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Organisation of Innovation in High-Tech Industries: Acquisitions as Means for Technology Sourcing[1]

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Abstract

Innovation activities in the semiconductor industry provide considerable challenges for technology and innovation management. In particular, firms frequently face make-or-buy decisions and such decisions have considerable management implications. The semiconductor industry has a long history of radical innovations which are taking place through distinct industry cycles of high and low demand. The paper investigates these issues for the Electronic Design Automation industry which is a specific sub-segment of the semiconductor industry. Based on database searches and structured interviews, the paper analyses empirically the reasons for make or buy decisions with regard to innovation and the level of acquisition activities of innovative small firms in the Electronic Design Automation industry. This analysis is supported by an analysis of the SEC filings of large firms in the Electronic Design Automation industry.

1. Introduction

Innovation activities in the semiconductor industry are diverse and driven by a variety of determinants. In particular, firms frequently face make-or-buy decisions, especially as concerns radical innovation. This, together with the cumulative and rapid nature of innovation makes innovation management a very challenging task in this industry. Especially, levels of R&D input are strongly affected by the highly cyclical nature of the industry, 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 firm's 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). Overall, the situation of the semiconductor industry can be characterised by strengthening patent rights and rapid technological change for cumulative technologies.

Electronic design automation (EDA) industry is a particular sub-segment of the semiconductor industry and focuses on chip design. Electronic design automation has a very clearly defined market structure and a number of small firms are active in the industry, which are frequently acquired by larger firms in the industry. The electronic design automation industry covers a number of complex processes from chip design through to testing. It can be subdivided in a large number of segments which focus on special aspects of design and testing processes. Increasingly, the products of the electronic design automation industry also get integrated 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.

The remainder of the paper is structured as follows. In Section 2, the different theoretical perspectives on innovation in the electronic design automation industry are introduced. An important aspect of this is also the perspective of innovation networks (Nooteboom, 1999; 2000) which refers to innovation networks as means for developing radical innovations. Subsequently, based on document reviews, structured and semi-structured interviews, the paper reports empirical findings on the motivation for make or buy decisions with regard to innovation and the actual process of acquisition of innovative small firms in the electronic design automation industry. The perspectives developed in

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Section 2 enable detailed analysis of rationales for and determinants of acquisition versus own innovation in this particular sub-segment of the semiconductor industry. The document review is based on a content analysis of the Securities and Exchange Commission (SEC) filings of the three largest firms in the industry. Finally, based on the findings of the empirical analysis, the paper draws conclusions as to whether the theoretical expectations can be confirmed.

2. Theoretical perspectives and development of research questions

Classical themes of technology and innovation management and the related concepts of architectural and competence-destroying innovation have particular relevance in the EDA industry, such as the distinction between radical and incremental innovation. These concern for example whether small start-ups are largely responsible for incremental innovation or whether radical innovation requires large-scale industry cooperation as has been set up in the past in semiconductor manufacturing. The paper discusses these aspects in some detail from a theoretical perspective and draws in doing so mainly on new institutional economics and transaction cost economics. This line of thinking may be particularly relevant for the EDA industry, since Sangionvanni-Vincentelli (2003) argues that partnering, intensive research collaboration and innovation networks may be needed to bring about radical innovation there.

In addition to this, another stream of scholarly work of relevance here is the economic theory of mergers and acquisitions and the numerous empirical studies related to it. Section 2 links theorising based on innovation and technology management theories with the economic theories of mergers and acquisition and based on this formulates questions about the conduct of firms in the EDA industry. Two aspects are noteworthy in this respect:

(i) Innovation cooperation in its various forms (see e.g. Tidd et al., 2005) can foster radical innovation. This seems to be particularly true for innovation networks, see e.g. DeBresson and Amesse (1991), which have been shown to successfully yield innovation on a number of occasions, and in the semiconductor industry in particular in terms of Sematech (Flamm, 2003; Spencer, 2003).

(ii) The acquisition of innovative start-up firms by means of takeovers can equally foster radical innovation in situation where large firms are lacking relevant competencies to carry out the innovation. Yet, this approach may be limited in that small firms are sometimes not capable to carry out specific radical innovations themselves, e.g. due to the limitations of newness and smallness they often face. In this case again, innovation cooperation may be necessary. Innovation networks as a specific form of innovation cooperation are therefore discussed in more detail in the following section before looking at economic arguments for acquiring innovation.

Innovation networks

Recent research on innovation networks (Tidd et al., 2005) has shown that innovation networks are often considered when innovation is so radical that no subgroup of firms can achieve it, but only a network. It may be in this case that a number of (larger or smaller) firms on the same level of the value chain cooperate closely (examples for such cooperation are Sematech in the USA or the cooperation of small textile firms in Italy’s industrial districts).

Three main theoretical perspectives on innovation networks can be identified. These are:

1) network theory based on e.g. the idea of weak versus strong ties and the notion that especially innovation networks integrate partners that represent loose ties, thereby increasing the search capability of the corporation, whereas other (e.g. bilateral) innovation cooperation such as joint ventures are more focused on strong ties (Granovetter, 1985).

2) a perspective on innovation networks from the perspective of strategic management drawing on the well developed resource- and market-based views;

3) a transaction cost-based approach rooted in new institutional economics and focussing on cost-benefit considerations.

From a network perspective, innovation cooperation can be horizontal or vertical. Whilst Gemünden et al. (1996) focus on vertical relationships along the supply chain and horizontal ones outside the competitive space, Hamel et al. (1989) propose that horizontal cooperation with direct competitors in the supply chain can improve the focal firm’s performance and results.

From a transaction-cost based point of view typical risks in innovation networks and how networks address these can be analysed in order to explain, why firms remain in the network despite of the risks associated. Notably, transaction cost and also network-based approaches to analysing innovation cooperation and innovation networks are not always suitable to address strategic advantages that result from innovation cooperation. Therefore, a complementary analysis from a strategic management perspective (e.g. based on the market- and/or resource-based views) seems advisable, which also relates to mergers and acquisitions.

Mergers and acquisitions

Economic theory has proposed a number of reasons for mergers and acquisitions (see e.g. Morris and Hay, 1991;

Milgrom and Roberts, 1992; Jansen, 2001).[2] For example under the assumption that the stock market is efficient, motives for a merger s or takeovers can be increased market power, reduced advertising and other promotional expenditure or efficiency gains which could not be realised without the merger. Other explanations that have been proposed for mergers are managerial takeovers, allocational takeovers, acquisitional takeovers or conglomerate mergers aimed at risk reduction (Morris and Hay, 1991).[3] Here, allocational takeovers refer to acquisitions which are motivated by a reallocation of assets to managers who make more efficient uses of them. This situation is possible if the assumption of fully-efficient firms is not made any more.

One of the reasons, why mergers and acquisitions may be a very appropriate means for innovation are studies into the obstacles to innovation, especially in larger firms. This body of literature (see e.g. Hauschildt, 2004; Henderson, 1993) points out that firms may not be able or willing to carry out specific types of innovation. Obstacles to innovation may emerge in the sense that larger firms are not able to carry out specific innovations. One of the main reasons fort his can be that some innovations are organisationally radical (Henderson, 1993; Henderson and Clark, 1990) either because firms do not have absorptive capacity (Cohen and Levinthal, 1990) or because such innovations require intensive learning and intellectual deliberation within the firm. Absorptive capacity can be lacking either because different or new skills of technologists or researchers of the larger firm are required (and essentially represent a problem of lacking human capital or lacking capabilities) or it can be that radically different organisational structures for R&D are required. Another important reason for an incapability to carry out specific innovations are certain ideological views or conservative attitudes in a firm, which Wheelwright and Clark (1992) refer to as a 'Product A filter'. Whilst such attitudes or views may be subjective from an external point of view, they may objectively deter innovation within the firm. Finally, a third reason why firms are incapable of certain innovations is that specific departments or individuals may attempt to avoid power redistribution as a result of an innovation being carried out or high risk aversion of individuals or departments (but not the firm as a whole).

