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Technology sourcing by large incumbents through acquisition of small firms

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ABSTRACT

Innovation activities in high technology industries provide considerable challenges for technology and innovation management. In particular, since these industries have a long history of radical innovations taking place through distinct industry cycles of higher and lower demand, firms frequently consider the option to use acquisitions as a means for technology sourcing. The paper investigates this behaviour for three high technology industries, namely semiconductor manufacturing, biotechnology and electronic design automation which is a specific sub-segment of the semiconductor industry. It analyses the association of firm characteristics with different aspects of acquisition behaviour with a particular focus being put on innovation-related firm characteristics. The paper confirms a substitutive relationship between acquisitions and own research activities as well as between own and acquired firm patenting, but also finds that firm size, financial conditions and geographical origin of the firm matter for acquisition behaviour.

Keywords: Acquisition, innovation, high technology, quantitative methods, research, R&D

JEL classification: L10, L86, M20

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INTRODUCTION

Innovation activities in high technology industries are diverse. In particular firms frequently face make-or-buy decisions, especially as concerns radical innovation. This, together with the cumulative and rapid nature of innovation means that acquisitions are a potentially very important route of technology sourcing and hence an interesting and relevant research topic that is also acknowledged in the literature (Bruno and Cooper, 1982; Chakrabarti and Burton, 1983; Dushnitsky and Lenox, 2005; Fey and Birkinshaw, 2005; Capron and Shen, 2007). The purpose of this paper is thus to more narrowly analyse the R&D-related determinants for the frequency and technological relevance of acquisitions and whether they are substitutive or complementary.

Whilst earlier research has done so for a broader set of industries (e.g. Desyllas and Hughes (2008) for eight industries), this paper focus on a more narrow set of three high technology industries. Since the issue with analysing a broader set of industries is that the acquiring firms can be of two types: strongly technology oriented or weakly technology oriented. In the former case it has been proposed that acquisitions are complementary to the acquiring firms' knowledge base and in the latter case that they substitute own R&D of the acquiring firm (Pieper, 1996). Empirically therefore, the former case would correspond to a positive, and the latter case to a negative association. In samples including a broader set of industries, both types of acquiring firms are present which may make it impossible to draw conclusions from the results about each type of firm separately since the empirical association is a mix of the (theoretically differing) associations for both types of firms. Therefore focussing on just a very narrowly defined set of three high technology industries in which firms are all of the strongly technology oriented type allows to draw more confidently conclusions for this latter type of firms alone.

In a paper related this one, Desyllas and Hughes (2008) explore the relationship of R&D and patenting with acquisitions and find a largely substitutive link. I extend their study by using the occurrence and extent of patenting by targets prior to acquisition as a more narrow measure of technology-related acquisitions. The number of (total and technological[1]) acquisitions and the technological value of acquisitions as measured based on prior patenting of the acquired start-ups jointly provide a very complete assessement of potential substitutive or complementary links between R&D determinants of acquirers and acquisitions.

Also, by using a patent-based, narrower measure of the technology-relatedness of acquisitions my paper extends extant literature which so far has only used broad proxies such as a firm being privately held as means to delineate technology-related and unrelated acquisitions.[2] The paper further contributes to the literature by addressing the question of a substitutive versus complementary relationship with a very specific measure of the technology-relatedness of acquisitions. It also contributes by providing a more detailed analysis of the link of target firm and acquirer patenting. After reviewing the literature in the next section, the paper derives hypotheses which are subsequently tested in the empirical analysis. After reporting the results, of this the paper draws conclusions and highlights managerial as well as academic implications.

LITERATURE REVIEW

Technology sourcing through acquisitions is a phenomenon well identified in the literature on high technology industries. For example in the semiconductor industry, levels of research and development (R&D) input are strongly affected by the highly cyclical nature of the

[1] Technological or technologically-related acquisitions are defined in this paper as those, for which the target firm has been granted at least one patent in the five years prior to acquisition, see also Clooydt et al. (2006). Using patents to gauge technological capabilities is appropriate in a sample of high technology firms, since for the latter patenting is common also for small firms, for example to create collateral for venture capital investments.

