Determinants and Dynamics of Technology-Related Acquisitions: The Intriguing Case of Software-Based High Technology Industries

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ABSTRACT

Innovation activities in high technology industries provide considerable challenges for technology and innovation management. In particular, the option to use acquisitions as a means for technology sourcing matters. The paper investigates the determinants and dynamics of this for software-based high technology industries. It analyses the association of acquirer characteristics with different measures of acquisition behaviour. The paper confirms a substitutive relationship between acquisitions and own research activities as well as between acquirer and target patenting. For a subset of acquisitions of the three largest acquirers in the industry it relates these findings in more detail to target characteristics. In particular, this reveals an important qualification of the usual effects of disruptive innovation.

Keywords: Acquisition, innovation, entrepreneurship, software

JEL classification: L10, L86, M20

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Introduction

Innovation activities in high technology industries provide considerable challenges for technology and innovation management, since they are tightly linked to geographical clusters (e.g. Silicon Valley). I analyse these challenges in a software-based high technology industry which is embedded in the semiconductor innovation ecosystem (Adner & Kapoor, 2010). The latter has a long history of radical innovations which are taking place through distinct industry cycles of high and low demand. However, the origin of such innovations is not always certain, since e.g. large firms may be hindered by organizational inertia or lack of skills which have only recently entered university curricula. It seems that the acquisition of technology-rich targets can address this weakness. The suitability of this approach is suggested by Markides and Geroski (2005) who argue that lower innovativeness is inherent for incumbents and that these large firms should be adopting an acquisition or network strategy with young firms that can mitigate for lower innovation levels without implying the need for an industry consortium such as SEMATECH as it is found in chip manufacturing (Flamm, 2003; Spencer, 2003).

This argument is consistent with the observation that for small firms, an emphasis on performance, technical superiority, or radical innovation provides a potential recipe for success under high market uncertainty even though these characteristics do not equate to success (Souder & Song, 1997).

The feasibility of the approach seems to depend very much on the nature of the industry considered. One important characteristic of software-based industries is their low capital intensity, which means that startups do not require large investments in fixed assets to enter. As a result of this, the total asset values of the average entrant in software-based industries are relatively low compared to other industries (such as the electronic materials or equipment industries) and therefore a complete acquisition of a technology-rich target is more easily feasible and hence more likely (compared to e.g. acquisition of just a minority shareholding in such a target). This paper analyses the acquisition dynamics in an exemplary industry based
on semi-structured interviews, as well as econometric and statistical analyses.

**Review of Extant Literature**

The conceptual innovation literature has essentially identified a continuum of acquisition reasons ranging from infeasibility and higher cost to higher risk or delays from in-house solutions. These motivations for acquiring technology-rich targets differ only in degrees (Gooroochurn & Hanley, 2007). The case of the acquisition being cheaper refers to transaction and opportunity cost and to efficiency considerations (i.e. the classical make-or-buy decision), whereas infeasibility refers to the inability of large firms to innovate in a radical manner, e.g. because they are hindered by their existing customers (Christensen & Bower, 1996; Christensen, 1997) or because of a lack of capabilities (Henderson, 1993). Concerning the infeasibility of R&D for incumbents because of lacking capabilities, reasons for acquisition can be further subdivided based on the specific capabilities or competences the incumbent is lacking. Relevant sub-categories are intellectual property (e.g. patents or other technological capital), human capital, organisationally radical innovation and the generally lower innovatory activity of incumbents (Henderson, 1993; Baumol, 2004). With respect to this last point, a distinction can further be made with regard to acquisitions aimed at entering new markets and acquisition of new technologies (Roberts & Berry, 1985; Roberts & Malone, 1996).

Henderson (2006) describes how the reaction of incumbents towards disruptive innovation can be understood in a similar manner. She argues that disruptive innovations frequently relate to missing organisational competencies and that because incumbents anticipate that their organisational routines do not enable them to pursue such innovation they rationally choose to focus on their existing markets and products. As described in more detail below, the implications of such behaviour in software-based industries may differ to those observed in hardware-based segments of the semiconductor industry, such as chip manufacturing or the
lithography segment originally studied by Henderson (1993) and the disk drive industry analysed by Christensen and Bower (1996). Whereas acquiring the capabilities needed to pursue organisationally radical and disruptive innovation as an incumbent often is prohibitively high in these latter segments, it seems that this is not the case in software-based industries, due to the generally lower capital intensity here. In industries where incumbents are not able to acquire competencies at a reasonable cost, they have to either hope that the innovation will not render them uncompetitive and subsequently force it out of the market, or else have to face a forced market exit. In software-based industries where cost of acquisition is relatively low, incumbents have a third option which is to acquire the competencies enabling them to pursue organisationally radical or disruptive innovation themselves. This line of argument would also explain why organisational radicality and disruptive innovation do not necessarily force exit, but ultimately lead to a substitutive relationship between the innovation activities of acquirers and targets.

As concerns empirical studies of acquisitions in high technology industries, Grimpe and Hussinger (2008a) find empirical evidence that acquisitions aim at pre-empting technology competition. Using a novel measure for creating entry barriers based on European Patent Office data, they also show in a sample of horizontal acquisitions that acquiring firms pay more for targets with large patent stocks (as a measure for technological knowledge) and for those with higher patent forward citations which supports the assumption of this paper that acquisitions in high technology industries are used mainly for external innovation sourcing. Related to this, Grimpe and Hussinger (2008b) find that patent stock is higher for target firms which supports the notion of acquisitions adding to acquirer’s technological knowledge. Hsu (2004) studies the impact of venture capital (VC) backing on commercialization strategies of startups with regard to the question of whether they enter the product market on their own or get acquired or license out. Linked to this Gans et al. (2002) analyse a dataset composed of the commercialization strategies of 118 startup projects in terms of product market, licensing
or trade sale which are drawn from a survey population made up of startups receiving external R&D financing from private VC or the Small Business Innovation Research program (SBIR) in the U.S. Their sample covers five SIC codes, namely biotechnology (2836), computer software (7372), industrial machinery and equipment (35), electronic equipment (36), and scientific instruments (38). The authors use binary and multivariate probit models to analyse whether their proposed effects for intellectual property (IP) control, transaction and sunk costs hold. In a multinomial model they look at the outcomes of acquisition and licensing relative to the base category of product market competition and find that licensing behavior is associated with the IP rights and complementary asset regimes, whilst acquisition is sensitive to the presence of venture capital investment. Hall (1990) finds that U.S. firms acquire innovative targets to gain access to their technologies. The results of Bloningen and Taylor (2000) support the notion that acquisitions substitute own innovation output in the semiconductor industry. They furthermore find a positive relationship between innovation efforts and acquisition as well as evidence that companies strategically choose between the acquisition of external innovation and internal R&D activities. Similarly Lerner and Merges (1998) find for the biotechnology industry that acquisitions are frequently used mechanisms to transfer knowledge.

