and hence the hypotheses about their rationale might not be mutually exclusive (Bower, 2001; Mueller, 2003), we ask whether these acquisitions are *best* understood in terms of two competing hypotheses. The first one is called "Searching for superiority", according to which acquirers will tend to acquire highly innovative firms. This hypothesis draws upon March's (1991) theoretical framework that distinguishes between explorative and exploitative learning. 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 hypothesis is called "Searching for inferiority", according to which acquirers will tend to acquire firms with relatively poor innovative performance. Their acquirers can take advantage from such acquisitions by turning around innovatively inefficient firms. This hypothesis originates from the traditional market for corporate control theory which states that competition in product and capital markets ensures that poor performers in economic or stock market terms will be eliminated from the market place (Singh, 1975, 1992). It is, however, taken forward from its standard form in the financial economics literature by being interpreted in a high technology context and pegged to specific target innovative characteristics.

Controlling for a rich set of financial variables that have been found to affect the takeover likelihood (e.g. Palepu, 1986; Ambrose and Megginson, 1992; Powell, 1997), the empirical analysis of target innovative characteristics accounts for both the inputs into the conduct of R&D and its output. It proxies R&D inputs by R&D expenditure per $million total assets (R&D-intensity), and R&D output by two patent-based measures. The first is the stock of accumulated knowledge that has been generated by past R&D which is proxied by the patent stock measured in both raw terms and citation weighted form. The second is patent-intensity proxied by the number of patents per $million of total assets – again in raw and weighted form.

Systematic evidence on the innovative characteristics of the acquired firms is scarce. To the best of our knowledge, the only study that provides a comprehensive analysis of target innovative characteristics, accounting for both the inputs (R&D expenditure) of the conduct of R&D and its output (patents) is for a sample of 116 takeovers of high-tech US public firms during the period 1977-1984 (Addanki, 1986). Addanki finds that firms that do R&D but have no patents are likely to be targets in takeovers. More generally, the probability of being acquired is negatively related to the number of patents. His results suggest that successful innovators are less likely to be acquired. The likelihood of being acquired is not affected by firm size (log of assets), but it is positively related to a negative shock in a firm's stock price.[iii]

Two additional relevant studies were carried out by Hall (1988, 1999). Although these studies do not account for R&D output measures, they provide evidence on the effect of R&D-intensity on the probability of being acquired. Hall (1988), using a sample of 568 manufacturing acquisitions in the US during the period 1976-1986, finds no significant difference between acquired and non-acquired firms in terms of size (assets) and R&D-intensity (stock of R&D over assets). Only firms acquired by private or foreign firms have a significantly lower R&D-intensity, but this is due rather to the fact that these targets tend to belong to non-high-tech industries (e.g. textiles), than to a trend having to do with the public status or origin of the acquirer. In her 1999 study, which is based on a sample of 861 manufacturing acquisitions in the US during the period 1976-1993, she finds that targets tend to be relatively smaller (employee number), and to have lower Tobin's q. Although no significant continuous relationship emerges between the probability of being acquired and R&D-intensity (R&D over sales), firms with a particularly high R&D-intensity (more than 50%) are less likely to be acquired. Acquired firms do not differ from non-acquired firms with respect to other variables employed, such as capital-labour ratio and cash flow ratio.

Our study takes the debate on the innovative characteristics of targets further by: (a) using more recent evidence – including acquisitions from the late 1990s – and including acquisitions that involve firms from both the US and other countries; (b) focusing on acquisitions involving high technology firms to ensure that innovation is an important element in corporate strategy and performance; (c) employing proxies for both the inputs of the conduct of R&D and its output.

The remainder of this paper is organized as follows. The next section develops the theoretical background and hypotheses of this study. This is followed by a section describing the data 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

Searching for superiority

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 competences and technologies. In a business environment, exploration without exploitation will prevent a firm from fully appropriating the returns that can be generated from the application of new knowledge aimed at improving or renewing processes, products or services. However, the on-going exploitation of the existing knowledge without exploration, after a point hampers the creation of new knowledge and eventually make the firm 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 competences and technologies is likely to trap a firm in sub-optimal equilibria (March, 1991).

Firms can extend their knowledge base by getting access to other firms' resources, particularly when they are not perfectly mobile or imitable (Das and Teng, 2000). Hence, 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 (Vermeulen and Barkema, 2001). The empirical evidence supports this role of acquisitions (Capron and Mitchell, 1998; Bresman et al., 1999; Vermeulen and Barkema, 2001). There is also a growing literature suggesting that firms should and do use various forms of corporate venturing to learn from knowledge sources beyond the boundaries of the firm (Schildt et al., 2003; Chesbrough, 2003).