[2] For example, Desyllas and Hughes (2008) only distinguish whether a firm makes no acquisitions in a year, acquires at least one public target, or acquires non-public targets only. Hence, it could be the case that a firm acquires ten non-public targets and only one public target but would still be in their first category. This makes the interpretation of their results difficult, particularly since they do not in parallel provide the distribution of public versus non-public targets in their dummy variable for acquiring at least one public target. My approach using target patenting avoids such problems.

industry (Levy, 1994), whose most severe downturn was in 2000 to 2001. R&D expenditure has significantly dropped in this period and has not recovered so far. In parallel to this, semiconductor firms' propensity to patent has considerably increased in US in 1980s, especially after formation of a centralized appellate court in 1982 as a means to strengthening patent rights (Hall and Ziedonis, 2001). As well, there is evidence of increasing innovation-related acquisition activity in the industry (Bloningen and Taylor, 2000; Sanchanta, 2007) Thus one effect of the downturn-induced drop in R&D funding and the parallel tightening of intellectual property rights seems to be a shift to a more open innovation model in the semiconductor industry, in which acquisitions play an important role (Pisano, 1990; Hagedoorn and Duysters, 2002; Puranam et al., 2003; 2006; Graebner, 2004).

Another example for the important role of innovation-related acquisitions is the electronic design automation (EDA) industry which focuses on chip design and covers a number of complex processes from abstract design through to chip testing. It has a highly concentrated market structure with three large firms and a significant number of small firms being active in the industry, the latter of which are frequently acquired by the industry's large firms. Increasingly, the products of the electronic design automation industry also integrate into chip manufacturing processes in order to enable direct feedback from the production to the design stage in turn making innovation processes even more challenging and hence acquisitions as a means for technology sourcing potentially even more viable.

Finally, the biotech industry is also characterised by strengthening patent rights (especially in the US) and rapid technological change with cumulative technologies. Again, acquisitions are a frequent phenomenon in this industry as are intensive collaboration and cooperation activities (Jack, 2007; Hoffmann, 2007; Jack, 2006; Rothaermel and Deeds, 2004;

Pangarkar, 2003). Puranam et al. (2006) argue that the information technology and biotech industries are very similar with regard to acquisition behaviour aimed at technology sourcing.

Next to acquisitions for technology sourcing, research on innovation networks (e.g. Teichert, 1994; Tidd et al., 2005) suggests that these are often considered as an alternative when innovation is so radical that no subgroup of firms can achieve it, but only a complete network. It may be in this case that a number of (larger or smaller) firms at the same level of the value chain cooperate closely. This concerns for example cooperation in the context of Sematech in the US since innovation in semiconductor manufacturing often requires large-scale industry cooperation as well as other forms of cooperation such as the innovation networks characterising cooperation of small textile firms in Italy's industrial districts. This line of thinking is also relevant for the EDA and biotech industries. For example, Sangiovanni-Vincentelli (2003) argues that intensive research collaboration and innovation networks may be needed to bring about radical innovation in the EDA industry and Pangarkar and Klein (2001) and Zhang et al. (2007) point to the relevance of cooperation in the biotech industry.

In addition to the literatures on external technology sourcing and innovation networks in high technology industries, another stream of scholarly work which is of relevance here is the economic theory of mergers and acquisitions in general and particularly the empirical studies related to it, for example in terms of make or buy decisions regarding technology sourcing (e.g. Rüdiger, 1998).

This literature points to the fact that takeovers may be especially suitable if small start-ups come to a point where they do not realize their potential due to lack of complementary assets such as distribution channels or because of too slow growth.

Overall, the literature review thus reveals evidence for the suitability of both approaches innovation networks as well as acquisitions to realise (in particular radical) innovation in high technology industries. Given the significant body of work on innovation cooperation and networks (e.g. Ahuja, 2000; Mowery et al., 1998), the focus of the remainder of this paper is on acquisitions and in particular on what characteristics of acquiring firms (and here in particular those related to R&D) determine the acquisition of innovative or entrepreneurial start-ups as concerns the number of (total and technology-related) acquisitions and the technological value of acquisitions as measured based on prior patenting of the targets.[3]

HYPOTHESIS DEVELOPMENT

Hitt et al. (1991) argue in the context of technological sourcing that acquisitions cause lower (industry-adjusted) R&D and (citation-weighted) patenting intensities and state that this is a partial explanation for the bad post-merger performance frequently encountered. Their argument, whilst proposing the same association of own R&D and acquisitions as Desyllas and Hughes (2008) reverses the causality. According to Börsch-Supan and Köke (2002) issues of reverse causality are frequently the case in empirical management research and causality can only be inferred on the basis of theoretical arguments. The view that low R&D and patenting intensities causes acquisition activity is theoretically supported by the literatures on obstacles to innovation (e.g. Witte, 1973; Christensen and Bower, 1996) and on the division of labour for innovation (Williamson, 1975; Grandstrand and Sjolander, 1990) which posit that there are objective impediments that deter or render less efficient innovation especially in larger firms. Two main reasons for this seem to apply. Firstly, some innovations can be organisationally radical (e.g. Henderson and Clark, 1990) e.g. because firms require intensive learning and