Grandstrand and Sjolander (1990) provide evidence that startup innovation is more radical than that of incumbents and suggest a division of scientific labour between entrants and incumbents that implicitly establishes their roles as targets and acquirers in an ultimately substitutive system approach to innovation. Opposed to this Desyllas and Hughes (2008) find that from a target perspective acquisition is a phenomenon for which innovation related variables explain only to a small degree acquisition by a large firm. According to them, larger and less profitable startups are acquired. This paper therefore also represents a test of these two opposing views. Lehto and Lehtoranta (2006) find that the success in innovation activity affects the likelihood of a firm to be acquired and Lindholm (1996, 1997) shows that small
firms take active steps to increase the chance for being acquired. Lindholm (1997) in her sample finds evidence, that whilst the importance of licensing as a means for technology sourcing did not significantly increase between 1977 and 1987, it did so for technology-related acquisitions, which is another phenomenon this paper will test in the narrower context of software-based industries.

In summary, the purpose of this paper is in the following to analyse the determinants for acquisitions in terms of frequency and technological relevance and to relate this to the question of substitutiveness as well as to industry contexts.

Development of Research Questions

The research questions underlying the analysis derive from the literature review and focus on the factors motivating larger incumbents to acquire smaller firms and startups in software-based industries. Related to the latter point, 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. Terwiesch et al. (1998) stress that R&D performance is more crucial for the economic success of larger incumbents than for younger firms with lower market shares, which suggests that they are more likely to substitute R&D weaknesses by means of acquisitions.

The relevance of acquisitions for substituting R&D weaknesses can also be linked to theoretical arguments concerning obstacles to innovation in larger firms. Hauschildt (1999) and Henderson (1993) provide examples why firms may not be able or willing to carry out specific types of innovation. Obstacles to innovation can emerge on the one hand in the sense that larger firms are not able to carry out specific innovations. One of the main reasons for this can be that some innovations are organisationally radical (Henderson, 1993; Henderson &
Clark, 1990). One response of firms to not being able to carry out an innovation at acceptable
cost can be the acquisition of technology-rich targets in order to make up for their missing
capabilities. This paper aims to extend the knowledge about motivations and mechanisms by
clarifying which factors determine the acquisition of relatively young and technology-rich
target firms and how the pattern of acquisitions evolves (i.e., what the acquisition dynamics
are and how they can be explained). Important dimensions of technological acquisitions that
have been used in the literature to address these aspects are the number of acquisitions as well
as their technological value ((Desyllas and Hughes, 2008; Hoetker, 2005; Puranam et al.,
2003; 2006; Cloydt et al., 2006). Based on the arguments presented in this section, the main
research questions to be addressed in the empirical analysis to follow are:

1. Is acquisition in the EDA industry motivated by substitutiveness or complementarity with
own R&D? Does the association differ depending on the dependent variable? Do acquisitions
relate more to radical or incremental innovation and what are the root causes for such a focus?
2. Do acquisitions relate mainly to specific technology segments acquired at one point in time
by all firms? What is the timing, i.e. when are targets acquired? Can timing and segment
specificity be related to the substitutive versus complementary nature of acquisitions?

Empirical Research Context and Methodology

The empirical analysis centers on one specific sub-segment of the global semiconductor
industry, namely Electronic Design Automation (EDA) that has very beneficial characteristics
for addressing above research questions. First, EDA is a relatively concentrated industry that
is characterized by continued acquisition activity. Secondly, because of its embeddedness in
the semiconductor industry, there is permanent demand for innovation from EDA firms.
Given the exploratory nature of this study and the above research questions, a multi-stage
empirical strategy is considered appropriate (e.g. Miles and Huberman, 1994). The analysis
therefore initially employs statistical and econometric analysis of the more aggregate quantitative aspects of the above research questions based on primary data collected from established sources such as the SDC Platinum and Worldscope Disclosure databases and the U.S. Patent and Trademark Office. This quantitative data covers the acquisitions by the 14 largest firms in the EDA industry during the period of 1981 until 2005. Data was collected on a number of explanatory variables concerning various firm characteristics (leverage, sales, R&D intensity as a measure for R&D efforts and inputs, liquidity, patents granted and firm location). Patents of acquirers are a measure of R&D output and productivity (if normalised by sales for acquirers). These explanatory variables are potential determinants of the dependent variables relating to acquisition behaviour.

In keeping with extant literature, the dependent variables of the analysis are the total number of acquisitions and the number of patents granted to a target prior to acquisition. Whilst the former variable is a good activity measure that can help to understand dynamic aspects, target patenting prior to acquisition can be used to assess the extent of its technological base. 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 in the literature before (Cloodt et al., 2006) and is considered a suitable balance between the declining value of a target’s knowledge stock 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.

Both dependent variables are based on count data and therefore a negative binomial model is used. To analyse panel data as is at hand here, two well-established models exist, namely random and fixed effects (Johnston & DiNardo, 1997). The difference between the fixed effects and the random effects model is based on whether the time-invariant effects are

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1 It was not possible to use operating margin and cash flow as measures for profitability, since these were highly correlated with R&D intensity. Therefore, sales growth was used as a joint proxy for profitability and industry opportunity.
correlated with the regressors (which is the case for the fixed effects) or not (in case of the random effects model). For these models, the specification is:

\[ u_{it} = c_i + e_{it} \]  

\[ s_{it} = \alpha + \beta' X_{it} + c_i + e_{it} \]  

where \( i = 1, \ldots, N \) units under observation, and \( t = 1, \ldots, T \) time periods for which data were collected. \( S_t \) denotes the relevant dependent variable for a firm \( i \) in period \( t \) (number of acquisitions or number of target patents), \( X_{it} \) represents a set of independent variables, \( \beta' \) a vector of coefficients for the independent variables, \( c_i \) unobserved individual heterogeneity and \( e_{it} \) an idiosyncratic error satisfying \[ E[e_{it}|X_{it}, c_i] = 0 \] that is, the model assumes no correlation between \( e_{it} \) and \( c_i \). For the negative binomial 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 \( X_{it} \). This means that although the basic specification given in (1) and (2) remains identical, 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. Because 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 test is used.