Even in cases where the desired assets, resources or capabilities can be developed internally, acquisitions can be the preferred strategy representing a less risky and faster way of exploiting commercially viable knowledge assets (Chakrabarti et al., 1994; Francis and Smith, 1995). If successfully completed[iv], an acquisition can be seen as a less risky strategy, as some uncertainty inherent in the innovation process (Arrow, 1962) is resolved before the acquisition time. An acquisition-intensive strategy can then be understood in a real option framework (Dixit and Pindyck, 1994). The decision not to invest in risky R&D projects is the equivalent of getting the right to acquire the winning firm (innovator) after uncertainty has been resolved. Also, acquisitions have the advantage that acquired companies have track records that can be analysed to make financial projections for future costs and expected performance (Hitt et al., 1996). A takeover is a faster strategy when in-house R&D or some other stage along the value chain requires complementary assets that a firm does not possess (Teece, 1992, 1998). This is particularly true when there are no markets for such assets or when the target is further along the learning curve of a particular knowledge field. The time advantages of acquisitions are empirically verified by Danzon et al. (2004) who find evidence that acquisitions are employed by pharmaceutical firms as a quick reaction to an unexpected short-fall in their R&D pipe-line.

These arguments suggest that acquirers that wish to source external innovation-related assets will direct their acquisition activity toward firms with a "superior" innovative activity. Accordingly, we hypothesize that the targets in such acquisitions will be firms with a "superior" innovative record reflected in high R&D-intensity, high patent-intensity, and a high stock of accumulated R&D output generated by past R&D efforts.

Searching for inferiority

The searching for inferiority view of high technology acquisitions takes the opposite stance compared to the previous hypothesis. The key idea can be found in various streams of literature; firms with excess resources buy weaker firms and then use the acquirer's excess resources to improve the performance of the target (See Capron and Mitchell, 1998). We focus here on the theory of the market for corporate control which is one of the most frequently cited approaches in the financial and economic literature on acquisitions.

The market for corporate control theory states that competition in product and capital markets implies that poor performers in economic or stock market terms will be eliminated from the market place (Singh, 1975, 1992). In this sense, the market for corporate control is viewed as an arena in which managerial teams compete for the rights to manage corporate assets ensuring that assets are shifted to their most efficient uses or management (Jensen and Ruback, 1983; Jensen, 1986). Because of the high technology focus of this study, this theory is, however, extended from its standard form in the financial economics literature to account for the empirical evidence of the existence of a positive relationship between innovative activity and economic performance (Franko, 1989; Amendola et al., 1993; Geroski et al., 1993; Cosh et al., 1996). For this purpose, the performance assumptions expressed in economic terms are restated in innovation terms. Accordingly, this model would predict that firms with a poor record of innovative performance will tend to be acquired by efficient firms who wish to exploit the potential for turning the former around. Poor innovative performance may arise for a number of reasons, such as under-investment in R&D, failure to direct research to the appropriate area, ill-chosen research projects, inadequate or inappropriate human or physical capital, or management of projects. The consequences of poor innovativeness can be recorded as lack of cutting-edge products or relatively costly operations.

An auxiliary explanation that deserves some attention in elaborating on the acquirers' acquisition motives in the contest of the market for control is derived from internalisation theory (Morck and Yeung, 1992). According to this theory, certain assets, and particularly intangible assets such as technical knowledge, are better exploited by acquisition to "internalise" the activity inhibiting either firm contracting because of market failures as well as the potential for spreading fixed costs over a larger scale. Such firms will prefer an acquisition to greenfield expansion under the assumption that the stock market penalizes the firms (i.e. potential targets) whose innovative performance falls short from its potential.[v] The firms wishing to expand will compare the costs of acquiring the assets they need through *de novo* investment and the costs of acquiring these assets already in place (Hasbrouck, 1985). Then, inefficient targets will be viewed by their acquirers as "bargains" or "cheap buys" (Palepu, 1986; Powell, 1997).

Taken together, these arguments suggest that acquirers will be primarily motivated by the potential for turning around innovatively "inferior" firms. Therefore, we hypothesize that targets in such acquisitions will be firms with a poor innovative record reflected in some combination of a low R&D-intensity, low patent-intensity, and a low stock of accumulated R&D output generated by past R&D efforts.

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 deals in which the acquirer has some part of its sales in one of the high technology industries specified by Hall and Vopel (1996)[vi] and both the acquiring and the acquired firms have their primary activity 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.[vii] We focus on acquisitions involving publicly traded firms operating in one of the ten most merger-active industrialized countries[viii], namely Australia, Canada, France, Italy, Japan, the Netherlands, Sweden, Switzerland, the UK, and the US. The population of acquisition deals come from Thomson Financial's SDC Platinum, which reports 1,635 deals[ix] announced during the period from January 1984 to June 2001.

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[x] 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).[xi] 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 patent 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 a maximum of 6,425 firms, including both acquired and non-acquired firms.

The sample over which the financial characteristics and R&D-intensity of firms are examined includes 511 acquisitions after imposing the restriction that data are available on all the key financial variables.[xii] These deals account for approximately 31% of the volume and 40% of the value of the total acquisition activity included in the initial sample. The patent- and citation-weighted patent-based characteristics of firms can only be assessed on the basis of a sample including 448 and 328 acquisitions respectively. This is because, on the one hand, only a subset of the acquired firms 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 acquired firms over which the pre-acquisition firm characteristics are assessed introduces some bias towards larger firms. While the overall median size (ln total assets in $1996 thousands) of all acquired firms equals 11.18, the median size of the 511 targets with the required data equals 11.28. The bias is more serious for the sample of firms over which their patent-based characteristics are assessed, where the median size of the 448 targets 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 variables

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

Independent variables

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, 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.[xiii] R&D output is defined as the ratio of the number of successful patent applications to $million of total assets[xiv] 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[xv], which is calculated by the standard perpetual inventory formula assuming a 15% depreciation rate per annum (See Hall, 1990). The patent-intensity and the patent stock are also calculated using the number of normalized citations received by forward patents to account not only for the quantity (raw patent count) but also the quality of the patented inventions. The disadvantage of citation-weighted patent measures is that the citation data end in 1997.