Next to not being able to carry out specific innovations, firms may also simply not be willing to carry out specific innovations which they consider as being too risky for the firm as a whole. This may either be because the market development or the need fort he innovation is uncertain (market uncertainty) or because technological developments are uncertain or doubts regarding the operability of specific parts exist (technological uncertainty). Also, firms may object simply against the timing of an innovation. Another set of reasons may relate to large firms not wanting to irritate customers with too many innovations of which longer-term only few survive.[4] Thirdly, firms may not be willing to carry out innovations that imply the destruction of valuable assets or would render obsolete important competencies. Fourthly, objection may exist because of missing or limited fit of an innovation to existing products of the firm. If this means that individuals or departments objectively feel incapable of succeeding with such an innovation, than rejecting to carry it out in the first place may be individually rational. Fifthly, an innovation may economically radical either in terms of reducing cost or by increasing performance so much that existing products of the firm become uncompetitive. In such a case, a firm may decide not to carry out the innovation in order not to cannibalise existing products' sales.

Especially this last point is important since it may imply that large firms tend to favour incremental over radical innovations. Sangiovanni-Vincentelli (2003) claims, that start-up firms in the EDA industry have largely realised incremental innovations and that the level of radical innovation in the EDA may be too low, which refers back to the argument made in the previous that innovation networks are needed for radical innovation (Bingham, 2003). Jovanovic (1992) models the behaviour of small firms as drawing stochastically information on the market. Based on this information, the firms adjust their behaviour and their strategies. Those firms capable of learning based on new information are able to grow whilst those incapable cannot survive on the market. This can explain why larger firms acquire small firms that have managed to survive for some time on the market, as is suggested for the EDA industry. Larger firms in acquiring a surviving small firm gain information that has been translated in appropriate strategies. Especially in fast changing industries in which per definition the level of information generation is high, such acquisition behaviour may help to economise on the firm's resources by letting other firms carry out exploration and by then picking the survivors and in doing so acquiring an amplified signal from the market on which more easily decisions can be based. Linking this with the work of Utterback (1996) on the emergence of dominant designs and the subsequent focus on process innovation in an industry and the model of Klepper (1996) one can also conclude that smaller firms are particularly likely to emerge in areas where the dominant design has not yet been established. If these areas are those where information production is highest and where consequently mergers or acquisitions are most likely to occur, then this innovation may be more radical than argued by Sangiovanni-Vincentelli (2003) and Bingham (2003).

The above considerations on mergers and acquisitions show that these can be another efficient means for firms to carry out innovation by acquiring successful start-ups in the industry. In summary, there is evidence for the suitability of both approaches, innovation networks as well as mergers and acquisitions to realise (in particular radical) innovation in

[2] The terms takeover and acquisition are used interchangeably throughout this paper.

[3] Morris and Hay (1991) classify mergers based on the markets involved as horizontal, vertical or conglomerate mergers. They also suggest differentiating according to the type of transaction involved into agreed mergers, contested takeovers, divestments and management buy-outs.

[4] As concerns EDA, this may particularly be relevant, since the main software has a very well-defined flow of different process steps and changes may easily cause indirect problems in other parts of this flow which may require their reversal. Since this is process that is difficult to communicate to customers and thus potentially costly they may prefer to only make changes to this flow that have clear benefits and little potential for issues.

the EDA industry. For example, allocational takeovers may an important reason in the EDA industry if small EDA start-ups frequently come to a point when they do not realize their potential due to lack of complementary assets such as distribution channels or because of too slow growth. Based on the theoretical perspectives derived from extant literature especially on innovation cooperation and on mergers and acquisitions and their linkages to the EDA industry three research questions shall be addressed in the remainder of this paper:

1) Is there evidence of above-average merger activity in the EDA industry?

2) What are the reasons for mergers and acquisitions the EDA industry, especially with regard to innovation aspects?

3) If a significant part of the mergers or acquisitions in the EDA industry relates to innovation aspects, does this refer more to radical or more to incremental innovation?

3. Method and Results

Based on trade literature and database searches, semi-structured and structured interviews, the motivation for make or buy decisions with regard to innovation and the acquisition of innovative small firms by large incumbents is analysed. These provide insights into the rationales for and determinants of acquisition versus own innovation in this particular sub-segment of the semiconductor industry. The analysis of trade literature and databases is supported by a content analysis of the Securities and Exchange Commission (SEC) filings in order to achieve an overview of recent acquisitions.

Trade literature and database searches

The following Figures 1 to 3 show the acquisitions of the three largest firms in the industry, Cadence, Mentor and Synopsys. They show for all three firms an upward trend in both, the number of mergers as well as their value in million USD. This seems to indicate, that at least for the three largest firms that emerged during the second phase of the industry, an extensive and persistent level of acquisition activity with increasing intensity over time was the case.

For some periods of high acquisition activity, other explanations may 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 start-ups to be acquired because other exit strategies such as an IPO were not possible any more and also, venture capital was more scarce to finance growth or further development of the start-up's business idea or business model. On the other hand, the downturn in the semiconductor industry may have led to reduced acquisition activity, so that both effects could have largely cancelled each other out.

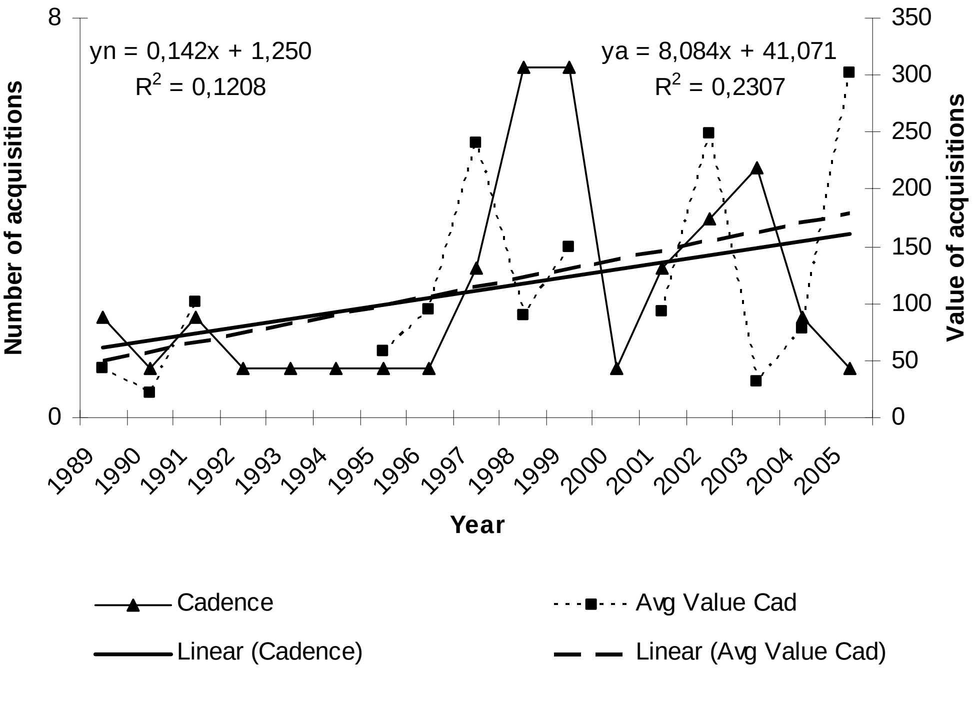

Figure 1: Cadence mergers (Sources: SEC 10-k forms 2002-2004, EE Times, Thompson)