To enable an analysis of the remaining aspects of above research questions, the aggregate quantitative analysis of acquisition in the EDA industry on the first stage was supplemented on the second stage by a more fine-grained analysis of a subset of the data which was augmented with secondary data from trade journals, industry publications, company websites, a content analysis of Securities and Exchange Commission (SEC) filings and qualitative primary data from 14 exploratory (semi-structured) interviews with founders, senior
professionals and experts with detailed knowledge of the EDA industry. Specifically, for the largest three firms in the industry and the period between 1989 to 2004 data on the age of the target at the time of acquisition, more detailed information on the main business segment the target was active in, and more detailed information on acquisitions in specific segments in terms of case studies and deal values was gathered. This additional data collected on a subset of entries in the large scale dataset that formed the basis for the first stage of the empirical analysis helps to address in particular whether acquisitions relate more to specific technologies acquired at one point in time by all firms, whether acquired firms in the EDA industry pursue more radical innovation than the acquiring firms, and what the timing of acquisitions is.

Results

Analysis of first set of research questions

Aggregate quantitative analysis

In order to address the first set of research questions posed namely what the reasons were for acquisitions the EDA industry, especially with regard to their substitutive or complementary relationship with the acquirers’ own innovation activities, panel regression models were estimated to identify significant determinants of the acquisition behaviour of large firms in terms of extent (total number of acquisitions) and degree of technological knowledge acquisition (as measured by the total number of patents granted to the acquired firms in the acquisition year and the five years prior to it). Tables 1 and 2 summarise these estimations. As can be seen from Table 1, concerning the total number of acquisitions made, a significant association is found for acquirer sales levels. For the R&D and patenting intensities the

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2 Interviewees were based in the USA as well as in Germany and represented the two largest as well as some of the smaller firms in the EDA industry, major clients of EDA firms in the semiconductor industry, and academics from universities and major research centres in USA and Europe. Interview lasted between one to two hours with three interviews being carried out over the phone and the remainder in person. Where necessary, interviews were translated into English for analysis purposes.

3 The results for a model including the logarithm of Tobin’s Q as additional measure of profitability and economic opportunities yielded very similar results and are thus not reported here due to size limitations.
association is significant and negative.

Table 1: Negative binomial model, dependent variable: total number of acquisitions

<table>
<thead>
<tr>
<th>Variables</th>
<th>Random effects estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial leverage (total assets to total equity)</td>
<td>-0.4462 (0.3216)</td>
</tr>
<tr>
<td>Current ratio (current assets to current liabilities)</td>
<td>-0.0772 (0.1194)</td>
</tr>
<tr>
<td>Sales growth (% over previous year)</td>
<td>0.0022 (0.0034)</td>
</tr>
<tr>
<td>Sales (natural logarithm of net sales in mn €)</td>
<td>0.4045 (0.1296)**</td>
</tr>
<tr>
<td>R&amp;D intensity (R&amp;D expenditure to net sales in %)</td>
<td>-0.0463 (0.0218)**</td>
</tr>
<tr>
<td>Missing R&amp;D intensity data (dummy; 1 = missing)</td>
<td>-29.4861 (1218611.5)</td>
</tr>
<tr>
<td>Patenting intensity (Patents granted by application year to net sales in %)</td>
<td>-0.0233 (0.0127)*</td>
</tr>
<tr>
<td>Missing Patenting intensity data (dummy; 1 = missing)</td>
<td>-0.2490 (0.5038)</td>
</tr>
<tr>
<td>Company headquartered in Europe (dummy; 1 = yes; base category: United States)</td>
<td>-0.1852 (0.5309)</td>
</tr>
<tr>
<td>Company headquartered in Asia (dummy; 1 = yes; base category: United States)</td>
<td>-1.0021 (0.6245)</td>
</tr>
<tr>
<td>Constant</td>
<td>14.7703 (637.8766)</td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-114.63298</td>
</tr>
<tr>
<td>Log (r)</td>
<td>18.60954</td>
</tr>
<tr>
<td>Log (s)</td>
<td>3.682155</td>
</tr>
<tr>
<td>No. of observations (individuals)</td>
<td>105 (14)</td>
</tr>
<tr>
<td>Wald Chi²</td>
<td>42.86 &lt; 0.001</td>
</tr>
<tr>
<td>Hausman specification test Chi²</td>
<td>0.00</td>
</tr>
<tr>
<td>p-value</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Notes: Significance levels: * p < 0.1; ** p < 0.05; *** p < 0.01; unbalanced panel data with observations per group: min = 3; max = 13; average = 7.5; Likelihood-ratio test vs. pooled: Chi² = 0.22, p-value >= Chi² = 0.318

To assess in a more direct way the innovativeness of the acquired firms is to evaluate their stock of technological knowledge. This is done in the model reported in Table 2 for which the dependent variable is the number of patents acquired by the target in the five years prior to acquisition. As can be seen in Table 2, the main factors significantly associated with the
number of patents granted to the target are sales (positively), patenting intensity (negatively) and if the company is headquartered in Europe (positively). The coefficient of the patenting intensity in Table 2 is considerably greater it was before in the case of the number of acquisitions. Together with the fact that the coefficient for R&D intensity is not significant this is an important finding whose implications are discussed in detail in the conclusions.

Table 2: Negative binomial model, dependent variable: patents granted to target in 5 years prior to acquisition

<table>
<thead>
<tr>
<th>Variables</th>
<th>Random effects estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial leverage (total assets to total equity)</td>
<td>0.2068 (0.4146)</td>
</tr>
<tr>
<td>Current ratio (current assets to current liabilities)</td>
<td>-0.3507 (0.3348)</td>
</tr>
<tr>
<td>Sales growth (% over previous year)</td>
<td>-0.0083 (0.0102)</td>
</tr>
<tr>
<td>Sales (natural logarithm of net sales in mn €)</td>
<td>1.0966 (0.2969)**</td>
</tr>
<tr>
<td>R&amp;D intensity (R&amp;D expenditure to net sales in %)</td>
<td>0.0097 (0.0142)</td>
</tr>
<tr>
<td>Missing R&amp;D intensity data (dummy; 1 = missing)</td>
<td>-24.3519 (203473.2)</td>
</tr>
<tr>
<td>Patenting intensity (Patents granted by application year to net sales in %)</td>
<td>-0.0663 (0.0261)***</td>
</tr>
<tr>
<td>Missing Patenting intensity data (dummy; 1 = missing)</td>
<td>-0.5224 (1.0713)</td>
</tr>
<tr>
<td>Company headquartered in Europe (dummy; 1 = yes; base category: United States)</td>
<td>2.2475 (0.9131)***</td>
</tr>
<tr>
<td>Company headquartered in Asia (dummy; 1 = yes; base category: United States)</td>
<td>0.7629 (1.3680)</td>
</tr>
<tr>
<td>Constant</td>
<td>-8.3025 (2.4877)***</td>
</tr>
</tbody>
</table>