[3] Another reason for focussing in this paper on acquisitions is that initial exploratory interviews with experts in all three industries analysed (biotech, semiconductors and EDA) have revealed, that innovation cooperation and innovation networks in these industries is largely confined to pre-competitive research, which significantly limits the scope of an analysis of innovation cooperation (with the partial exception of biotech, where innovation cooperation activity is also observable between dyads of individual firms), as compared to acquisitions.

intellectual deliberation within the firm (Levinthal and March, 1993) or because radically different organisational structures for R&D are required (Benner and Tushman, 2002; Leonard-Barton, 1992). Secondly, absorptive capacity (Cohen and Levinthal, 1990) can be lacking because different or new skills are required from technologists or researchers of a larger firm. Based on these causal mechanisms developed in the literature it can be concluded that the association between R&D activities acquisition should be negative, and especially so for technologically-related acquisitions leading to the following hypotheses:

H1a: The R&D intensity of acquiring firms is negatively associated with the number of acquisitions.

H1b: The association is stronger for technological acquisitions than it is for the acquisitions of a firm in general.

H1c: The R&D intensity of acquiring firms is negatively associated with the number of patents granted to a target prior to acquisition.

Economic theory has proposed a number of reasons for acquisitions (see e.g. Trautwein, 1990; Morris and Hay, 1991; Milgrom and Roberts, 1992). For example under the assumption that the stock market is efficient, motives for takeovers could be increased market power, reduced advertising and other promotional expenditure or efficiency gains which can not be realised without the acquisition. Other explanations that have been proposed for acquisitions are managerial takeovers, allocational takeovers, acquisitional takeovers or conglomerate mergers aimed at risk reduction (Morris and Hay, 1991). Given the variety of motives for an acquisition, it may be that in acquisitions aimed at technology sourcing, firms aim to mitigate more specific weaknesses, such as low R&D output, as proxied by the patents generated in relation to the size of the firm (i.e. patenting intensity). Therefore, it is appropriate to compare different measures of acquirer R&D activity. In the case of patenting intensity, it could be that it is more strongly associated than R&D intensity with the patent-related characteristics of targets. Hence comparing the association of R&D and patenting intensities with acquisition related variables and variables relating to the R&D characteristics of targets enable a direct test of how specific aquirers attempt to mitigate own weaknesses through external technology sourcing. Of course, to the extend that acquirers are rather unspecific in mitigating weaknesses, the links proposed in H1a and H1b with regard to acquisitions in general and more narrowly defined technological acquisitions should still hold in the case of patenting intensity. Therefore the following hypotheses are formulated with regard to patenting intensity:

H2a: The patenting intensity of acquiring firms is negatively associated with the number of acquisitions.

H2b: The association is stronger for technological acquisitions than it is for the acquisitions of a firm in general.

H2c: The patenting intensity of acquiring firms is negatively associated with the number of patents granted to the target firms prior to the acquisition.

As concerns acquisitions for R&D purposes, a complementary relationship between acquisitions and own R&D has been proposed by some scholars, i.e. a positive association of R&D and patenting intensities and acquisitions (Veugelers and Cassiman, 1991; Cassiman and Veugelers, 2006). Opposed to this, Desyllas and Hughes (2008) analyse the association of R&D and patenting with acquisitions in a sample of broadly defined high technology industries. They find that decreasing returns from exploiting a firm's existing knowledge base and the choice between making or buying R&D are main drivers for the acquisition of innovative firms and conclude that there is a substitutive link of firm's own R&D with acquisitions which confirms earlier findings by Bloningen and Tyler (2000). However, Desyllas and Hughes (2008) also find a significant positive association between acquisition activities and the patent stock as a firm. I intepret this as a complementarity between absorptive capacity generated through own R&D and acquisitions. For larger firms to benefit from the information gathered by small firms, absorptive capacity is necessary (Cohen and Levinthal, 1990). Absorptive capacity here refers to a level of own technological knowledge that enables a large firm to integrate in an efficient and effective manner the technological knowledge gained with the acquisition of a small firm. One approach to assess the level of a firm's own accumulated technological knowledge is to evaluate its patent stock accumulated over time whilst accounting the depreciation of the value of the knowledge reflected by patents over time (Hall, 1990; Hall et al. 2007). For technology-related acquisitions, absorptive capacity is more important, since here integration is more demanding. This leads to the following hypotheses with regard to patenting stock:

H3a: The patent stock of acquiring firms is positively associated with the number of acquisitions.