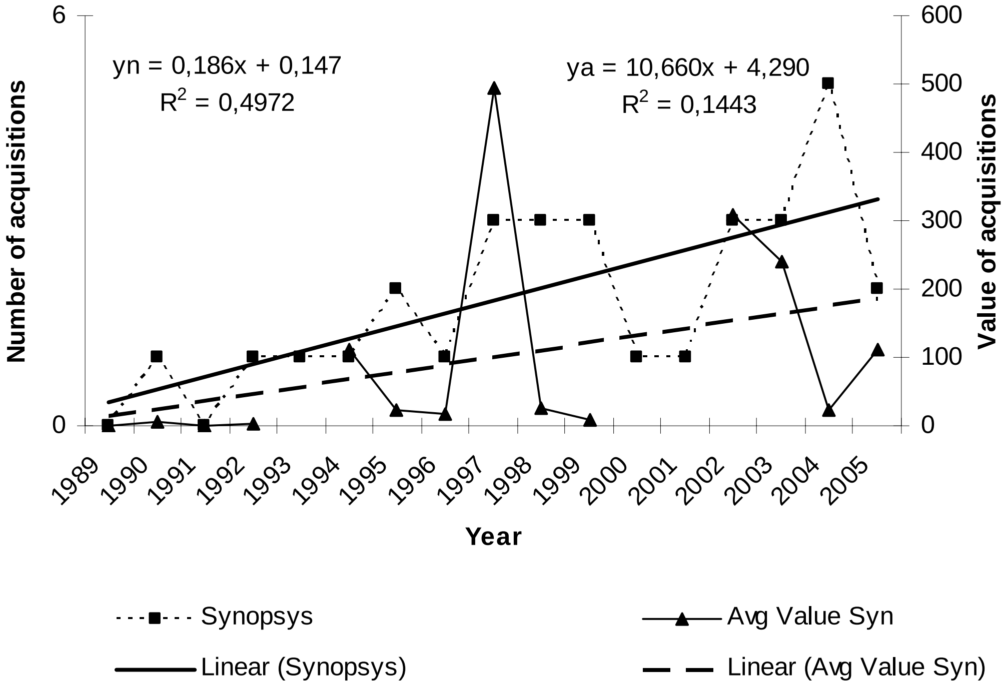

Figure 2: Synopsys mergers (Sources: SEC 10-k forms 2002-2003, EE Times, Thompson)

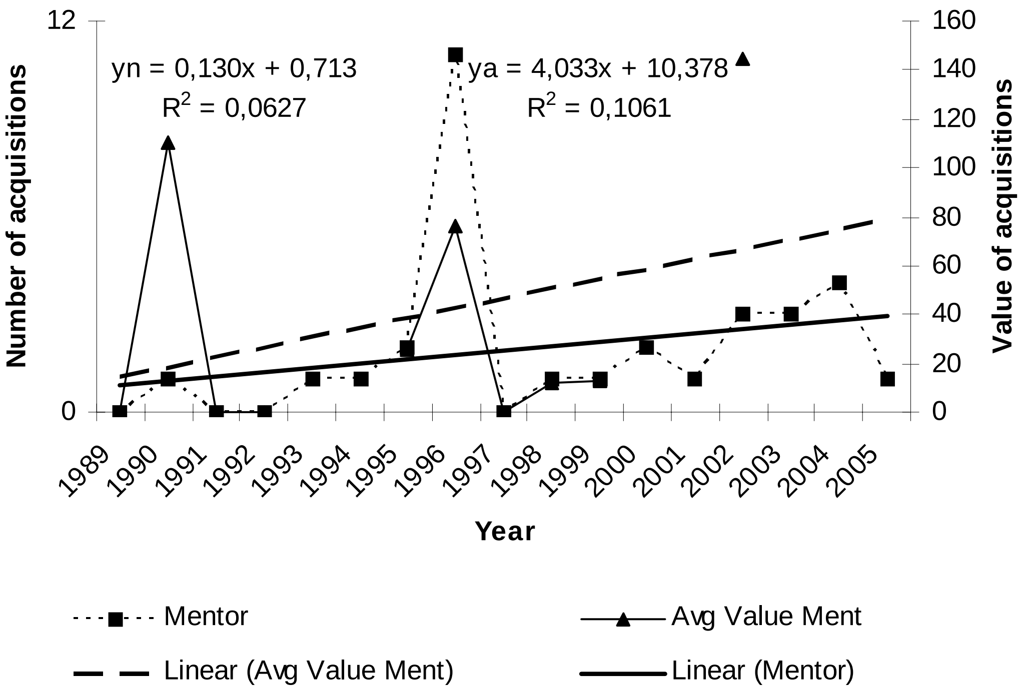

Figure 3: Mentor mergers (Sources: SEC 10-k forms 2002-2003, EE Times, Thompson)

The second research question posed was what the reasons are for mergers and acquisitions the EDA industry, especially with regard to innovation aspects. To address this, Table 1 provides an overview of the recent acquisitions of Synopsys in order to enable a more qualitative analysis for the reasons and motivations of each merger.

Table 1: Recent acquisitions of Synopsys with detailed information

Year	Company acquired, detailed information on takeover and acquisition reasons
1999	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 more effectively with Cadence Inc. and Avant! Corp. in the field of deep submicron design tools.
1999	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.
2001	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.
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 solutionsto 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 (DVC™) 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.[5]
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 toes into production. TCAD software aims at transistor (device) structure modelling and simulation of the steps of semiconductor wafer manufacturing processes.

[5] Source: http://www.findarticles.com/p/articles/mi_m0EIN/is_2003_April_14/ai_100011076, access 03/03/2006

2004	Leda: Acquisition of specific assets and the 80-person engineering and support team of a developer of mixed-signal IP experienced in digital and mixed-signal IP design located in Yerevan, Armenia to join the Synopsys DesignWare® IP engineering team. Track record of successfully developing and providing IP shall help Synopsys to meet customer demand for its portfolio of DesignWare IP.[6]
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

Going into detail in Table 1 and analysing the most recent takeovers of Synopsys together with information on the specific aspects of each acquisition it becomes clear, that technological reasons and the purchase of innovation play a significant role.

Semi-structured exploratory interviews

Semi-structured interviews with industry experts and employees of EDA companies were carried out to investigate innovation activities in the EDA industry in more depth. This approach has been used by others for similar research topics (e.g. Gruber and Henkel, 2006) and is also advocated methodologically (e.g. Miles and Huberman, 1994; Lamnek, 2005). The aim was to confirm whether a significant part of the acquisitions in the EDA industry relates to innovation aspects, and whether start-ups realise radical innovations that are later absorbed by large incumbent firms through acquisition or whether the acquired innovations were incremental in their nature? Since interviews allow covering a wide number of issues, this also enables some more insights about the other two research questions posed earlier.

From October 2005 until June 2006 13 interviews were carried out with senior professionals with detailed knowledge about the EDA industry. Experts were based in the United States as well as in Germany and represented major firms in the EDA and semiconductor industries, as well as major research centres in America and Europe. Each interview lasted between 1-2 hours. One interview was carried out by e-mail, three interviews over the phone and the remaining interviews in person. Phone and personal interviews were subsequently transcribed. This written material was subsequently coded inductively in order to derive categories. This was done using the Nvivo software.

Coding was open, that is new categories and subcategories were defined as they emerged in pieces of the written material and in total 596 text segments from the 12 interviews were coded. Overall, the coding scheme analysing innovation activities in the EDA industry resulted in 11 categories on the first level, 17 on the second level, 17 categories on the third level and 5 categories on the fourth level, resulting in 50 categories. Concerning mergers and acquisitions the hierarchical coding tree reproduced in the Appendix can be derived from this. It contained 2 categories on the first level, 9 on the second level, 15 on the third level and 4 on the fourth level, resulting to 30 categories in total.

As the Appendix shows, the categories identified fit well with the theoretically derived categories introduced in the literature review. Basically, reasons for acquisitions in the EDA industry can be subdivided in those that are R&D-related and those which are not.

Concerning the non-R&D reasons the literature reviewed in section 2 argues that reasons for acquisitions are gains in market share, inefficiencies in the acquired firm, agency issues and capital market imperfections. Gains in market share aimed at increasing market power have also been identified in the exploratory interviews an could be further subdivided in more specific reasons relating to market share, such as acquisitions to gain back former customers or acquisitions to get access to specific customers. Channel acquisitions which have also been mentioned in the interviews can help to spread fixed advertising and other promotional expenditures over a larger base. Also stock market expectations have been argued to be a reason for acquisitions, which relates to the theoretical argument of inefficiencies and allocational takeovers.

Next to the reasons identified in literature other explanations not related to R&D that have been proposed in the interviews relate to the acquisition of recent and particular business models. Whilst all the reasons mentioned so far refer largely to the demand side, i.e. the demand of large firms for acquisition, in terms of industry structure the exploratory interviews also revealed a number of important supply side factors. One of these is that acquisition can take place because venture capital providers wish to exit their investment and are therefore make an offer to prospective acquirers. This could also be motivated by the fact that venture capitalists (VCs) perceive that a start-up funded by them is missing important complementary assets to expand in a satisfactory manner (see e.g. Teece (1986) on the relevance of complementary assets in research-intensive industries and segments), but is essentially one common exit option for VCs.