Control variables

The set of firm characteristics that were considered to model the acquisition probability also included some additional financial variables, in accordance with earlier studies (Singh, 1975; Palepu, 1986; Hall, 1988, 1999; Powell, 1997). This is because some variables, such as firm size, are likely to influence both the innovative and acquisition activity of firms. The controls employed proxy for firm size, economic performance, and the availability of financial resources.

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). A recent relevant study employing a similar proxy is Powell (1997).

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) [xvi]. The interpretation of the effect of Tobin's q on the acquisition probability should be treated with care, since, apart from reflecting stock undervaluation (Morck et al., 1988), it is also likely to reflect managerial performance (Powell, 1997) or, having a forward looking numerator, a firm's growth opportunities (Gugler et al., 2004).

The financial status of firms is proxied by leverage and liquidity. 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. 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. We also accounted for the cash flow ratio as a proxy for the amount of funds available to a firm for operations and investment. However, it was eventually excluded from the models estimated to avoid possible multicollinearity bias, since it was found highly correlated (0.96) with operating return (See Table 1).

Model specification

We employ a logit model (See Greene, 1997, Chapter 19) to estimate the acquisition probability, since the takeover incidence in a given year takes strictly non-negative values and hence the classical linear model is inadequate.[xvii] Similar estimation methods have been used in previous empirical work (Palepu, 1986; Hall, 1988, 1999; Powell, 1997). Given the cross-section and time series nature of our dataset, we initially considered panel data estimation methods that have the advantage that they allow us to account for some unobserved heterogeneity across firms (Hsiao, 1986). However, we found that the null hypothesis that the panel-level variance component[xviii] is unimportant could not be rejected at the 5% significance level and the estimates from the random-effects[xix] estimator were identical to those from the simple logit model. Therefore only the simple logit model estimates are reported. Robust standard errors to within-firm serial correlation are calculated, 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.

Table 1 provides descriptive statistics and correlations for all the variables.[xx] It is interesting to notice that firm size and the stock of accumulated knowledge (patent stock in raw or weighted form) are not particularly correlated. 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 53,873 observations on 6,425 firms, 1983-2001

		Obs	Mean	Median	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Total Assets (ln)	53,873	11.637	11.550	2.240	5.114	17.529	**1.00**												
2	Total Assets Growth	53,873	0.359	0.055	1.488	-0.782	15.083	-0.04	**1.00**											
3	Operating Return	53,873	-0.021	0.085	0.488	-4.858	0.539	0.37	0.00	**1.00**										
4	Tobin's q (ln)	53,873	0.583	0.410	0.734	-0.853	3.779	-0.25	0.16	-0.31	**1.00**									
5	Cash Flow Ratio	53,668	-0.067	0.050	0.508	-5.211	0.387	0.36	0.01	**0.96**	-0.32	**1.00**								
6	Leverage	53,873	0.615	0.249	2.452	-14.957	22.605	0.14	-0.01	0.05	-0.10	0.05	**1.00**							
7	Liquidity	53,873	3.067	1.894	3.998	0.046	36.217	-0.18	0.26	-0.01	0.14	0.00	-0.09	**1.00**						
8	R&D-intensity (un-adjusted)	46,690	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	53,873	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)	18,749	0.379	1.487	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)	15,647	-0.112	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	18,749	0.027	0.000	0.097	0.000	1.298	-0.23	0.06	-0.22	0.23	-0.20	-0.05	0.12	0.28	0.28	0.13	0.15	**1.00**	
13	Cite-weighted Patent-intensity	15,647	0.040	0.000	0.174	0.000	2.237	-0.20	0.07	-0.19	0.22	-0.17	-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 public 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 being acquired 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 and patent-intensity in raw or citation-weighted form. 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 citation data end in 1997.