Log-likelihood Log (r) Log (s) No. of observations (individuals) Wald Chi² p-value Hausman specification test Chi² p-value
-122.23788 13.90972 16.99318 105 (14) 22.56 < 0.0125 0.00 1.000

Notes: Significance levels: * p < 0.1; ** p < 0.05; *** p < 0.01; unbalanced panel data with observations per group: min = 3; max = 13; average = 7.5; Likelihood-ratio test vs. pooled: Chi² = 0.00, p-value >= Chi² = 1.000
Overall, the results show that patenting intensity has consistently a significant negative association with two different measures of acquisition behaviour in the EDA industry. This strongly supports the notion that acquisitions compensate weak innovation output indicated by lower levels of acquirer patenting intensity. Furthermore, the argument, that acquisition of innovation is a substitute for own R&D efforts is supported by the results as concerns the number of acquisitions. In addition to these overall results of the aggregate quantitative analysis, evidence for substitutive relationship also emerges from the exploratory interviews.

Qualitative interview analysis

In particular, in the interviews different reasons for acquisitions were referred to, which however all suggest substitutive role of acquired technological knowledge and hence confirm results of the aggregate quantitative analysis, as for example in the following quote: “With Synopsys .. making the acquisition of Avant! ... you have another example where you see that acquisitions are helping the big ones to ... implement new technology, breakthrough technologies, to fill the gap” or “When Cadence acquired Simplex, it was to fill a hole ... So that means, here in this case it was to fill a hole that Cadence was no more able to fill. After ... all the internal tentative to develop a new tool and fill the gap ... the decision was to acquire Simplex, which was a growing startup at that time which already had a solid base of customers and a challenging technology”. 

Next to this evidence for a direct substitutive relationship, the interviews also support the notion of substitutive acquisitions as an indirect solution to address difficulties with the internal creation of technological knowledge, as is witnessed by the following statements: “This is another thing characterising the market that they buy firms so that the competitor does not buy them. This is especially the case for Cadence, but also Synopsys has moved in the meantime somewhat in this direction” and “Of course there are forces, namely: I buy to avoid others buy”. These statements suggest that if incumbents would not make an
acquisition, then competitors derive advantages from this and therefore acquisition though not technologically beneficial for the acquirer still eases competition and is desirable from this standpoint.\footnote{However, such an indirect solution to cope with the incapability of timely in-house development does not seem generally rational for incumbents, since they could invest the same resources into acquiring a suitable target that directly mitigates their weakness. Therefore, only if such a target is not available, the behavior described in the interview quotes seems rational.} In line with this logic, it is also stressed that targets are acquired to gain control of IP rights which are different to technology, since acquirers do not need the technology protected by the IP right, as is illustrated in the following quote: “You buy a company just because of the IP so that you can sue somebody else ... that has happened and right now, well people in EDA will try to get as much IP as they can”. Consistent with the capabilities identified earlier, it was also suggested in the interviews that in the large firms in the EDA industry levels of internal innovation are low and that these large firms are not very good internally in investing into new technologies. Furthermore, the acquisition of human capital was stressed as an important factor as is witnessed by the following quote from the interviews: “sometimes you buy a company because of the people who are in that company”. As the underlying root cause to the substitutive link identified in the aggregate quantitative analysis and confirmed in the qualitative analysis presented so far, interviewees suggested organizational radicality and inertia as well as a strong focus on existing customers, both of which relate well to extant literature which proposes that acquirers are incapable to develop technology at all or quickly enough themselves in the first place (Henderson, 1993; Christensen, 1997). The following quotes provide evidence that incumbents are indeed too slow or incapable in stating that for them: “.. it’s better to acquire technology to have something up and running rather than spending time developing it themselves or they failed developing it ...” and “Why are they acquiring? It is because there are competitive threats. So that means a hole in the flow that I am not able to fill”.

Reasons for this failure of acquirers to develop technology in time or at all were identified in the interviews: “Within such a big organization, there is always a lot of politics, who is going
to be next big one, I mean the head of the business unit. That means if you have different groups they are certainly consolidated between certain business units. So, let’s say ‘analog’ is developing all the analog stuff, but within ‘analog’ you have the layout, the schematics and who is going to head that, is it someone who is coming from the schematic or from the layout? So you have always .. battles” and “They are getting too heavy, I mean too big, that means they are losing their dynamics in terms of reacting very quickly and tackling the niche issues and because of their background and legacy customers and legacy tools and so on, it is very difficult to them to propose complicated new stuff, because they have to provide intercompatibility and interoperability with the previous versions and the older stuff and so on”. Hence the interview quotes suggest that the substitutiveness identified at the level of the aggregate quantitative analysis can be related to organizational issues (Henderson, 1993), but also to market conditions as exemplified by the last quote. This relates well to the work of Christensen (1997) on disruptive innovation and also other remarks made by the interviewees confirm this notion. For example, lock-in by existing customers and demands from important customers were identified as factors inhibiting innovation and these are typical Christensen-type situations, as is illustrated in the following quote: “an important customer with an important legacy, and we need to do that [innovation] to keep the market” which refers to the core arguments and categories of the concept of disruptive innovation as defined in Christensen (1997). In summary therefore, the aggregate quantitative analysis and insights from the semi-structured interviews ultimately suggest generic weaknesses of incumbents as the main acquisition motive.

Analysis of second set of research questions

Augmented subset analysis

In order to corroborate this insight and to address the second set of research questions formulated above which refer to the type of target and innovation the data used for the aggregate quantitative analysis is augmented in the two ways described above in that firstly,
based on further results from the semi-structured interviews qualitative and contextual information is added that helps to better understand which insights from the analysis are peculiarities of the EDA industry and which can be generalised to other software-based high technology industries. Secondly, the subset of the data used in the panel estimations that formed the first (aggregate and quantitative) stage of the empirical analysis that was enriched based on the trade literature, database searches, and document reviews of the SEC filings of the three largest firms in the industry, is analysed quantitatively. Combining both augmentations in the following answers those aspects of the above research questions that could not be answered conclusively from the panel estimations which formed the basis of the first stage of the empirical analysis. The following Figures 1 and 3 show initially the long-term temporal pattern of acquisitions for the three largest firms in the industry, Cadence, Synopsys and Mentor for the time between 1989 and 2005 which forms the temporal basis of the more detailed analysis reported in the following. The figures show for all firms an upward trend in both, the number of acquisitions as well as the average deal value (in million USD). This seems to indicate, that at least the three largest firms have an extensive and persistent level of acquisition activity that increased in intensity over time.