[6] Source: http://www.us.design-reuse.com/news/news9046.html, access 03/03/2006

One important supply side aspect identified in the interviews seems to be a certain peculiarity of the EDA industry, namely the relatively low capital intensity of start-ups, which usually do not require large investments in fixed assets. As a result of this, the total asset value of the average entrant in the EDA industry is relatively low compared to other industries (such as the electronic materials or equipment industries) and therefore a complete acquisition of a start-up is more easily feasible and thus seems more likely (compared to e.g. acquisition of just a shareholding in a start-up). This facet of the industry is one of the reasons for acquisition identified in the interviews as being related to the market or industry conditions.

Other reasons in this respect are the strong cyclicality in the semiconductor industry as a whole which could make start-ups in the EDA segment of a the value chain a chap buy in a downturn of the semiconductor industry, given that they will be more susceptible to a revenue loss than larger firm. In the interviews, contrary positions were taken in this respect in that some interviewees acknowledged that acquisitions should increase in a downturn, because start-ups experience financial strain and their valuation may be lower. Others pointed out, that usually in a upturn of the semiconductor industry there is little change taking place in the EDA solutions of large semiconductor manufacturers and that consequently start-ups are "cheap" to acquire and are possibly also needed more by large EDA firms who are under pressure do develop improved solutions as offerings to customers.

Another important factor identified in the interviews is the change of market structure in EDA industry. It seems that historically the growth of EDA start-ups on their own was easier because the industry as a whole was in an early stage of its life cycle which implies that industry growth rates were high. Opposed to this, the interviewees indicated that today the EDA market is rather saturated.

As concerns partially R&D-related reasons, as a first category the lack of downstream assets for DEA start-ups seems to be an important reason for acquisition (rather than licensing) in its own right because in an asset-/capital-extensive sector like EDA the cost of acquisition are similar to the cost of licensing. In principle, in the EDA industry acquisition can be a substitute for licensing which would imply the testable proposition of generally lower levels of licensing compared to other segments of the semiconductor industry.

As a second category partially related to R&D and explaining why incumbents acquire that emerged in the coding process on the second level, defensive acquisitions can be identified. These can be divided into two sub-categories, namely acquisitions aimed at avoiding that a competitor acquires and acquisitions aimed at blocking the emergence of a new market niche served by a start-up. Concerning acquisitions aimed at hindering a competitor on the third level two more sub-categories can be identified from the interviews, namely whether the acquisition concerns a start-up that emerged from a third competitor or whether this is not the case.

Next to non-R&D reasons and partially R&D-related reasons, (essentially) R&D-related reasons for the acquisition of start-ups were also identified during the interviews and again these can be related to those reasons identified in the literature discussed in section 2. One basic reason for acquisition is that the R&D acquired could not be carried out by the incumbent, i.e. it was objectively not feasible for him due to missing capabilities, or it was only feasible at very high cost. Next to this, it is also possible, that the R&D in question was cheaper to b acquired than to be carried out by the incumbent itself. There is essentially a continuum between infeasibility and cheapness in that those two basic reasons for acquiring start-ups differ essentially only in degrees. The latter 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 the former refers to the inability of large firms to innovate in a radical manner, e.g. because they are hindered by too many or existing customers which is well documented in the literature.

The interviews indicated a balance of power between customers and large EDA firms an a rather short willingness to wait of customers being one important reason for acquisitions. The moment that the customer requests a feature a large EDA firm usually does not have enough time to innovate themselves and it did not innovate earlier because of the uncertainty regarding what innovation the customer wants most. Reasons for this are because such an innovation often leads to many other (costly) changes required in the design flow and because the innovation meets with obstacles and inertia from the sales force (which is e.g. concerned with it cannibalising existing products). Because of this, there is a trend observable in the industry towards very close cooperation with specific customers (e.g. Cadence and Freescale).

Concerning the infeasibility of the R&D for incumbent, reasons for acquisition can be further subdivided based on the specific capabilities or competences the incumbent is lacking. In the interviews four sub-categories were identified in this respect, namely acquisition for people (i.e. critical human capital), acquisition for intellectual property (e.g. patents), acquisitions due to organisationally radial (but economically incremental) innovation (Henderson, 1993) and the generally lower innovatory activity of incumbents (especially in an industry like EDA where industry concentration is high). With regard to this last point, a distinction can further be made with regard to acquisitions aimed at entering new markets and acquisition of new technologies.

Concerning R&D acquisition being a cheaper option two sub-categories can be distinguished, namely that acquisition is more certain than own R&D (indicating that risk considerations matter for the decision to acquire instead to pursue own R&D) and that faster development is possible for the incumbent through acquisition compared to the time needed for own R&D. An important theme that emerged from the interviews is that acquisition often takes place if large incumbents attempt to complete their design flow which nevertheless leaves open the point as to whether the R&D acquired is infeasible for the incumbent or only inefficient in terms of make or buy.

The empirically identified categories for R&D-related acquisition reasons also are mirrored by those reasons identified in the theoretical literature. The latter basically propose three reasons for R&D related acquisitions, namely acquisition for exploration (related to infeasibility in the empirical analysis), acquisition resulting to substitute own

R&D with acquisition (related to the empirical category of “cheaper” R&D acquisition) and acquisition in order to realise economies of scale or scope in R&D (which did not feature prominently as a reason in the empirical analysis). Concerning acquisition for exploration the literature proposes access to new technologies and entry into new markets as two sub-categories. These fit well with the sub-categories relating to lower innovation activities of large incumbents with regard to either new markets or new technologies (where the latter often refer to completion of the design flow in terms of important gaps in the tools of a specific EDA vendor).

Structured interviews with start-ups and entrants

Based on the semi-structured interviews, a short questionnaire was developed to be used for structured interviews especially with smaller firms in the industry. From the exhibitor list of the DATE 06 conference which took place 6-10 March 2006 in Munich, 70 smaller and younger EDA firms were identified for which no financial data was available on the Thompson databases. The questionnaire and descriptive statistics are summarised in the Appendix.

These firms form the population that was approached for a structured interview during the conference. Of the firms, 31 provided information during a structured interview based on a 2-page questionnaire, resulting into a 42% response rate which is deemed acceptable to draw conclusions that are representative for the population. The survey was answered largely by general managers (n=20) and marketing and sales personnel (n=6) with the questionnaire being partly completed jointly with the respondents (n=18) and partly by the respondents on their own (n=13). There was wide variety in the primary technical design focus of the start-ups, ranging from e.g. analog and mixed signal design via system-on-chip design to verification. About half of the firms had more than one technical design focus. As concerns firm size an firm age, there is a wide distribution with about half the firms having less than 20 employees and the other half having more than 20 employees.

Table 2: Firm size distribution of start-ups interviewed

Category	Frequency	Percent	Valid Percent	Cumulative Percent
Less than 10	7	22.6	22.6	22.6
10-19	10	32.3	32.3	54.8
20-49	7	22.6	22.6	77.4
50-99	3	9.7	9.7	87.1
100-249	2	6.5	6.5	93.5
250-499	2	6.5	6.5	100.0

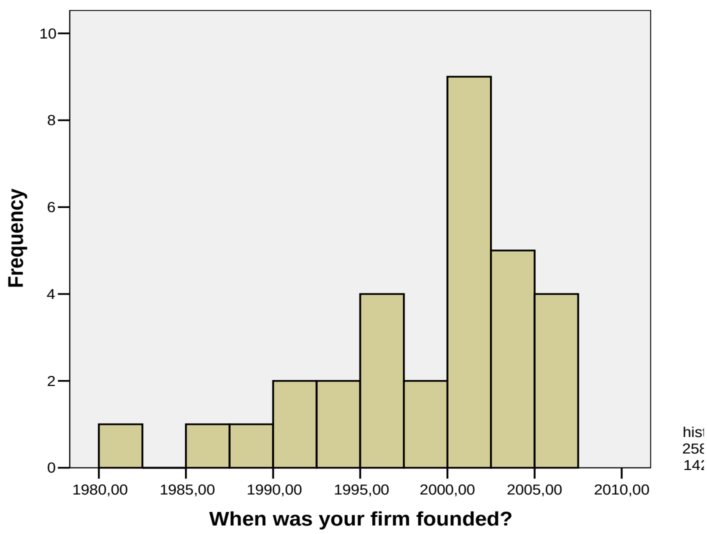

Figure 4: Age distribution of firms interviewed

Table 3 provides a summary of the answers to eight items referring to reasons as to why larger firms did not carry out the specific innovations before the start-ups had carried them out. Answers were provided on a 5-point Likert scale ranging from “not at all relevant” via “somewhat relevant” to “extremely relevant”. Prior to the analysis 4 missing values were replaced using the Expected Maximisation algorithm.