The econometric models are estimated over completed acquisitions during the period 1984-2002 that involve firms with the appropriate data. All covariates have been lagged by one year to avoid endogeneity problems. Country, industry and time dummy variables are included in the estimated specifications to account for the possibility of time or cross-sectional dependence of deals (Beck et al., 1997).[xxi] 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 (skewness, missing observations, non-linearity) of some of the variables some additional adjustments have been adopted.[xxii] First, 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. A similar adjustment is adopted by Hall (1999) to proxy for highly R&D-intensive growth firms in an early stage of their life cycle without many marketed products. Second, 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. That is, similar to Hall (1999), 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. Third, a dummy is employed for firms with zero (citation-weighted) patent-intensity, to distinguish between firms with some versus no R&D output.[xxiii] Finally, a dummy is employed for observations in which the logarithm of total assets exceeds the fourth percentile of all observations (13.17), as we suspect some non-linearity in the relationship between firm size and the (log) odds of a firm being acquired.[xxiv]

RESULTS

Panel A of Table 2 presents the results for the simple logit model estimated over 53,873 observations on 6,425 firms, including 511 acquisitions. Focusing on the regression over the full sample, despite a rather low McFadden R-squared (9.2%), the Wald test rejects the null hypothesis that the model as a whole does no better than simply using a constant term at a 5% significance level. The low R-squared is not a surprise, given the evidence from previous empirical work that the distinction between acquired and non-acquired firms is blurred in practice with major overlaps between the two groups (e.g. Hughes, 1993; Hall, 1999; Gugler et al., 2004).

Although the firm characteristics that are employed as regressors are found to be jointly significant by a likelihood ratio test, a large part of the explanatory power of the model seems to come from the year, country and industry dummies, which are also jointly significant. The results suggest that the (log) odds of a firm being a takeover target increases with firm size, but only up to a certain level, after which it decreases (due to the significantly negative dummy for very large size). Also, targets tend to have statistically significantly lower operating return, lower Tobin's q, and lower liquidity, as well as a significantly higher R&D-intensity.

Table 2. Regressions for estimating the probability of being acquired

Panel A. Financial variables and R&D-intensity

Regressor	All	US	Non-US
Constant	-9.541*	-9.457*	-21.457*
	(0.835)	(0.864)	(0.087)
Total Assets (ln)	0.202*	0.205*	0.227*
	(0.036)	(0.039)	(0.088)
Dummy High T. Assets	-0.723*	-0.749*	-0.808**
	(0.19)	(0.217)	(0.431)
Total Assets Growth	-0.059	-0.050	-0.035
	(0.045)	(0.046)	(0.133)
Op. Return	-0.552**	-0.435	-1.435**
	(0.326)	(0.343)	(0.848)
Dummy Op. Return Negative	-0.104	-0.150	0.391
	(0.236)	(0.253)	(0.599)
Tobin's q (ln)	-0.217*	-0.282*	0.021
	(0.079)	(0.093)	(0.13)
Leverage	-0.020	-0.016	-0.046
	(0.021)	(0.023)	(0.049)
Liquidity	-0.032*	-0.028**	-0.135*
	(0.014)	(0.015)	(0.05)
R&D-intensity	0.946*	1.111*	0.593
	(0.232)	(0.243)	(0.772)
Dummy No R&D	0.052	-0.046	0.873*
	(0.124)	(0.138)	(0.392)
Country dummies	Yes	No	Yes
Industry & Year dummies	Yes	Yes	Yes
No of Observations	53,873	31,381	22,080
No of Acquisitions	511	407	104
Wald Test	308.55	245.04	212.59
Degrees of Freedom	45	36	43
P-value	0	0	0
Log Likelihood	-2,623.9	-2,018.7	-539.3
Pseudo R-squared	0.09	0.07	0.18

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

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

	Patents			Citation-weighted Patents		
Regressor	All	US	Non-US	All	US	Non-US
Constant	-5.444*	-5.606*	-4.352	-5.698*	-5.917*	0.077
	(0.568)	(0.584)	(3.138)	(0.646)	(0.659)	(3.925)
Total Assets (ln)	0.151*	0.163*	-0.040	0.187*	0.199*	-0.182
	(0.04)	(0.041)	(0.241)	(0.046)	(0.046)	(0.315)
Dummy High T. Assets	-0.613*	-0.642*	-0.132	-0.807*	-0.827*	-0.277
	(0.204)	(0.21)	(1.076)	(0.245)	(0.252)	(1.132)
Total Assets Growth	-0.097	-0.094	-0.335	-0.055	-0.054	-0.376
	(0.074)	(0.073)	(0.526)	(0.068)	(0.068)	(0.782)
Op. Return	-0.118	-0.174	1.815	-0.234	-0.183	-3.540
	(0.33)	(0.333)	(2.28)	(0.393)	(0.397)	(4.506)
Dummy Op. Return Negative	-0.188	-0.212	-0.018	-0.142	-0.119	0.000
	(0.242)	(0.249)	(1.311)	(0.289)	(0.291)	(0)
R&D-intensity	0.491**	0.536*	1.082	0.631*	0.652*	-3.055
	(0.254)	(0.255)	(1.99)	(0.301)	(0.3)	(7.911)
Dummy No R&D	-0.102	-0.127	1.436	-0.054	-0.090	2.470**
	(0.176)	(0.181)	(1.057)	(0.205)	(0.209)	(1.4)
Patent Stock (ln)	0.042*	0.036*	0.187**			
	(0.016)	(0.016)	(0.104)			
Patent-intensity	-0.195	-0.200	0.356			
	(0.477)	(0.493)	(1.407)			
Dummy Zero Patent-intensity	0.227	0.207	0.933			
	(0.146)	(0.151)	(0.628)			
Citation-wtd Patent Stock (ln)				0.036*	0.034*	0.109
				(0.016)	(0.016)	(0.093)
Citation-wtd Patent-intensity				0.053	0.099	-0.875
				(0.305)	(0.301)	(2.465)
Dummy Zero Cit.-wtd Patent-intensity				0.326**	0.365*	-0.519
				(0.172)	(0.175)	(0.829)
Country dummies	Yes	No	Yes	Yes	No	Yes
Industry & Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
No of Observations	23,977	18,265	3,280	20,576	15,761	2,396
No of acquisitions	448	428	20	328	316	12
Wald Test	201.1	166.4	91.8	113.9	90.0	246.1
Degrees of Freedom	37	34	27	35	32	22
P-value	0.0	0.0	0.0	0.0	0.0	0.0
Log Likelihood	-2,043.2	-1,942.0	-87.0	-1,566.2	-1,497.9	-55.9
Pseudo R-squared	0.08	0.04	0.29	0.07	0.03	0.26