\[5\] In the years 1989 to 2005, the percent share of acquisitions by these largest three firms in all acquisitions in the industry ranged between over 40% to 100%, the latter of which was the case in four years where these three firms carried out all acquisitions. In all but one year, the largest three firms carried out over half of the acquisitions.
For some periods of high acquisition activity, other explanations could however also be brought forward. For example, it may be that the burst of the internet bubble and the severe downturn in the semiconductor industry in 2000/2001 significantly influenced the acquisition activity of larger EDA firms. The burst of the internet bubble may have forced more startups and smaller firms to be acquired because other exit strategies such as an initial public offering were not possible anymore and venture capital was scarcer to finance growth or further development of the firm. On the other hand, the downturn in the semiconductor industry could have also led to reduced acquisition activity, so that both effects may have largely cancelled out.
To detail the generic temporal acquisition pattern reported in Figures 1 to 3 further, Table 3 provides examples of some of the recent acquisitions of Synopsys in order to give more detailed qualitative indications for the reasons and motivations of each acquisition and to identify important areas of the quantitative analysis to follow.
Going into detail and analysing examples of the most recent takeovers of Synopsys in Table 3 together with information on the specific aspects of each acquisition it becomes clear, that technological reasons and the purchase of innovation are a significant determinant of acquisitions. As can also be seen, a considerable number of acquisitions relate to IP, which confirms the interview findings. Whereas the first reason (purchase) can refer to both, radical as well as incremental innovation, the last one (IP gains) predominantly to radical innovation.

Table 3: Examples of recent acquisitions of Synopsys with detailed information

<table>
<thead>
<tr>
<th>Year</th>
<th>Company acquired, detailed information on target and acquisition reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>Stanza, Inc.: Move from logical to physical design; Stanza had 6 employees at time of acquisition; Customers of Stanza were National Semiconductor Corp, S3 Inc and C-Cube Microsystems Inc. Addition enables Synopsys to compete better with Cadence Inc. and Avant! Corp. in the field of deep submicron design tools.</td>
</tr>
<tr>
<td>1999</td>
<td>Gambit: Acquisition of 87.5% stake in Gambit who is a provider of automation services. During the fourth quarter of fiscal year 2000 Synopsis closed certain facilities acquired in the Gambit acquisition.</td>
</tr>
<tr>
<td>2001</td>
<td>C Level Design Inc.: Developer of computer integrated graphics systems whose technology assets (including the technology behind C Level's System Compiler software for RTL and a patent for synthesizing high level languages into HDL awarded in 2001 to C Level) were acquired by Synopsys to integrate the CycleC simulation technology into the Snyopsys VCS simulator.</td>
</tr>
</tbody>
</table>
2002 Avant!: Completion of Synopsys portfolio of physical design and verification products. Synopsys acquires Avant!’s Saber product, which offers mixed signal system level design tools for power, test, automotive, telecommunications and military/aerospace markets.

2002 inSilicon: Expansion of portfolio of standards-based connectivity IP for e.g. USB, IEEE 1394, 802.11.

2002 Co-Design Automation: Acquisition of a provider of computer programming services to assist in the development of state-of-the-art design language services, especially next generation hardware language verification technology for use in future releases of Synopsys verification products.

2003 Numerical Technologies, Inc.: Acquisition of a developer of subwavelength lithography solutions to complement existing design for manufacturing tools.

2003 Qualis Verification IP: Acquisition of the verification IP assets used to perform verification methodology consulting and training in order to integrate the Qualis’ Domain Verification Component (DVCTM) technology into the Synopsys DesignWare® Verification IP. As part of the acquisition key Qualis staff joined Synopsys, e.g. Janick Bergeron, CTO and expert for verification methodology.

2003 InnoLogic Systems, Inc.: The firm, which provides research and verification services to firms using silicon in their products was acquired jointly with the verification IP assets of Qualis, Inc. Synopsys states that bidding for future acquisitions may be intense, and that it may be difficult to acquire additional firms at acceptable prices.

2004 ADA Inc.: Acquisition of a leading provider of automated circuit optimization solutions for analog, mixed-signal and custom integrated circuits which extends the analog and mixed-signal offerings of Synopsys. According to Synopsys, the acquisition enables the introduction of novel analog and mixed-signal design technologies.

2004 Cascade Semiconductor Solutions, Inc.: Acquisition of the privately held developer of digital logic IP solutions and provider of PCI Express™ digital IP solutions which completed Synopsys’ PCI Express IP portfolio and extended Synopsys’ leading position in the PCI family of IP.

2004 Accelerant Networks: Acquisition of this private firm providing highly efficient technology for high-speed serial interfaces expands Synopsys’ IP portfolio to provide a full offering of standards-based and chip infrastructure IP. Synopsis notes that it can offer customers low-risk, integrated analog and digital IP solutions by linking Accelerant’s unique (serializer-deserializer) cores with its own digital ones.

2004 Integrated Systems Engineering AG: Expansion of the design for manufacturing (DFM) portfolio by acquiring a provider of technology CAD (TCAD) software products and services. Synopsys notes that DFM became more important to customers because DFM products reduce costs and minimize risks before an IC toe into production. TCAD software aims at transistor (device) structure modelling and simulation of the steps of semiconductor wafer manufacturing processes.

2005 HPL Technologies, Inc.: Acquisition of a provider of yield management and test chip software for the semiconductor and flat panel display industries, including semiconductor IP, data analysis platforms, factory floor systems and professional services. The acquired firm’s yield optimization tools are used by most of top 25 manufacturers. HPL engineering staff also joined Synopsys who was the first to offer a complete design-to-silicon flow to link directly into the semiconductor manufacturing process.

Sources: Synopsys website, SEC 10-K forms 2002-2004; EE Times website; Thomson

The following Table 4 summarises results on the first part of the second set of research questions formulated above. In order to assess whether the three largest firms in the industry (Cadence, Synopsys and Mentor) simultaneously acquire targets in similar fields of technology, based on detailed descriptions and the target SIC codes of the most recent acquisitions by the top 3 firms in the industry (like the one provided in Table 1 for Synopsys),
the technology segment most relevant for each individual acquisition was identified.\textsuperscript{6} Then, for each year, acquisitions were compared across the top 3 firms and identical fields of technology were identified. Table 4 identifies the number of acquisitions of each firm that were in a technology segment in which also the other firms made acquisitions in that year. The percentage figures provided give the percentage share in the total of the acquisitions of that firm that was related to technology segments where also the other firms made acquisitions. The right column of Table 4 provides the number of acquisitions in the technology segment out of total number of acquisitions of three largest EDA firms in the year.