Table 3: Descriptive statistics for structured interview items on reasons for innovation (N=31)

Item	**Min**	**Max**	**Mean**	**Standard deviation**
1. New skills or capabilities are needed for the firm to pursue your innovation that do not already exist in the large firms that lead the market	1.00	5.00	3.5161	1.3384
2. In order to carry out successfully your innovation. a large firm would have to go through extensive learning and intellectual deliberation	1.00	5.00	3.3548	1.4955
3. Large firms that lead the market are too risk-averse to carry out the innovation	1.00	5.00	3.3226	1.1941
4. A top 3 large firm does not pursue your innovation because its fit with their existing products is low or they only promote few approaches	1.00	5.00	2.9677	1.2243
5. The organisation of R&D activities in large firms is not adequate to carry out your innovation without a lot of additional efforts	1.00	5.00	2.8710	1.3100
6. Large firms are so involved with the day-to-day requirements of their customers that they do not have resources for the innovation	1.00	5.00	2.7419	1.3897
7. Large firms do not want to irritate customers with too many innovations of which only a few are maintained in the long term	1.00	4.00	2.4194	1.0575
8. Carrying out the innovation would destroy valuable assets or competencies of a large firm that is a market leader	1.00	5.00	2.3226	1.3263

As can be seen from Table 3 all mean values are between 2.3 and 3.5, i.e. between slightly and somewhat important. This may indicate that all items suggested are of similar relevance, but that none of them is the one major reason why large firms in the EDA industry do not carry out certain innovations. Also, for all except of one item, each possible value has been chosen by at least one respondent, indicating a wide spread of judgements.

In order to condense further the information from the different items on the reasons for why larger firms did not carry out an innovation carried out by a smaller one, an exploratory factor analysis was carried out, for which the results are reported in Tables 4 and 5.

Table 4: Variance explained by factors in factor analysis for innovation reasons

Factor	**Initial Eigenvalues and Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.482	31.022	31.022	2.195	27.439	27.439
2	1.408	17.606	48.627	1.455	18.190	45.629
3	1.159	14.481	63.109	1.398	17.480	63.109

The first factor explains approx. 27.4% of the total variation in the data, the second one 18.2% and the third factor explains a further 17.5% of the variability encountered in the data. Overall, approx. 63% of the total variation encountered in the data is explained by the three factors with Eigenvalues greater than unity that were extracted. Table 5 provides the factor loadings for each item on each of the three factors. These factor loadings form the basis for interpreting the factors with regard to their meaning. Figure 5 shows how the factors relate to patenting by the start-ups.

Table 5: Rotated component matrix for factor analysis of reasons for innovation[7]

Item (as in Table 2)	**Factor**		
	No capabilities / assets	Low risk / day-to-day	No fit / irritation
1.	0.774		
2.	0.707		
3.		0.617	
4.			0. 704
5.	0.676		
6.		0.886	
7.			0. 853
8.	-0.598		

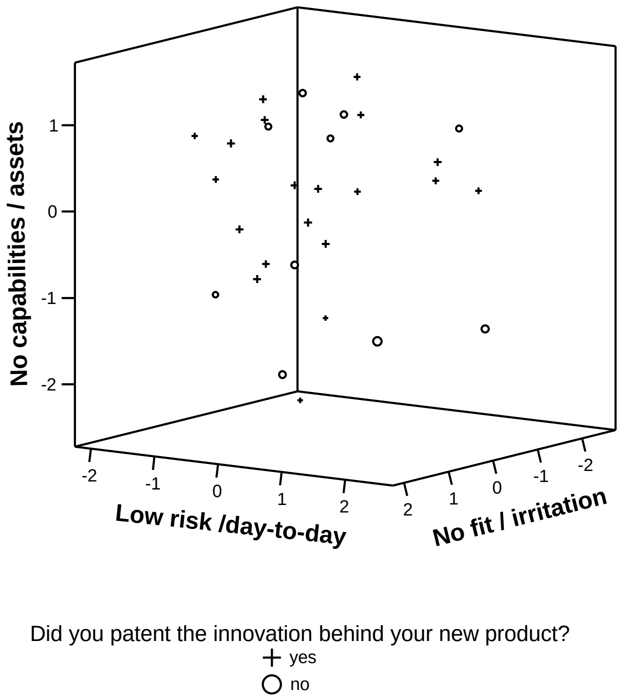

Figure 5: Graphical representation of factor scores for all firms

[7] The KMO measure for the factor analysis was 0.592, which is an average value. In addition to this, the individual KMO measures based on the anti-image correlations on the main diagonal of the anti-image correlation matrix were all above 0.42 (with only two being below 0.5) and therefore the correlation matrix of the data set is considered suitable for carrying out a factor analysis on the data set. Bartlett's test for sphericity was significant at the 0.10 level.

Exploratory and multivariate analysis of acquisition probability of start-ups

In the following, an analysis is carried out about the determinants of acquisition probabilities. Tables 6 and 7 provide an overview of the probability distribution with regard to the next year and the next 5 years, respectively. Concerning the exploratory analysis, the following Figures 6 to 11 show the univariate relationship of different types of innovation with the probabilities of acquisition in one year and five years, respectively.

Table 6: Probability of acquisition in next 12 months (unknown: 2 responses, equalling 6.5%)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	12	38.7	41.4	41.4
	1-25%	9	29.0	31.0	72.4
	25-50%	4	12.9	13.8	86.2
	50-75%	4	12.9	13.8	100.0

Table 7: Probability of acquisition in next 5 years (unknown: 2 responses, equalling 6.5%)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	5	16.1	17.2	17.2
	1-25%	3	9.7	10.3	27.6
	25-50%	7	22.6	24.1	51.7
	50-75%	6	19.4	20.7	72.4
	75-100%	8	25.8	27.6	100.0

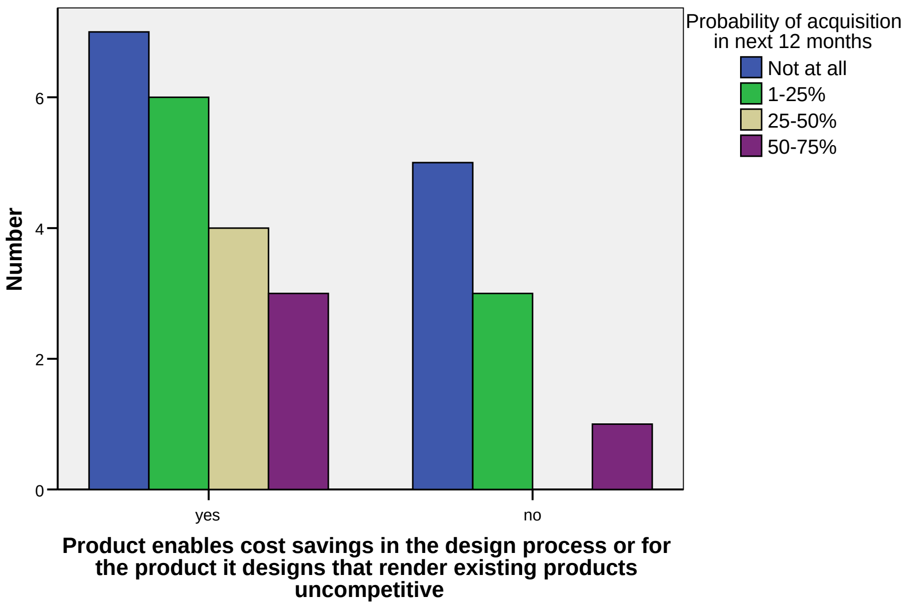

Figure 6: Cost saving product and probability for acquisition in the next 12 months

For the data underlying Figures 6 and 7, no significant association between the nominal variable whether the product enables cost savings and the ordinal variable for the probability for acquisition within the next five years was found.