The regressions include firms from Canada, Japan, the UK and the US. In the patent-based regressions the base industry is SIC 283 and the base year is 2000. In the citation-weighted patent regressions the base industry is SIC 283 and the base year is1998. In the first and fourth columns the base country is the US, and in the third and sixth columns it is the UK. See notes to Table 2, Panel A.

Panel B of Table 2 shows the results for the patent-based and the citation-weighted patent-based specifications estimated over 23,977 and 20,576 observations including 448 and 328 acquisitions respectively. The fall in the sample size implies that only observations on firms from the US, the UK, Canada and Japan survive. Focusing on the regressions for the full sample, despite the small values of the McFadden R-squared for both specifications (8.2% and 6.9%), the likelihood ratio test rejects the null hypothesis that the coefficients are jointly zero. Controlling for firm size, growth and operating performance, the significantly positive relationship between R&D-intensity and the acquisition probability is verified, while we also find a significantly positive relationship between the size of the (citation-weighted) patent stock and the acquisition probability. Although a negative relationship between patent-intensity and the acquisition probability is implied by the negative coefficient of patent-intensity and the positive coefficient of the dummy for zero patent-intensity, both coefficients are statistically insignificant. In the regression with citation-weighted patents, however, the positive coefficient of the dummy for zero citation-weighted patent-intensity becomes statistically significant, suggesting that targets are indeed more likely to have a zero citation-weighted patent-intensity.[xxv]

We conclude that the (log) odds of a firm being acquired is positively but non-linearly related to firm size, and negatively related to profitability, Tobin's q and liquidity. In relation to targets' innovative profile, targets are more likely to have a high R&D-intensity, a large stock of accumulated knowledge, but no R&D output (zero citation-weighted patent-intensity) before they are acquired.

Table 2 also reports the results of estimating the regressions separately for US and non-US firms.[xxvi] Not surprisingly, since US targets account for almost 80% of all targets, US targets appear to have all the financial characteristics mentioned above. The only exception is that although the coefficient of operating return in Panel A remains negative it is no longer significant. They also tend to have a significantly higher R&D-intensity, a larger stock of (citation-weighted) patents and they are more likely to have a zero citation-weighted patent-intensity. Non-US targets also appear to have similar financial characteristics as those described for the full sample, but the coefficient on Tobin's q becomes insignificant. However, they do not seem to have a particularly different innovative profile from non-acquired firms. The only significantly different characteristic is a higher patent stock (but only in raw form), while there is some indication that they are more likely to be non-R&D-reporting firms; yet the dummy for missing R&D equals to unity for only about 17% of the acquired firms. It should be acknowledged that the small number of acquisitions by non-US firms in Panel B does not allow us to identify any conclusive relationships.

As far as the importance of year, country and industry effects is concerned, the following trends emerge on the basis of the relevant dummies included in the logit model of Table 2, Panel A. The acquisition probability peaks in the mid-1980s, the late-1980s/early-1990s, the mid-1990s and the late-1990s.[xxvii] Although this trend follows the world stock market movements (provided by Datastream), it seems that there is more in the activity; the marginal effect in 1995 exceeds that in the late-1990s when market valuations in high technology industries skyrocketed. Canadian and British firms face a takeover threat which is almost comparable to that faced by US firms, while Japanese firms appear to be the most insulated from the threat of being taken over. These results are broadly consistent with the distinction of systems into market-insider and market-outsider systems (Franks and Mayer, 1995; Mayer, 1998). Firms in SIC 48, 73 (primarily software firms which are also active in computers and computer equipment) and 87 (business services including R&D and testing services) face a relatively higher risk of being taken over, while those in SIC 37 (transportation), face a considerably lower takeover risk.

Sensitivity checks

We estimate a specification for a sub-sample of 15,307 observations (including 176 acquisitions) where data on all financial, R&D and citation-weighted patent-related variables are available. The results, presented in the first column of Table 3, differ in some respects from those of Table 2. First, the coefficient on operating return is insignificantly different from zero although negative. Second, although the R&D-intensity coefficient remains positive, it becomes insignificant. However, these differences reflect the effect of the large fall in sample size rather than any omitted variable bias from the relationships established using the two complementary specifications.[xxviii]

Finally, we re-estimate the same specification, but this time without normalising R&D-intensity to zero when R&D expenditure is missing (second column of Table 3). Again, we find insignificant coefficients on profitability, R&D-intensity, as well as on the dummy for zero citation-weighted patent-intensity. Still, these coefficients have similar signs to those of Table 2.