Table 4: Homogeneity of acquisitions of the top 3 EDA firms based on technology field

<table>
<thead>
<tr>
<th>Year</th>
<th>Cadence</th>
<th>Mentor</th>
<th>Synopsys</th>
<th>Acquisitions in technology segment out of total number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>1990</td>
<td>100%</td>
<td>100%</td>
<td>0%</td>
<td>67%</td>
</tr>
<tr>
<td>1991</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>1992</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>1993</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>1994</td>
<td>100%</td>
<td>100%</td>
<td>0%</td>
<td>67%</td>
</tr>
<tr>
<td>1995</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>1996</td>
<td>100%</td>
<td>63%</td>
<td>100%</td>
<td>70%</td>
</tr>
<tr>
<td>1997</td>
<td>67%</td>
<td>0%</td>
<td>67%</td>
<td>67%</td>
</tr>
<tr>
<td>1998</td>
<td>14%</td>
<td>100%</td>
<td>33%</td>
<td>36%</td>
</tr>
<tr>
<td>1999</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>2000</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>2001</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>2002</td>
<td>33%</td>
<td>25%</td>
<td>33%</td>
<td>30%</td>
</tr>
<tr>
<td>2003</td>
<td>66%</td>
<td>20%</td>
<td>0%</td>
<td>27%</td>
</tr>
<tr>
<td>2004</td>
<td>40%</td>
<td>50%</td>
<td>0%</td>
<td>27%</td>
</tr>
</tbody>
</table>

\textsuperscript{6} Overall, nine segments are identified.
As can be seen, the overlap in technology segments as shown in Table 2 is very limited. Only in 8 of the 17 years analysed, an overlap was found at all. Even on these occasions, the overlap never constituted more than 70% of all acquisitions made by the three largest EDA firm in that year. This indicates that acquiring technology that is novel to the industry as a whole is not dominating the observed acquisitions, even though it seems to be a prominent occasion in some years (especially 1990, 1994, 1996 and 1997). From this it follows that several reasons matter simultaneously.

This is also suggested by the total number of acquisitions per segment. In all segments except one at least two firms did acquisitions and in one third of the segments all three large firms acquired. Furthermore, the number of acquisitions per segment differs only up to 60% between firms which was however only the case in one segment (in four segments the difference was 0%, in three it ranged between 28% and 50%, and in one only one firm acquired). All of the three largest firms acquired from 1989 to 2005 in three segments (in which, respectively, 11%, 50% and 14% of all acquisitions across this period took place) and only in one segment (representing 2% of all acquisitions of the largest three firms in the EDA industry over the period from 1989 to 2005), only one of the three largest firms acquired and the other two never did an acquisition.

Finally, there is no clear evidence of temporal clustering of acquisitions in specific technologies, even though in some segments acquisitions concentrate on shorter time periods (in all segments acquisitions take place in at least two years, in two in six years, in one each in 10 and 15 years, respectively). In four out of the nine segments, the time span between the first and last acquisition covers more than half of the 17 years studied. Only in four years (1989, 1990, 2000, 2005), all acquisition targets were from only one segment, to which however the majority of targets across all years belonged. In all other years, acquisitions took

As concerns the timing of acquisitions, based on 50 acquisitions (i.e. those of the acquisitions of the largest three firms during 1989 to 2005, for which the founding year of the target could be identified), a skewed distribution of target age at the time of acquisition can be identified. The mean age of targets at the time of acquisition is 7.62 years, whereas the median is 5 years (standard deviation: 5.42 years). This shows that acquired targets tend to have already some market experience, but that acquisition chances tend to become lower after a certain firm age. This interpretation is also confirmed by data on the deal values as far as it was available for the acquisitions carried out by the largest three firms between 1989 and 2005. The highest deal value is 827m USD and the mean is 145m USD (standard deviation: 184m USD). Again, the distribution is skewed with the median being 100m USD which somewhat corresponds to the distribution of firm age. This suggests, that most targets are not any more early-stage startups but also not very mature firms, which is also reflected in the following interview quote on the acquisition behavior of the largest three firms in the EDA industry: “They are never doing an acquisition on a very low rate. ... they are considering an acquisition only when the concept is matured-out and there are enough customers”.

Case study analysis

In order to provide more qualitative insight into acquisition dynamics in the EDA industry and to illustrate in detail some of the qualitative aspects related to acquisitions, a case study of one specific and very recent sub-segment of EDA is analysed in the following. This segment emerged because increasingly the products of the electronic design automation industry are integrated into 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. Hence a genuine sub-segment of the EDA industry which is focusing on this more recent trend,
namely design for manufacturability (DFM) emerged. The case study of this novel segment helps to better understand the interaction of some of the findings described earlier in the analysis. DFM is currently concerned with three main areas, namely critical area analysis, chemical mechanical polishing and lithography compliance check, with others emerging over the next several years (Goldman, 2008). An implication of this is that potential targets only compete directly with one another if they are in the same area, and hence acquisitions do not necessarily imply pre-emption towards competitors, which qualifies the interview results in this respect by suggesting that the indirect effect identified above may be less relevant than thought.

DFM is a relatively young sub-segment of the EDA industry with the number of firms being active in it changing from 15 (2004) to 25 (2005), 25 (2006) and 23 (2007), respectively (Gartner Dataquest, 2006; Gary Smith EDA, 2007; 2008). Notably, the development of the number of companies in the DFM sub-segment supports the notion of large incumbents acquiring new technologies, rather than developing them in house, and this was also confirmed by the interviewees. Indeed, several of the large incumbents have acquired DFM firms in recent years, most notably Synopsys acquired Numerical Technologies in 2003 and Cadence acquired Clearshape in 2006. According to the interviewees, Mentor developed its DFM tools largely in-house, but recently acquired Ponte.7 DFM is a technology where the demand is largely driven by chip manufacturing companies and firms at the electronic systems level. In the interviews it was acknowledged, that DFM is an area with very intensive development in recent years, where relatively many firms have entered.