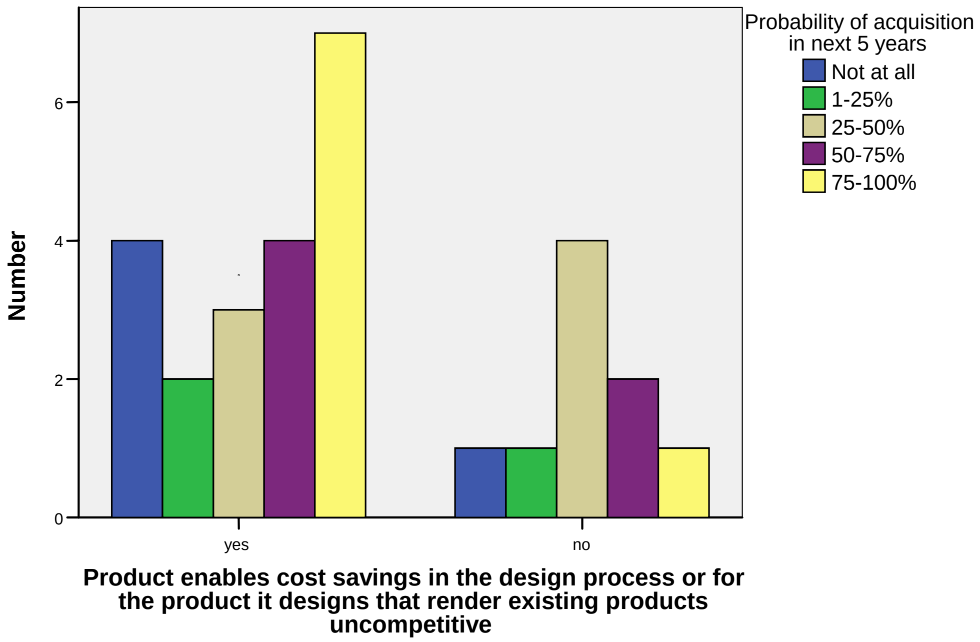

Figure 7: Cost saving product and probability for acquisition in the next 5 years

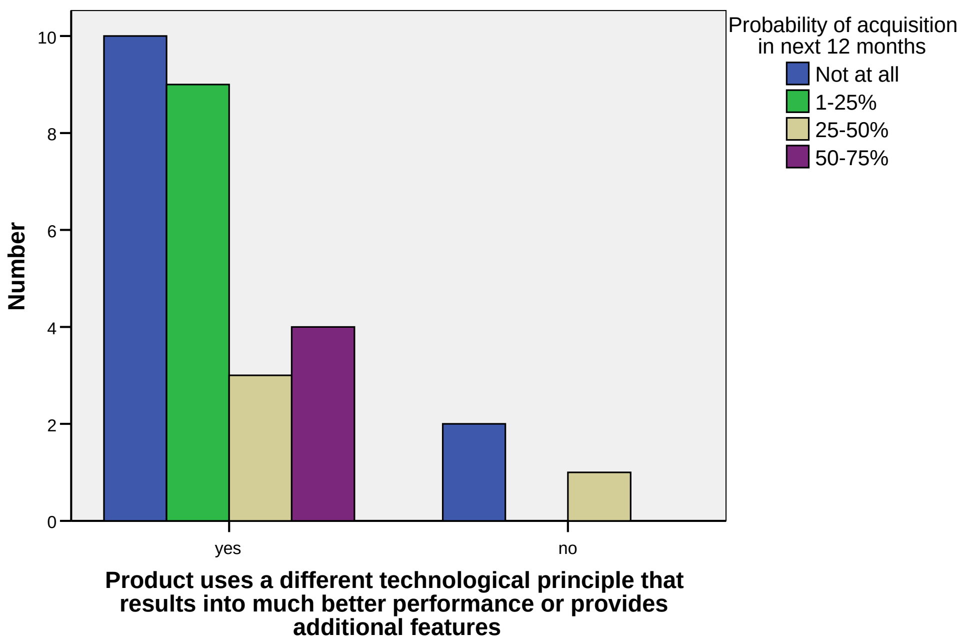

Figure 8 Product using different technological principle and probability for acquisition in the next 12 months

As concerns Figures 8 and 9 relating acquisition probabilities to the usage of a different technological principle also no significant association could be identified, which is partly due to the very skewed distribution of the latter.

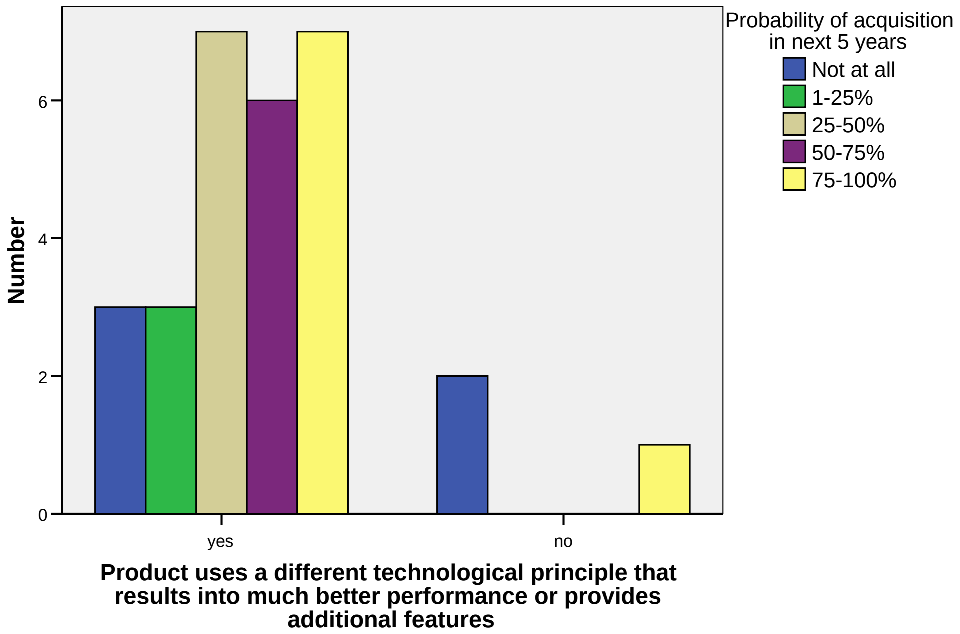

Figure 9: Product using different technological principle and probability for acquisition in the next 5 years

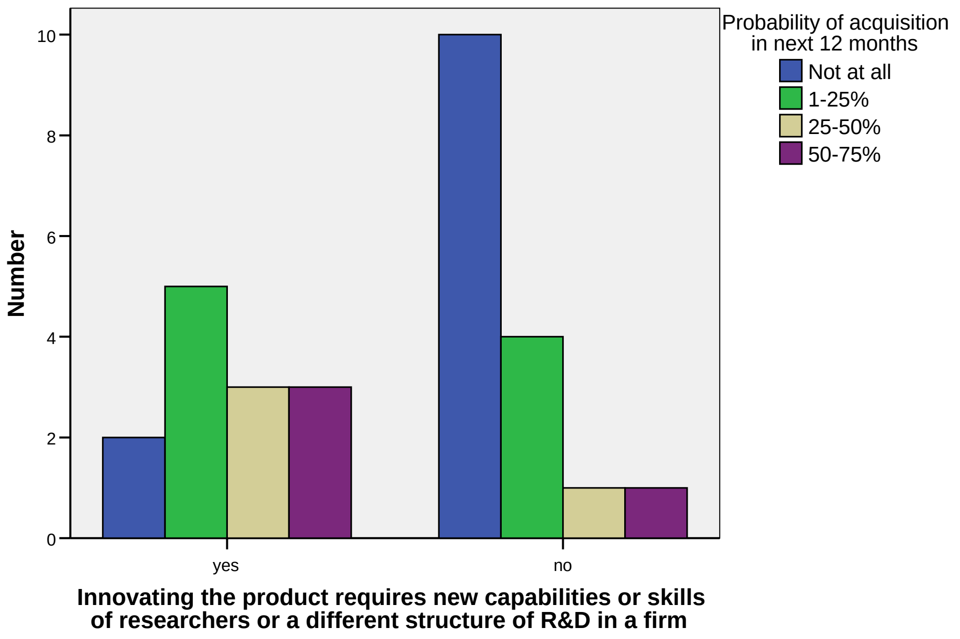

Figure 10: Product based on organisationally radical innovation and probability for acquisition in the next 12 months