H3b: The association is stronger for technological acquisitions than it is for the acquisitions of a firm in general.

H3c: The patent stock of acquiring firms is positively associated with the number of patents granted to target firms prior to the acquisition.

DATA AND METHODOLOGY

Data for the quantitative analysis was collected from the SDC Platinum, Bloomberg and Worldscope Disclosure databases as well as the US Patent and Trademark Office (USPTO) website. The data set comprises the largest firms in the EDA, biotech and semiconductor industries during the period of 1981 until 2004. However to avoid truncation bias with regards to patents, the analysis was subsequently limited to the 1981 to 2002 period. Using USPTO patent data is appropriate since the large majority of the firms analysed are US-based and since in high technology industries, also non-US firms commonly apply for patents at the USPTO. Hence any "home advantage" of US-based firms is very small. All firms making up the first 80 per cent of the market by sales value were included in each industry, resulting in 14 EDA, 50 semiconductor and 20 biotech firms being analysed. Data was collected on a number of variables concerning various acquirer firm characteristics, for which statistics and correlations are provided in Table 1.

Insert Table 1 about here

Patents of a large firm are both, a measure of absorptive capacity (if used to calculate patent stock[4]) and for normalised R&D outputs (if used to calculate patent intensity). Patents of an acquired start-up can be used to assess the extent of its technological base and capabilities that are worth leveraging (Hoetker, 2005; Puranam et al., 2003; Puranam & Srikanth, 2007). Using a five-year timeframe prior to the acquisition year to measure the level of technological knowledge is somewhat arbitrary, yet this approach has been utilised frequently before (Hoetker, 2005; Clooydt et al., 2006) because it is considered a suitable balance between the declining value of knowledge and patent protection which increases with every year a patent ages and the increasing level of knowledge stock with every additional year included to measure the level of technological knowledge. It was not possible to use operating margin and cash flow as measures for profitability, since these were empirically highly correlated with R&D intensity, especially in the semiconductor and EDA industries. Therefore, sales growth was used as a joint proxy for profitability and industry-related opportunities. Also location dummies and controls for leverage and liquidity are included since they affect acquisiti-ons (Desyllas & Hughes, 2008). All models are estimated with and without industry dummies.

[4] Patent stock was calculated based on the method propose in Hall (1990), using a 15% depreciation rate. No adjustments were made to the number of granted patents for the application year that corresponds to the first year that the firm entered the data set.

To analyse panel data, two well-established models exist, namely random and fixed effects (Johnston and DiNardo, 1997). Since the number of acquisitions and the technological value of acquisitions as measured based on prior patenting of the acquired start-ups are all count data, negative binomial random and fixed effects models are estimated for these as independent variables. The difference between the fixed effects and the random effects model is based on whether the time-invariant effects are correlated with the regressors (which is the case for fixed effects) or (in case of the random effects model) not. For these models, the specification is:

$$u_{it} = c_i + \varepsilon_{i,t} \quad (1)$$

$$y_{it} = \alpha + \beta' \mathbf{X}_{it} + c_i + e_{it} \quad (2)$$

where $i = 1, \ldots, N$ units under observation, and $t = 1, \ldots, T$ time periods for which data were collected. y_{it} denotes an acquisition-related dependent variable for firm i in period t, $\mathbf{X}_{it}$ represents a set of independent variables, β' a vector of coefficients, c_i unobserved individual heterogeneity and e_{it} an idiosyncratic error that satisfies $E[e_{it}|\mathbf{X}_{it}, c_i] = 0$. The model is estimated through GLS assuming no correlation between e_{it} and c_i. For the fixed effects model, other than the random effects model, the assumption is that the individual effect c_i is correlated with the time-variant independent variables $\mathbf{X}_{it}$. This means that although the basic specification given in (1) and (2) remains, the interpretation differs, in that the disturbance c_i is a constant (and thus represented by a dummy variable) for each unit of analysis, i.e. here for each specific firm. The fact that the disturbance is a constant in the fixed effects model implies that all time-invariant variables will be dropped during the estimation.

To decide which of the two models (random or fixed effects) is more appropriate, the Hausman tst is involved. If the Hausman test is significant, then the fixed effects model is more appropriate.