Table 3. The probability of being acquired: sensitivity checks

Regressor	All independent variables	Observations with R&D data
Constant	-6.603*	-6.908*
	(1.023)	(1.094)
Total Assets (ln)	0.213*	0.231*
	(0.069)	(0.073)
Dummy High T. Assets	-0.931*	-1.040*
	(0.346)	(0.362)
Total Assets Growth	-0.009	-0.107
	(0.115)	(0.163)
Op. Return	0.063	-0.113
	(0.6)	(0.627)
Dummy Op. Return Negative	0.033	0.105
	(0.439)	(0.446)
Tobin's q (ln)	-0.284**	-0.282**
	(0.157)	(0.169)
Leverage	-0.004	-0.001
	(0.036)	(0.038)
Liquidity	-0.057*	-0.051*
	(0.024)	(0.023)
R&D-intensity	0.709	0.731
	(0.496)	(0.511)
Dummy No R&D	-0.165	
	(0.286)	
Citation-wtd Patent Stock (ln)	0.037**	0.043*
	(0.022)	(0.024)
Citation-wtd Patent-intensity	0.300	0.297
	(0.402)	(0.41)
Dummy Zero Cit.-wtd Patent-intensity	0.422**	0.406
	(0.238)	(0.252)
Country, Industry & Year dummies	Yes	Yes
No of Observations	15,307	13,649
No of acquisitions	176	160
Wald Test	110.3	95.0
Degrees of Freedom	38	36
P-value	0.0	0.0
Log Likelihood	-864.8	-781.3
Pseudo R-squared	0.10	0.10

The regressions include countries from Canada, Japan, the UK and the US. The base country is the US, the base industry is SIC 283, and the base year is1998. See notes to Table 2, Panel A.

Further analysis: Acquiring versus acquired firms

After uncovering the average trends in the characteristics of the acquired firms relative to non-acquired firms, we examine for each couple (i.e. acquirer and target) in a particular acquisition their relative characteristics using a univariate analysis. The couples of firms are compared with respect to the independent variables included in the regression analysis with the addition of the propensity to patent in raw and weighted form, which is defined as the number of patents over R&D expenditure in $million (1996 prices).[xxix] We explicitly account for this variable in the light of the market for corporate control model, which implies that the acquired firms will tend to have poor innovative efficiency relative to their acquirers. The median differences for the variables of interest across all the couples of acquiring-acquired firms with available data and after controlling for country, industry and time effects are reported in Table 4.

Each acquiring (acquired) firm is matched to a control[xxx] non-acquiring (non-acquired) firm from the same country and industry (primary 2-digit SIC code[xxxi]) with a size as similar as possible. Size has been identified as one of the most important matching parameters and a number of firm characteristics are likely to be correlated with it (Barber and Lyon, 1996). Then, for each variable we calculate the difference between the acquiring firm minus its matched control and the target that it acquires minus its matched control. This method allows us to compare the characteristics for only 276 couples of acquiring and acquired firms involving primarily US firms.[xxxii] The last column indicates the proportion of positive differences in the total number of non-zero differences. The null hypothesis of no difference in the distributions between acquiring and acquired firms is tested by the Sign test and the Wilcoxon signed-rank test.[xxxiii]

Table 4. Univariate comparisons of acquirers and their acquired units

	Acquirers Control-adjusted versus Targets Control-adjusted		
	Firm No	Median	% Positive
Total Assets Growth	276	0.124*	59.8*
Operating Return	276	0.068*	64.5*
R&D-intensity	276	-0.002	49.5
Patent Stock (ln)	276	1.190*	66.3*
Cite-weighted Patent Stock (ln)	215	1.990*	67.0*
Patent-intensity	276	0.000	56.3*
Cite-weighted Patent-intensity	215	0.004*	60.0*
Propensity to Patent	243	0.042*	61.7*
Cite-weighted Propensity to Patent	179	0.093*	66.4*

Total Assets are measured in $1996 thousands. ln indicates the natural logarithm. % Positive is the proportion of positive differences of the total number of non-zero differences. * Statistically significant at the 5% level, using a two-tailed Wilcoxon matched-pairs signed-ranks test (see median differences), and a two-tailed Sign test for the % of positive differences.

The results imply that the acquirers tend to be statistically significantly faster growing and more profitable firms. Turning to the innovative characteristics, the acquirers have a significantly larger stock of accumulated knowledge in both raw and weighted form. They also have a comparable R&D-intensity, but interestingly they seem to yield a somewhat higher R&D output (particularly citation-weighted patent-intensity). This fact is also reflected in a significantly higher R&D productivity (particularly citation-weighted propensity to patent) of the acquirers.