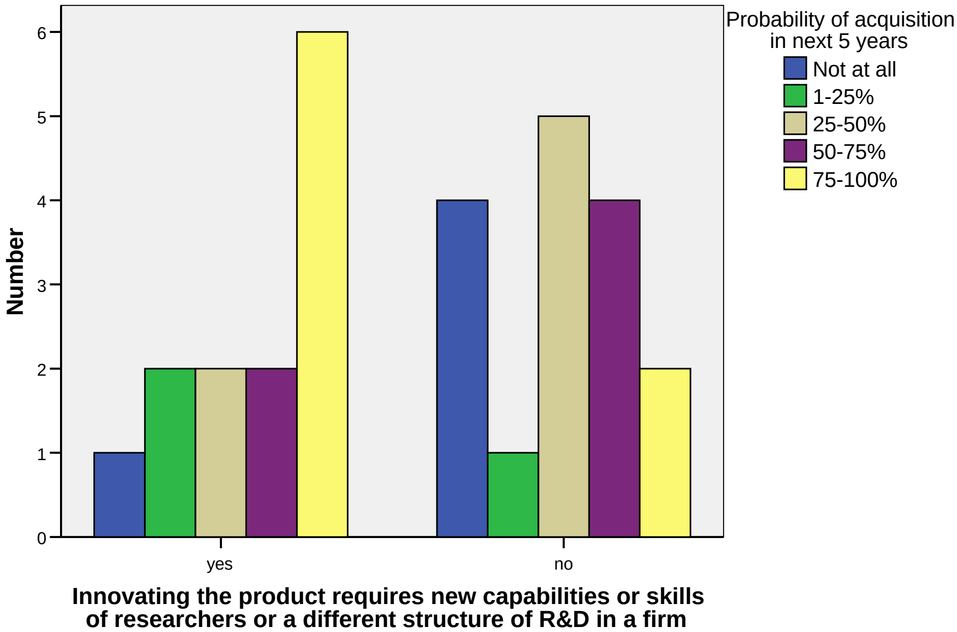

Figure 11: Product based on organisationally radical innovation and probability for acquisition in the next 5 years

Concerning Figures 10 and 11 relating to organisationally radical innovations a significant association was found based on the Exact Chi-square statistic (being appropriate since 75 per cent of the cells had an expected frequency below 5) at the 0.10 level. This indicates that in the short run carrying out an organisationally radical innovation is significantly positively associated with the probability of acquisition of the start-up. However, in the longer run, this association becomes insignificant, as can also be seen from Figure 11.

Based on the exploratory analysis therefore little association between the type of innovation and the acquisition probability could be identified. In order to ascertain this finding in a multivariate analysis, ordinal Logit models were estimated. In these, next to the two binary variables analysed in Figures 6 to 11 additional variables were included. The variable referring to whether a product was based on a technologically different principle was substituted in the multivariate analysis by the binary variable of whether or not the start-up had patented the innovation underlying the new product since this is very closely related to a differing technological principle and is a more objective measure of technological difference and therefore more suitable.

The other variables used were the age of the firm, as well as its square (since inspection of error bar graphs indicated a non-linear relationship with acquisition probabilities), the size of the firm (measured in terms of the firm being either a larger or a smaller start-up with the threshold level being 20 employees) as well as the two factors “Low risk/day-to-day” and “No fit/irritation” that emerged from the factor analysis reported earlier. These latter two variables were included to control for differences in perception across start-ups that may be related to different perceptions about acquisition probabilities. By including these two variables, at least some of the heterogeneity across firms can be addressed.

Tables 8 and 9 summarises the results of this multivariate analysis. The findings did not change in terms of significance and direction of the association when firm size was operationalised in different ways, namely as four or six size categories included as dummy variables in the regression and as an 8-point continuous variable of firm size. Also inclusion of a dummy variables assuming unity if the start-up was active in more than one technical design area (i.e. measuring the breadth of the start-up’s technical base) and if the respondent was a senior manager of the firm were not found to be significant and did not alter the results reported below in terms of significance levels and coefficient orders of magnitude and signs (these last two variables were subsequently dropped again from the model for reasons of parsimony). Therefore the results seem to be robust towards a number of different specifications of the model.

The results of the multivariate regression analysis indicate that both, the short-term as well as the long-term acquisition probability are significantly and positively associated with whether or not an innovation is organisationally radical. Thus contrary to the intuition from the exploratory analysis, the multivariate analysis reveals a significant association. Beyond this, in the short term the second factor identified in the factor analysis (Low risk/day-to-day) has a significant negative association, the age of the firm a significant positive association and the square of the firm age a significant negative association. However, these effects become insignificant for the longer-term acquisition probability.

Table 8: Ordinal Logit model predicting probability of acquisition in next 12 months

	Variable	Coefficient	Std. error	Wald	Df	Significance
Threshold	[probability12months = Not at all]	2.875	1.757	2.679	1	0.102
	[Probability12months = 1-25 per cent]	4.968	1.921	6.688	1	0.010
	[Probability12months = 25-50 per cent]	6.345	2.065	9.437	1	0.002
Level	Low risk / day-to-day	-1.182	0.573	4.259	1	0.039
	No fit / irritation	0.111	0.444	0.062	1	0.804
	Age	0.559	0.288	3.753	1	0.053
	Age squared	-0.026	0.012	5.181	1	0.023
	[Patenting = yes]	-1.643	1.119	2.156	1	0.142
	[Patenting = no]	0(a)	.	.	0	-
	[Cost savings / economically radical = yes]	1.654	1.034	2.560	1	0.110
	[Cost savings / economically radical = no]	0(a)	-	-	0	-
	[Organisationally radical innovation = yes]	3.721	1.326	7.874	1	0.005
	[Organisationally radical innovation = no]	0(a)	-	-	0	-
	[Small start-up = no]	-0.343	0.998	0.118	1	0.731
	[Small start-up = yes]	0(a)	-	-	0	-
Model fit		**-2 Log-likelihood**				
	Model with constant only	71.514				
	Final model	53.241		18.273	8	0.019
Pseudo R-squared	Cox and Snell	0.479	Nagelkerke	0.520	McFadden	0.256

Note: (a) Parameter set to zero because of redundancy

As can be seen from Tables 8 and 9, the longer-term acquisition probability is generally higher, which may indicate that larger EDA firms attempt to replicate an innovation carried out by a start-up initially in-house, but eventually need to acquire if and only if the innovation is organisationally radical in the sense described by Henderson (1993) which implies that the large firm can per definition only carry it out with great obstacles and resource commitments. An interesting question in this respect is if organisationally radical innovations usually occur only in the transition from one generation of EDA firms to the next (and in one generation of firms in the industry only organisationally incremental innovations) or in each generation (Henderson, 2006; Pisano, 2006). The Appendix also provides data on the marginal effects for all independent variables used in its Tables A1 to A4.