RESULTS

To quantitatively address the hypotheses developed earlier in the paper significant associations for the level at which large firms acquire and to what degree they acquire patents were analysed.

Table 2 summarises the results concerning the total number of acquisitions (technology-related as well as not technology-related) for which a significant positive association is found for sales and for patent stock. For the R&D intensity the association is significant and negative. This means that firms with a high R&D intensity tend to acquire on average more than those with low R&D intensity. A company being headquartered in Asia is negatively associated with the total number of acquisitions.

Insert Table 2 about here

Testing for joint significance shows, that the industry dummies are jointly significant ($\chi^2 = 6.83$, $p = 0.03$) and the country dummies are jointly insignificant ($\chi^2 = 5.48$, $p = 0.14$).

Table 3 shows that for more narrowly technology-related acquisitions defined as the number of acquisitions of firms that were granted at least one patent, R&D intensity is negatively associated and patent stock positively. Beyond that being headquartered in Asia has a significant negative (as was also for the total number of acquisitions). In this case, testing for joint significance revealed, that both industry and country dummies are jointly insignificant ($\chi^2 = 1.11$, $p = 0.58$ and $\chi^2 = 4.12$, $p = 0.25$, respectively).

Insert Table 3 about here

Desyllas and Hughes (2008) argue that acquisitions of private firms should be more strongly related to the acquisition of innovation than those of large public firms, since private acquisitions refer more often to smaller start-ups that are specialised in technological niches. Distinguishing in this way between the acquisition of private and public firms as a proxy for technological proficiency is however a relatively imprecise approach. A more reliable indicator to assess the innovativeness of the acquired start-ups is whether or not they have patented at all recently to evaluate their recent patent stock (Puranam & Srikanth, 2004; Puranam et al., 2006). This is done in the models reported in Table 4 for which the dependent variable is the total number of patents granted to the acquired start-ups in the five years prior to acquisition and in the acquisition year itself. As can be seen, the main factors significantly associated with the number of patents that have been granted to the acquired firm until including the fifth year prior to the acquisition are patent stock (positive), patenting intensity (negative) and whether the company is headquartered in Japan (in both cases negative).

Insert Table 3 about here

As before, testing for joint significance revealed, that the industry dummies are jointly significant ($\chi^2 = 1.10$, $p = 0.58$) and the country dummies are jointly insignificant ($\chi^2 = 2.48$, $p = 0.48$).

CONCLUSIONS AND FUTURE RESEARCH

The exploratory interviews carried out in the biotech, EDA and semiconductor industries prior to the quantitative analysis (see Footnote 3) provide evidence, that many of the acquisitions in the three high technology industries I analyse are related to R&D aspects. This can be related to the obstacles to innovation in larger firms and the institutional division of labour for innovation. Witte (1973), Henderson (1993) and Hauschildt (1999) discuss reasons why firms may not be able or unwilling to carry out specific types of innovation. One response of firms to not being able to carry out an innovation at acceptable cost or within an acceptable timeframe can be the acquisition of start-ups in order to make up for their missing capabilities (Markides and Geroski, 2005) and to source the necessary technology. This is enabled by a division of labour in innovation between small start-ups and large incumbents, which would imply a substitutive relationship of own R&D and external acquisitions. On the other hand, it has been suggested that the link between making and buying R&D is complementary, especially as concerns the capability to absorb external knowledge (Cassiman & Veugelers, 2006). I have specified a set of hypotheses to formally test these propositions on the basis of quantitative data and partly based on insights from qualitative interviews. Overall, the results of this testing show that the patenting and R&D intensities of firms are associated significantly with firms' acquisition activities as is proposed by the hypotheses.

More specifically, H1a and H1b are confirmed based on the results reported in Tables 2 and 3. In particular, in the case of H1b, the absolute strength of the association of R&D intensity with the number of acquisitions is more than 25% higher for technology-related acquisitions compared to overall acquisitions. However, H1c is rejected. H2a is rejected, whereas H2b is partly supported, since the coefficient for technology-related acquisitions is more than double the absolute value compared to that for acquisitions in general and is almost significant at the 10%

level (p = 0.12). H2c is fully supported, indicating a more narrow substitutability between acquirer and target patenting that was so far not tested for in the literature. This can be understood as a specific form of rational behaviour of acquiring firms that have a weakness mainly in exploitation (for which patenting intensity is a proxy), rather than exploration (for which R&D intensity proxies). As this only holds for the most direct measure of exploitation weakness (i.e. the number of patents granted, but not number of and likelihood of technology-related acquisition), it suggests, that a weakness in terms of patents leads acquirers to specifically aim for those targets that can mitigate exactly this weakness by having a high number of patents in the field where the acquirers recent patenting is weak. Notably and supporting this interpretation, R&D intensity is not significant when the number of recent target patens is the dependent variable, but only patent intensity.