DISCUSSION

Our analysis suggests that acquisition is a very noisy phenomenon and that financial and technology related variables explain only a modest part of the probability of becoming a target. In broad terms, targets tend to be relatively larger compared with non-acquired firms, but beyond a certain point larger size reduces the (log) odds of a firm being acquired. Also, the probability of being acquired is negatively related to profitability, Tobin's q and liquidity. Focusing on the innovative characteristics, it appears that targets, in general, tend to have a relatively larger stock of citation-weighted patents compared with non-acquired firms. US targets, which account for the vast majority of sample targets, also tend to have a significantly higher R&D-intensity and, they are more likely to have a zero citation-weighted patent-intensity in the year before they are acquired. Accounting for firm size and R&D-intensity, the lack of any valuable R&D output can be taken as an indication of target inefficiency in the conduct of the R&D process relative to non-acquired firms. Compared with their acquirers, targets have a relatively smaller stock of citation-weighted patents, comparable R&D-intensity, but lower citation-weighted patent intensity and propensity to patent.

These findings suggest that high technology acquisitions represent a much more complex phenomenon compared to the two competing hypothesis assumed. That is, the *rationale* of the overall acquisition activity cannot be captured by a simple answer to the question whether it is "inferior" or "superior" innovators that become acquired. The findings that targets are more likely to have no R&D output before they are acquired relative to non-acquired firms, despite being highly R&D-intensive, and that they have lower R&D output and R&D productivity relative to their acquirers, despite a comparable R&D-intensity, are broadly consistent with the target "inferiority" hypothesis. The findings that the targets tend to have low profitability and poor growth prospects, reflected in their low Tobin's q, are also in accordance with a wider view of the "inferiority" hypothesis, interpreted in economic terms this time. However, the findings that targets invest heavily in R&D relative to their asset base *per se* and, most importantly, that they have a large stock of accumulated R&D output generated by past R&D efforts relative to non-acquired firms suggest that some target characteristics rather conform to the "superiority" hypothesis.

What seems to be a critical factor in order to reconcile the evidence with the abstract theoretical hypotheses is *timing*. It appears that, although targets are indeed actively involved in R&D and have succeeded in the past in generating significant R&D output[xxxiv], even a short-lived short-fall in their R&D pipe-line, at least when accompanied by poor current and expected future economic performance, turns out to be enough to increase the likelihood of being acquired. In this sense, we believe that high technology acquisitions reflect a process which is primarily driven by acquirers wishing to exploit the potential for turning around firms which, despite a good past record, appear to be innovatively and economically inefficient before they are acquired. A plausible intuitive explanation could be that targets are old firms at a declining stage in their life cycle. In the absence of data on the age of the targets, we can only rely on the information provided by their large size and the statistically insignificant dummy for firms with large operating return losses, which was employed as a proxy for young high-growth firms, that seem to hint toward that direction.

Our results differ, in some respects, from those that are uncovered when all manufacturing firms are examined. Unlike our sample's high-tech targets, which tend to be relatively large and to have a high R&D-intensity, Hall (1988) finds an insignificant difference from non-acquired firms in terms of both size and R&D-intensity, while Hall (1999) finds that acquired firms are somewhat small and that the firms with very high R&D-intensity are less likely to be acquired. Apart from differences in the time period covered from the samples, these differences in findings can be attributed to the possibility that high technology acquisitions have unique features. This view is strengthened by the existence of similarities between our findings and those of another high technology specific US study of Addanki (1986). In both studies it seems that publicly traded firms that are acquired are likely to be R&D-intensive firms without any (valuable) pre-acquisition patenting activity. Finally, our findings are consistent with the claim made by Dessyllas and Hughes (2005), who examine the innovative characteristics of the acquirers using a sample of acquisitions similar with ours, that the motive of sourcing innovation-related assets is not particularly relevant to acquisitions of public firms, at least as a primary explanation.

Our findings suggest that the future research agenda should be directed towards two additional relatively unexplored issues, if it is to reach a more thorough understanding of the role that acquisitions can play as part of a firm's broader competitive strategy. First, it would be interesting to perform a similar analysis with respect to the much more numerous privately held targets. The innovative "superiority" hypothesis is more relevant in the case of acquisitions of high technology start-up private firms (See for example Williamson, 1975). There is evidence to suggest that this is the case at least in the UK where models of acquisition in the small unquoted business sector show a positive link between innovation and acquisition likelihood (Cosh et al., 1999). Second, the validity of the hypothesised drivers of high technology acquisitions can be re-enforced by examining the effect of acquisitions on the economic and, most importantly, the innovative performance of the combined entity. This would allow exploring whether and when the acquirers' intentions are actually materialised.

CONCLUSIONS

In this paper we investigated the motives of high-tech acquirers by analysing their revealed preferences in terms of the high-tech companies they acquire. Using a large sample of acquisitions involving publicly traded firms from various countries we asked whether high technology acquisitions are best understood in terms of acquirers seeking to source externally special innovation-related assets by acquiring firms with "superior" innovative performance; or acquirers seeking to acquire firms with "inferior" innovative performance in order to turn them around and expand.