Also, interviewees felt that DFM represents a major technological change in the industry, where success was considered pivotal: “... strategically these guys have the capability of doing DFM or they are really not going to be around in the next generation. So, the driving

7 Partly, the somewhat deviating behavior of Mentor as concerns acquisitions is linked to the geographic location of their R&D group in Oregon. This, according to one interviewee led to very little R&D staff turnover, whereas for large EDA firms located in Silicon Valley, the permanent transition of staff from the other two large firms into startups is much more pronounced and is also increasing the likelihood for these startups to become targets.
force behind that has been survival". One example of these emerging technological needs was the shift from rule-based to modeling-based DFM with the transition of chip geometries from 130nm (modeling unnecessary) via 65nm (modeling preferable) to 45nm (modeling essential). It was pointed out during the interviews that such shifts regularly occur every two years in EDA, thus driving particularly DFM-related technology needs. The fact that several of the young firms active in DFM have been acquired (with the two largest EDA firms both participating in this), indicates that they had developed technologically more superior tools than the large firms in the industry. What emerges is also that acquisition processes in reality can be rather complex (Goldman, 2008). For example, in the field of critical area analysis, Ponte has developed the leading technology and was subsequently acquired by Mentor. In chemical mechanical polishing, Clearshape developed the best technology and was subsequently acquired by Cadence. Finally, in the field of lithography compliance checking, a large incumbent (Synopsys) developed the leading technology. However, in 2004 Synopsys already acquired Integrated Systems Engineering of Switzerland in an early move into the DFM area. In summary, the DFM case study provides additional evidence against large firms acquiring in segmental waves, as was indicated by the earlier analysis based on Table 4, but also provides a more nuanced picture.

Conclusions

This paper contributes to better understand the acquisition dynamics in software-based high technology industries with a focus on the relevance of innovation aspects as well as the specificity and timing of acquisitions. As concerns the latter two points, the analysis of augmented data for the largest three firms in the EDA industry revealed no high segment specificity of acquisitions, i.e. all source a broad range of technologies externally. Therefore, acquisitions can be considered a generic phenomenon in EDA which is consistent with the substitutiveness of acquisitions with regard to own R&D efforts and outputs found in the
aggregate quantitative analysis and the underlying root causes identified in the semi-structured interviews, especially organisational rigidity/inertia and market/customer demands. Since these root causes are generic issues, acquisitions should also be generic, i.e. across all segments, which the analysis of the augmented data for the acquisitions of the largest three firms confirms. Compared to the issue of selectivity, the question of timing is less clearly resolved in that both, acquisitions early on or later when a target is proven in the market seem feasible in the light of organisational rigidity and are encountered in the data analysed.

The results also suggest links to the work of Christensen (1997) and his concept of disruptive innovation in that large firms in the EDA industry were found have an overly strong focus on existing customers. However, it seems that it is not the case that the large firms in the EDA industry go out of business or significantly underperform because of this (as is the usual implication of Christensen’s theory), but that they often manage to mitigate their mistakes by means of acquisitions. Therefore the findings are not fully consistent with Christensen’s theory in that the mistake of staying on an existing technological trajectory is frequently not lethal or seriously damaging to large incumbents, but at least in some cases can be corrected. Yet, there are also some periods in the EDA where the whole set of established firms went out of business during the transition from one period to the next. Here the full logic of Christensen’s seems to apply, but evidently it does not in all situations. It seems that the disruptive innovation mechanism was lethal in the EDA industry particularly in the big shift from being a hardware-based industry in the first generation to becoming a solely-software-based industry later on, but that with the capital extensive software base of the industry now the innovator's dilemma can be circumvented by means of acquisitions. This enables the “fast second” strategy proposed by Markides and Geroski (2005), but Christensen-type focus on existing customers also helps to explain why acquisition takes place rather late and at higher cost as is indicated by the results of the augmented quantitative analysis and the comments
made in the semi-structured interviews. Therefore, one important academic contribution of this research is that it qualifies the concept of disruptive innovation by identifying conditions under which large firms remain unaffected by this phenomenon. Beyond this the analysis also contributes to better understanding the fundamental logic that underlies the rich acquisition dynamics described for the different levels of analysis in the EDA industry in this paper.

Innovation as a reason for acquisition requires 1) the suitability of acquisitions for large incumbents to source technology and 2) possibility for acquisition (i.e. existence of targets with an available product or technological solution) as necessary conditions. As concerns 1), the findings discussed so far confirm the suitability of acquisitions to substitute own R&D activities of incumbents in the EDA industry. As the semi-structured interviews reveal, a need for acquisitions can exist if for a novel technology (e.g. DFM), none of the incumbents has access or if for an existing technology only the focal firm is lagging, whereas other incumbents have it already (e.g. in the case of the Avant! acquisition by Synopsys).

As concerns 2), in terms of innovation ecosystems and evolutionary notions such as path dependency the EDA industry (and other software-based industries) can be characterised by a number of structural features that explain the acquisition dynamics observed empirically. Firstly in terms of structure, the low capital intensity of the industry matters, which enables with low capital investments. Related to this, in the software-based EDA industry organisationally radical innovation largely emerges from entrants, whereas incremental innovation largely comes from incumbents. Hence the value of what can be gained by acquiring a target is high and because of low capital intensity is available at reasonable prices.

A second aspect that matters for acquisitions in the EDA industry (in that it creates a permanent technology gradient and innovation demand by customers) is the continuous need for innovation in the semiconductor industry at large. This relates to the question why there

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8 As concerns the phenomenon that second tier EDA firms acquire, the interviews and the historic acquisition dynamics and patterns in the EDA industry suggest that this can well to a chain of acquisitions, where usually one of the largest three firms in the industry eventually acquires this second tier firm. Hence the ultimate pattern in the industry seems to remain largely unchanged.
are always new niches opening up in the EDA industry that provide interesting options for startups to pursue promising innovation activities. It seems that the constant occurrence of niches is driven by the continuous innovation demand due to the semiconductor industry being based on cumulative technological progress. Whilst this does not necessarily imply innovation activity by entrants it seems that this feature in combination with high uncertainty in both, the EDA and the broader semiconductor industry results in large firms being cautious in terms of radical innovations, leaving the floor on this to small firms and startups. This was also confirmed in the semi-structured interviews.\(^9\)

Finally, an important ingredient for the evolutionary stability of the EDA industry innovation ecosystem that has emerged over time is the cumulative nature of products which consist of a continuously increasing number of sequenced modules. The creation of these products is path dependent, and earlier entrants (i.e., incumbents) are at an advantage as concerns flow completion. This increasingly makes direct market entry difficult for startups in the industry. In sum, the empirically observable acquisition dynamics in the EDA industry seem to be the superposition of the low capital structure and the permanent occurrence of new niches combined with the historic trend of flow completion. This means that a new technology can easily emerge through innovation activity of a small firm and incentives for startups and small firms exist due to the continuous demand for innovation in the semiconductor industry. This can happen today as easy as it could in the past, and the case of DFM which was described above is as a case study witnessing this. What has changed though is the possibility for firms to grow on their own which was much easier in the past. Because over time it became increasingly difficult for startups to grow by themselves, the occurrence of acquisitions has unavoidably increased and stabilized at high activity levels. This is exactly what was observed

\(^9\) An open question is here, why uncertainty is so high, but it seems that this also has to do with the nature of cumulative technological progress in the industry and the complex compound probabilities resulting from this.
empirically in the augmented and aggregate quantitative empirical analyses reported above.\(^{10}\) Given the capital extensiveness of the sector, acquisition is not very costly (as is confirmed from the augmented quantitative analysis) and thus seems to be more frequently then licensing or cross-licensing which is often observed in the more capital intensive chip manufacturing segment of the global semiconductor industry.