H3a proposing a positive association of patent stock with the number of acquisitions is supported fully as is H3c proposing a positive association of patent stock with the number of patents granted to targets. Also, H3b concerning the comparative effect of patent stock is supported in that the effect more than double in absolute value (0.25 versus 0.12) for technology-related acquisitions as compared to total acquisitions.

Linking my findings from analysing the acquisitions of technology-related firms defined based on patents to extant literature, they support the intuition of Desyllas and Hughes (2008) that acquisitions of private firms relate more strongly to technology in that I find a similar pattern between acquisitions in general and technologically-related acquisitions (based on whether targets patent or not) as they find between public and private acquisitions in that most associations of R&D-related variables in my sample are stronger for technology-related and private acquisitions. For example, in line with the reasoning of Desyllas and Hughes (2008) that the effect sizes for R&D intensity are higher in absolute values for the acquisition of privately held firms only, I find the same difference between the effect sizes of acquisitions in general and technology-related acquisitions i.e. a unit reduction of R&D intensity leads to higher increase of the number of acquired companies in the latter type of acquisitions.

This means that I find similar qualitative relations as concerns the association of R&D intensity and patent-related variables with technological versus overall acquisitions. Hence once could conclude by analogy, that my findings (measuring more specifically technology-related targets) lend support to the proposition that private firms are more technology-oriented.[5] This can be interpreted as a stronger substitutive relationship between R&D spending with technology-related (or private, in the case of Desyllas and Hughes) acquisitions which could indicate that such acquisitions are a better substitute for own R&D and patenting than are acquisitions where targets are not patenting or acquisitions of publicly-listed firms.

My analysis uses however an additional and more specific measure of technological orientation in that it also analyses the association of R&D-related acquirer characteristics with the total number of patents that targets were granted in the five years prior to acquisition. Desyllas and Hughes (2008) find that the ratio of patents applied for per assets is insignificant in all their regressions. A contribution of my paper is to evaluate this result using the more direct link of acquirer patenting with target patenting. My findings in this respect also support the notion that technology-related acquisitions compensate weakening exploitation indicated by lower patenting intensity and this finding also supports that acquisition of innovation is a substitute for own R&D, especially for technology-related ones.

In terms of future research, given that the qualitative insights from my interviews also indicate that cooperation and innovation networks are potentially very relevant for firms to

[5] It needs to be pointed out though, that Desyllas and Hughes (2008) do not formally test their argument of private firms being more strongly technology-oriented beyond casual case evidence. Hence my results using a more narrow definition of technology-relatedness (based on target patenting) are stronger evidence for the basic argument Desyllas and Hughes (2008) make.

address issues of weakening exploitation and reduced resource inputs to innovation activities, but that their role may differ according to the industry concerned, potential differences between industries with regard to this should be explored further. Also, as concerns licensing as yet another option of external technology sourcing, Gans et al. (2002) argue that small firms and start-ups are more likely to commercialise themselves (rather than licensing or aiming for acquisition), the lower the control over intellectual property (IP) rights, the higher transaction costs for finding a suitable partner for licensing or acquisition and the lower sunk costs associated with product market entry are. Conversely, for an acquirer licensing implies that the licensing party can exert stronger influence on the IP usage conditions for the licensee compared to the option of acquisition and the interplay of those two perspectives should determine the equilibrium level of acquisition. Hence this interplay could be another interesting area of future research.

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TABLE 1
Summary statistics and correlations[a]