We found evidence that acquisition is a very noisy phenomenon and that financial and technology related variables explain only a modest part of the probability of becoming a target. We did, however, find that, compared to non-acquired firms, high technology targets tend to be somewhat larger, to have poorer profitability and lower Tobin's q and liquidity. In relation to their innovative profile, targets, in general, seem to have a relatively larger stock of accumulated knowledge (stock of citation-weighted patents), and US targets, in particular, also tend to have relatively higher R&D inputs (R&D-intensity), but they are more likely to generate no R&D output (citation-weighted patent-intensity) before they are acquired.

These findings suggest that the *rationale* of the overall acquisition activity cannot be captured by a simple answer to the question whether it is "inferior" or "superior" innovators that become acquired. The major conclusion that can be drawn from our analysis is that high technology acquisitions reflect a process which is primarily driven by acquirers wishing to exploit the potential for turning around firms which, despite a good past record, appear to be innovatively and economically inefficient before they are acquired.

NOTES

[i] Blonigen and Taylor's (2000) analysis does not discriminate between acquisitions of public targets and former subsidiaries or private firms.

[ii] This estimate is based on 6,635 deals with disclosed value of which 1,547 involve public targets as reported by Thomson Financial's SDC. For the selection criteria of these deals see the section "Methods".

[iii] This variable is defined as the difference between a firm's actual and expected market value estimated by a model using firm size, R&D and patents as regressors.

[iv] Haspeslagh and Jemison (1991) and others have elaborated on the issues that need to be addressed for a successful integration of the acquired units.

[v] As a result, the market value of the latter will be low compared to the replacement cost of their assets.

[vi] Hall and Vopel's classification of industries is based on the industry-level R&D-intensity and on an informal assessment of investment horizons. According to these criteria, the high technology sector consists of Computers and Computer Equipment, Electrical Machinery, Electronic Instruments and Communication Equipment, Transportation Equipment, Optical and Medical Instruments, and Biopharmaceuticals.

[vii] The eight 2-digit SIC codes are as defined by Hall and Vopel (1996) 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*.

[viii] 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).

[ix] Because it is often argued that acquisitions that are related to disciplining inefficient management tend to be hostile and acquisitions that are related with reaping synergistic benefits tend to be friendly (See Morck et al., 1988), we checked for the number of hostile acquisitions. Hostile acquisitions account for only 2.3% of all deals, and their small number in the sample actually analysed does not allow a separate analysis.

[x] 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).

[xi] Our study is not the first one to employ US patent data for both US and non-US firms. Other studies include Bloom and Van Reenen, (2001) and Geroski et al., (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).

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

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

[xiv] 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.

[xv] We choose to proxy for the stock of accumulated knowledge using the stock of 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.

[xvi] 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).

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

[xviii] 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.

[xix] We employed the random-effects estimator so that to be able to control for time-constant factors (cf. fixed-effects).

[xx] 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.

[xxi] 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.

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

[xxiii] 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.

[xxiv] This dummy was introduced after some preliminary regression analysis which suggested that targets tend to be larger than "normal". This contradicts the findings of a large part of the literature examining economy-wide acquisitions, where acquired firms tend to be smaller compared with non-acquired firms (Hughes, 1993). We therefore suspected a non-linear relationship in accordance with Dickerson et al. (1998). The dummy turns out to have the predicted (negative) sign and it is statistically significant. The sign and the significance of the rest of the regressors are not affected by the inclusion of this dummy, so multicollinearity between the dummy and the continuous size variable does not seem to be a problem.

[xxv] This is an important trend, as some 184 (56%) of the 328 acquired firms have a dummy equal to one. Also, it seems that the usage of citation-weighted patent proxies adds some information to the analysis, since we find that the corresponding dummy for zero patent-intensity over the same sample is positive but insignificant.

[xxvi] Further disaggregation of non-US firms was not possible, particularly for the citation-weighted patent regressions, due to the limited number of acquisitions.

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

[xxviii] Running the two complementary specifications of Table 2 for the subset of observations in Table 3 we derived similar results for profitability and R&D-intensity to those reported in Table 3.

[xxix] As will be seen, the (citation-weighted) propensity to patent is reported for a smaller number of deals, because the ratio is not defined when R&D expenditure is zero or not reported.

[xxx] The potential controls of an acquiring firm are firms which were not active in any takeover activity over the three pre- and post-merger years, and that potential controls for an acquired firm are non-acquired firms during the three years following the year in which the firm in question is acquired. The imposition of this takeover abstinence window for controls is adopted since we carry out a one-to-one matching.

[xxxi] The only exceptions are firms in 283 which are specifically matched to 283 control firms, and firms in SIC 28 (excluding 283) are matched to SIC 28 (excluding 283) controls (See footnote xxi).

[xxxii] The 276 deals analysed involve 253 US acquiring firms and 269 US acquired firms. Because data on citations are available until 1997, comparisons on citation-weighted patent-based variables are only possible for 215 deals.

[xxxiii] The Sign test tests whether the proportion of positive differences equals 50%, while the Wilcoxon signed-rank test, in addition to the signs of differences, also takes into account their magnitude. Statistical significance is assessed at a 5% level.

[xxxiv] Recall that the patent stock is calculated using a 15% annual depreciation rate. Hence, this variable is calculated over a period between 6 and 7 years.

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