Next to explaining the logic behind the observed acquisition patterns in one specific software based industry, this paper could also relate the substitutive nature of acquisition activities that emerged from the aggregate quantitative analysis to qualitative mechanisms that were developed in the seminal works of Henderson (1993) and Christensen (1997). It also provided evidence in the augmented acquisition data of the largest three firms in the industry, that the implications of this are consistent with specific aspects of acquisition behavior, namely timing and segment (un-)specificity.

In terms of management implications from this analysis, targets and acquirers need to be distinguished. As concerns incumbents, acquisitions should be considered as an important means to substitute lacking competences and structures in the face of organisationally radical innovation. They can also help to reduce diseconomies of time compression and significant internal resistance from NIH (not-invented-here). Acquisitions therefore reduce the R&D cost and help to counter low R&D efficiency. The results of the aggregate quantitative analysis furthermore suggest that acquirers use acquisitions to compensate their main weaknesses. More specifically, results suggest that they differentiate between input and output aspects of R&D performance. Firms with low patenting intensity in this acquire targets with many prior patents, which is consistent with the findings of Loch et al. (1996) who suggest that a strategy

\(^{10}\) However it is unclear, if the ceteris paribus condition is really fulfilled in terms of the number of startups remaining constant. The latter seems to be only the case if either that the number of emerging technological niches remains constant or if at least the product of the number of technological niches and the number of startups per niche on average remain constant. It is not fully clear whether there is a mechanism that guarantees this. It seems that the cumulative nature of technological progress in the semiconductor industry at large could be such a mechanism. Otherwise the number of startups could decline in the less attractive conditions that develop continuously through the increasing completion of the design flow in terms of the tools offered by large firms in the industry or temporarily through recessional periods (when exit becomes more difficult).
aimed at increasing the overall efficiency of a firm’s R&D process by acquiring were an incumbent has the biggest weaknesses is most successful. This fits with the finding of a significantly stronger negative coefficient of patenting intensity and an insignificant coefficient for R&D intensity when prior target patenting is the dependent variable.

As concerns small firms and startups, the findings of this research suggest that they should be conscious of the conditions in their industry with regard to growth and entrepreneurial success. For example a high degree of industry concentration, a cumulative product nature or the need for other complementary assets may impede firm growth. Since it has been shown that smaller firms compete well based on superior technical performance (Terviewsch et al., 1998) the option of being acquired becomes important and should be addressed strategically.

Finally, as concerns limitations of the analysis, the factors ensuring the permanent supply of potential targets into the industry were not at the forefront of this paper. Still they seem to be an important element for the ultimate success of the innovation ecosystem (Adner, 2006) that enabled the persistent and increasing acquisition trend in the EDA industry in the first place. One explanatory factor for the supply side seems to be the permanent emergence of new technological needs, which is at least partly driven by the Industry Technology Roadmap for Semiconductors (Walsh et al. 2005). As one interviewee commented, “the entrepreneurial nature of the EDA business usually creates opportunities” which also reflects a notion well established in the entrepreneurship literature (Shane, 2000, 2003; Shane and Venkataraman, 2000) about the pivotal role of high level of technological opportunity especially for the creation of new firms and their market entry in high technology industries. Future research should aim for a better understanding of the supply side of the EDA industry and based on this try to formulate more general insights for the purposeful design of innovation ecosystems (Adner, 2006; Adner & Kapoor, 2010) in which the respective structural advantages of smaller and younger firms and larger incumbents are combined in order to increase the effectiveness and efficiency of innovation activities.


<table>
<thead>
<tr>
<th>Variables</th>
<th>Mn.</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
<th>Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Financial leverage</td>
<td>1.73</td>
<td>0.78</td>
<td>1.08</td>
<td>6.36</td>
<td></td>
</tr>
<tr>
<td>2 Current ratio</td>
<td>2.52</td>
<td>1.71</td>
<td>0.6</td>
<td>12.09</td>
<td>-0.36 ***</td>
</tr>
<tr>
<td>3 Sales growth over last year</td>
<td>35.42</td>
<td>97.32</td>
<td>-30.65</td>
<td>716.69</td>
<td>-0.07 -0.01</td>
</tr>
<tr>
<td>4 Sales</td>
<td>11.62</td>
<td>1.54</td>
<td>7.28</td>
<td>14.17</td>
<td>-0.06 -0.17* -0.32***</td>
</tr>
<tr>
<td>5 R&amp;D intensity</td>
<td>32.68</td>
<td>83.9</td>
<td>0</td>
<td>828.97</td>
<td>0.02 0.67*** -0.29***</td>
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<td>6 Patenting intensity</td>
<td>122.07</td>
<td>499.53</td>
<td>0</td>
<td>4137.93</td>
<td>0.02 0.59*** -0.34*** 0.91***</td>
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<tr>
<td>7 Patent stock</td>
<td>8.56</td>
<td>1.31</td>
<td>4.75</td>
<td>9.53</td>
<td>-0.02 -0.38*** -0.19*** 0.05</td>
</tr>
<tr>
<td>8 Firm headquartered in Japan</td>
<td>0.07</td>
<td>0.26</td>
<td>0</td>
<td>1</td>
<td>-0.14 0.39*** -0.1 0.04</td>
</tr>
<tr>
<td>9 Firm headquartered in Europe</td>
<td>0.15</td>
<td>0.36</td>
<td>0</td>
<td>1</td>
<td>0.11 0.11 -0.08 -0.25*** -0.07</td>
</tr>
<tr>
<td>10 Firm headquartered in Asia</td>
<td>0.06</td>
<td>0.24</td>
<td>0</td>
<td>1</td>
<td>-0.08 -0.11 -0.05 -0.26** -0.06</td>
</tr>
</tbody>
</table>

*a  * p < 0.1; ** p < .05; *** < 0.01