	Variables	Mean	Std. Dev.	Min.	Max.	Correlations 1	2	3	4	5	6	7	8	9	10	11	12
1	Total number of acquisitions	0.65	1.25	0	11	-											
2	Financial leverage [b]	2.35	6.43	0.72	166.11	-0.02											
3	Current ratio [b]	0.05	0.13	0	0.89	-0.11***	-0.08**										
4	Sales growth over previous year [b]	0.13	0.12	0	0.86	-0.04	0.05	0.19***									
5	Sales [b, c]	0.02	0.05	0	0.40	0.21***	-0.01	-0.03	-0.03								
6	R&D intensity [b]	6.48	13.46	0.04	292.68	-0.09**	-0.01	0.21***	0.04	-0.10***							
7	Patenting intensity [b]	0.41	1.36	-12	19.53	-0.001	-0.04	-0.13***	-0.06	-0.40***	-0.09***						
8	Patent stock [b, c]	8.56	1.31	4.75	13.24	0.21***	-0.02	-0.38***	-0.19***	0.05	-0.22***	0.30***					
9	Firm headquartered in Japan	3.99	0.82	0	5.36	0.01	0.02	-0.18***	-0.09**	0.07*	-0.08**	-0.01	0.46***				
10	Firm headquartered in Europe	0.18	0.35	-0.26	7.43	-0.03	-0.01	-0.09**	-0.02	0.16***	-0.04	-0.10***	-0.03	-0.12***			
11	Firm headquartered in Asia	0.24	0.17	0	0.95	-0.09***	0.14***	-0.13***	0.02	-0.14***	-0.06*	0.07**	-0.01	-0.14***	-0.10***		
12	DJS industry Technology	15.85	13.02	0	50	0.10***	0.04	-0.34***	-0.07**	-0.46***	-0.20***	0.32***	0.16***	-0.16***	-0.09***	0.18***	
13	DJS industry Healthcare	0.79	0.41	0	1	-0.09**	-0.06	0.48***	0.13***	0.48***	0.26***	-0.31***	-0.48***	-0.24***	0.03	-0.12***	-0.77***

[a] * $p < 0.1$;
** $p < .05$;
*** $p < 0.01$
[b] Lagged by one year
[c] Logarithmized

TABLE 2

RE negative binominal regression, dependent variable: total number of all acquisitions

Variables	Model 1	Model 2
Financial leverage (total assets to total equity)	-0.0331 (0.0567)	-0.0320 (0.0628)
Current ratio (current assets to current liabilities)	-0.0063 (0.0314)	0.0151 (0.0312)
Sales growth (% over previous year)	0.0003 (0.0005)	0.0003 (0.0005)
Sales (natural logarithm of net sales in 1000 €)	0.0962 (0.0472)**	0.1728 (0.0597)***
R&D intensity (R&D expenditure to net sales in %)	-0.0044 (0.0020)**	-0.0034 (0.0020)*
Patent stock (Cumulated number of (depreciated) patents granted)	0.1567 (0.0611)**	0.1223 (0.0647)*
Patenting intensity (Patents granted by application year to net sales)	-0.0010 (0.0010)	-0.0010 (0.0010)
Company headquartered in Japan (dummy; 1 = yes; base category: United States)	-0.6202 (0.4053)	-0.3329 (0.4435)
Company headquartered in Europe (dummy; 1 = yes; base category: United States)	-0.4485 (0.4410)	-0.4201 (0.4375)
Company headquartered in Asia (dummy; 1 = yes; base category: United States)	-0.9497 (0.4196)**	-0.8947 (0.4113)**
DJS industry Technology (dummy; 1 = yes; base category: Other)	-	0.7158 (0.4667)
DJS industry Healthcare (dummy; 1 = yes; base category: Other)	-	-0.1581 (0.6098)
Constant	0.0705 (0.8221)	-1.0447 (0.9511)
Log-likelihood	-652.6827	-649.2473
ln(r)	2.3616	2.4644
ln(s)	0.4391	0.5287
No. of observations (No. of groups)	660 (81)	660 (81)
Wald Chi²	84.14	92.47
p-value	< 0.0000	0.0000
Hausman specification test		
Chi²	6.52	7.20
p-value	0.2589	0.7063

Notes: Significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; unbalanced panel data, observations per group: min = 1; max = 16; average = 8.1; Likelihood-ratio test vs. pooled for Model 1: Chi² = 75.84, p-value > Chi² < 0.001; test for joint significance of year dummies: Chi² = 34.92, p-value > Chi² = 0.0025; Likelihood-ratio test vs. pooled for Model 2: Chi² = 61.07, p-value > Chi² < 0.001; test for joint significance of year dummies: Chi² = 35.28, p-value > Chi² = 0.0022

TABLE 3

Random-effects negative binominal regression, dependent variable: number of technological acquisitions

Variables	Model 1	Model 2
Financial leverage (total assets to total equity)	-0.0026 (0.0210)	-0.0023 (0.0205)
Current ratio (current assets to current liabilities)	-0.0020 (0.0385)	0.0007 (0.0409)
Sales growth (% over previous year)	0.0001 (0.0007)	0.0001 (0.0007)
Sales (natural logarithm of net sales in 1000 €)	0.0584 (0.0515)	0.0648 (0.0687)
R&D intensity (R&D expenditure to net sales in %)	-0.0047 (0.0026)*	-0.0047 (0.0027)*
Patent stock (Cumulated number of (depreciated) patents granted)	0.2441 (0.0692)***	0.2510 (0.0756)***
Patenting intensity (Patents granted by application year to net sales)	-0.0019 (0.0013)	-0.0021 (0.0013)
Company headquartered in Japan (dummy; 1 = yes; base category: United States)	0.7084 (0.4122)*	-0.5081 (0.4540)
Company headquartered in Europe (dummy; 1 = yes; base category: United States)	-0.6292 (0.4892)	-0.4839 (0.5012)
Company headquartered in Asia (dummy; 1 = yes; base category: United States)	-0.7655 (0.4524)*	-0.7727 (0.4550)*
DJS industry Technology (dummy; 1 = yes; base category: Other)	-	0.5041 (0.4849)
DJS industry Healthcare (dummy; 1 = yes; base category: Other)	-	0.4162 (0.6615)
Constant	1.0018 (2.5764)	0.5236 (2.8283)
Log-likelihood	-453.8760	-453.3208
ln(r)	4.0673	4.1556
ln(s)	0.4999	0.5022
No. of observations (No. of groups)	660 (81)	660 (81)
Wald Chi²	63.00	64.13
p-value	0.0000	0.0001
Hausman specification test		
Chi²	0.01	0.01
p-value	1.0000	0.9997

Notes: Significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; unbalanced panel data, observations per group: min = 1; max = 16; average = 8.1; Likelihood-ratio test vs. pooled for Model 1: Chi² =31.58, p-value > Chi² < 0.001; test for joint significance of year dummies: Chi² = 23.98, p-value > Chi² = 0.0654; Likelihood-ratio test vs. pooled for Model 2: Chi² = 31.40, p-value > Chi² < 0.001; test for joint significance of year dummies: Chi² = 23.67, p-value > Chi² = 0.0709

TABLE 4

Random-effects negative binominal regression, dependent variable: total number of patents granted to targets in the five years prior to acquisition

Variables	Model 1	Model 2
Financial leverage (total assets to total equity)	-0.0696 (30.0856)	-0.0708 (0.0864)
Current ratio (current assets to current liabilities)	-0.0020 (0.0363)	-8.70e-06 (0.0387)
Sales growth (% over previous year)	0.0002 (0.0007)	0.0002 (0.0007)
Sales (natural logarithm of net sales in 1000 €)	0.0910 (0.0404)**	0.0964 (0.0591)
R&D intensity (R&D expenditure to net sales in %)	-0.0038 (0.0025)	-0.0038 (0.0026)
Patent stock (Cumulated number of (depreciated) patents granted)	0.1946 (0.0511)***	0.1985 (0.0586)***
Patenting intensity (Patents granted by application year to net sales)	-0.0019 (0.0011)*	-0.0020 (0.0011)*
Company headquartered in Japan (dummy; 1 = yes; base category: United States)	-0.7453 (0.2858)***	-0.6016 (0.3243)*
Company headquartered in Europe (dummy; 1 = yes; base category: United States)	-0.7162 (0.3866)*	-0.6022 (0.4078)
Company headquartered in Asia (dummy; 1 = yes; base category: United States)	-0.4584 (0.3591)	-0.4641 (0.3605)
DJS industry Technology (dummy; 1 = yes; base category: Other)	-	0.3199 (0.3589)
DJS industry Healthcare (dummy; 1 = yes; base category: Other)	-	0.2616 (0.5250)
Constant	-4.4666 (0.6143847)***	-4.835 (0.7613)***
Log-likelihood	-1223.8385	-1223.4282
ln(r)	-0.9425	-0.9536
ln(s)	3.9063	3.8572
No. of observations (No. of groups)	660 (81)	660 (81)
Wald Chi²	54.37	55.36
p-value	0.0006	0.0010
Hausman specification test		
Chi²	4.33	0.00
p-value	0.5024	0.9991

Notes: Significance levels: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; unbalanced panel data, observations per group: min = 1; max = 16; average = 8.1; Likelihood-ratio test vs. pooled for Model 1: Chi² =14.56, p-value > Chi² < 0.001; test for joint significance of year dummies: Chi² = 12.40, p-value > Chi² = 0.6487; Likelihood-ratio test vs. pooled for Model 2: Chi² =14.27, p-value > Chi² < 0.001; test for joint significance of year dummies: Chi² =10.79, p-value > Chi² = 0.7671

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