Table 9: Ordinal Logit model predicting probability of acquisition in next 5 years

	Variable	Coefficient	Std. error	Wald	Df	Significance
Threshold	[probability12months = Not at all]	-1.720	1.352	1.620	1	0.203
	[Probability12months = 1-25 per cent]	-0.855	1.304	0.430	1	0.512
	[Probability12months = 25-50 per cent]	0.453	1.295	0.123	1	0.726
	[Probability12months = 50-75 per cent]	1.701	1.342	1.607	1	0.205
Level	Low risk / day-to-day	-0.224	0.491	0.209	1	0.648
	No fit / irritation	-0.242	0.403	0.360	1	0.548
	Age	0.010	0.226	0.002	1	0.963
	Age squared	-0.009	.009	1.069	1	0.301
	[Patenting = yes]	-0.605	0.932	0.422	1	0.516
	[Patenting = no]	0(a)	-	-	0	-
	[Cost savings / economically radical = yes]	0.808	0.840	0.924	1	0.337
	[Cost savings / economically radical = no]	0(a)	-	-	0	-
	[Organisationally radical innovation = yes]	1.828	1.056	2.994	1	0.084
	[Organisationally radical innovation = no]	0(a)	-	-	0	-
	[Small start-up = no]	0.837	0.966	0.750	1	0.387
	[Small start-up = yes]	0(a)	-	-	0	-
Model fit		**-2 Log-likelihood**				
	Model with constant only	87.644				
	Final model	73.637		14.007	8	0.082
Pseudo R-squared	Cox and Snell	0.394	Nagelkerke	0.412	McFadden	0.160

Note: (a) Parameter set to zero because of redundancy

4. Discussion and conclusions

Whilst high levels of acquisition activity in the EDA industry and the relevance of innovation aspects for a large proportion of the acquisitions is very visible in the data, the reasons for acquisitions in the EDA industry express broader variety. The factors for why larger firms do only to a lesser degree carry out innovations that are more radical in an economic or organisational sense which have been proposed in Section 2 are largely supported in the interviews but differ in their relevance. The need for new capabilities to pursue an innovation is perceived by smaller firms as the most important obstacle for large firms in the industry, followed by the need for a large firm to go through an extensive learning and intellectual deliberation process (which is particularly likely if capabilities are lacking). The third-most relevant aspect is that large firms are too risk-averse do carry out an innovation and prefer to acquire smaller firms that have innovated at a later stage. These findings from the structured interviews have also been borne out in the coding of the semi-structured interviews. In terms of innovation networks, the work by Kogut and Kulatilaka (1994; 2001) could indicate that they are a first phase of the innovation process in which network formation is crucial for the development of a radical innovation and would therefore correspond to creating a real option. In this logic, acquisitions could be interpreted as exercising an option that has been created as a result of an innovation network.

As concerns the question whether acquisitions in the EDA industry relate more to radical or incremental innovation the results indicate that indeed acquisitions relate at least in some cases to the former confirming findings from other industries about the preference of large incumbents for incremental innovation. This seems to be the case for organisationally as well as economically radical innovation, given that lack of capabilities is mostly related to organisationally radical innovation whereas the issue of risk aversion relates mainly to economically radical innovation.

However, the multivariate analysis of takeover expectations as perceived by start-ups indicates that largely organisationally radical innovations are those targeted for acquisition by large EDA firms. This may indicate that from the reasons identified in the semi-structured interviews particularly those relating to acquisition for people (i.e. critical human capital) and acquisition for intellectual property (e.g. patents) matter. The concerns raised by Bingham (2003) and Sangiovanni-Vincentelli (2003) about too low levels of radical innovation in the EDA industry therefore find some support in this analysis pointing to the need of considering at least for some innovation needs the use of innovation networks as means for radical innovation in the industry. The suitability of innovation networks is here further supported by theoretical analysis of such networks in Section 2 which indicates that innovation networks are capable of mitigating risks associated with innovation especially for smaller firms and may even justify government intervention in cases where their existence corrects for market failure. However, the situation my not be a market failure in that Markides and Geroski (2005) caution that lower innovativeness is inherent for incumbents and that these large firms should be adopting an acquisition or network strategy with young start-up firms that can mitigate for lower innovation levels without implying the need of a Sematech-like solution of an industry consortium.

In line with their argument, 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 the EDA industry may differ to those observed in other segments of the semiconductor industry, such as the lithography segment (Henderson, 1993). Whereas in cases when acquiring the competencies needed to pursue disruptive innovation as an incumbent can be prohibitively high in some industries, it seems that this is not the case in the EDA industry, 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 is not so disruptive, that it well render the incumbent uncompetitive and subsequently force it out of the market, or else have to face a forced market exit, as is documented for the lithography segment (Henderson, 1993). In the EDA industry, where as I argue below cost of acquisition is low, incumbents have a third option which is to acquire the organisational competencies enabling to pursue a radical or disruptive innovation. This line of argument would also explain why the dummy variable for organisationally radical innovation is significant in the regressions reported in Tables 8 and 9.

In summary, the semi-structured interviews with industry experts indicate that innovation is a reason for acquisition requires 1) the need for acquisition (issue is virulent) by the large incumbent and 2) possibility for acquisition (i.e. existence a small start-up with a lead in the issue / an available product or technology solution) as necessary conditions.

An issue can exist if for a novel technology, none of the large incumbents has access (e.g. DFM) or if for an existing technology only the focal firm is lagging, whereas other incumbents have it already (e.g. in the case of routing technologies and the Avanti! acquisition in case of Synopsys). In terms of ecology of innovation and evolutionary path dependency approaches the EDA industry could be characterised by a number of structural features and evolutionary processes that can explain the intensive acquisition pattern observed empirically. Firstly in terms of structure, the low capital intensity of EDA software and software-based innovation matters. Whereas for hardware-based products radical innovation seems to be pursued by both incumbents and entrants, for software-based innovation such as EDA software organisationally radical innovation seems to largely come from entrants, whereas incremental innovation largely comes from incumbents. Also in terms of technological radicality, the semi-structured interviews provide some evidence that start-ups need to have a radical idea at its core to succeed. An example is one of the firms surveyed during the structured interviews at DATE 06 which had developed a tool that automatised the quality assurance procedures in chip design.

The change in industry structure identified earlier means that start-ups to compete with a large firm it needs to have the same offer to the customer which implies high costs and therefore often is no viable option anymore to enter the market in current generation of large firms (i.e. Cadence, Synopsys and Mentor). It was pointed out in the semi-structured interviews that Magma Design Automation was the exception here, which however was enabled only by high external investments. In earlier generations (with market leaders being Kalmar in one of the first industry generations and Mentor, Daisy and Valid in the subsequent generation) therefore in terms of structure it seems to have been much more feasible for a start-up to enter the industry, whereas today it can only be through a niche. Because of today's complete flow large EDA firms have much more market power which makes it difficult for small start-ups to go on their own (because they would need a complete flow now which is a high investment). Since this implies that the barriers of entry are higher, the number of start-ups today is expected to be lower, which should be ascertained through further empirical analysis. Table 10 supports this based on the structured interviews of start-ups, indicating that they themselves only rarely consider it to be possible to develop a larger market share on their own.

Table 10: What happens to start-ups not acquired after some years?

	Frequency	Percent	Valid Percent	Cumulative Percent
Go out of business	8	25.8	33.3	33.3
Go into lucrative market niches	7	22.6	29.2	62.5
Go into lucrative niches or merge with another small firm	1	3.2	4.2	66.7
Go out of business or go into lucrative niche	8	25.8	33.3	100.0
unknown	7	22.6		

A second aspect that matters for acquisitions in the EDA industry in that it creates a steady-state situation where a permanent gradient exists in terms of innovation demands by customers is the continuous drive for innovation in the semiconductor industry at large. This relates to the question why there are always opening up new niches in the EDA industry that allow start-ups their initial innovation activities with low capital investments. It seems that the constant occurrence of niches as an "engine" for demand for innovation is due to the semiconductor industry being based on cumulative technological progress. Whilst this by itself does not necessarily imply innovation activity by start-ups 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, which was also confirmed in the initial semi-structured interviews. An open question is here, why uncertainty is so high, but it seems that this also has to do with the characteristic of cumulative innovation and technological progress in the industry.

In sum, the empirically observable acquisition dynamics in the EDA industry seem to be the superposition of the first aspect of low capital structure and the second one of permanent occurrence of new niches combined with the historic trend of flow completion. This means that a new radical technology can emerge, likely through innovation activity of a small start-up. This can happen today as easy as it could in the past, and DFM is one of technologies witnessing this. What has changed though is the possibility for a start-up to grow on its own which was much easier in earlier generations of EDA firms. Because over time it became increasingly difficult for start-ups to grow by themselves an increase in acquisitions (or mergers between two smaller firms, as also indicated to be a common outcome in Table 10) should increase and this is also what can be observed empirically. Given the capital extensiveness of the sector as indicated in the semi-structured interviews, acquisition of start-ups is not very costly and thus seems to be more frequently then licensing or cross-licensing which is often observed in the more capital intensive chip manufacturing industry.

As also described elsewhere in analysis this should lead to an increase of acquisitions, ceteris paribus. However it is unclear, if the ceteris paribus conditions is really fulfilled in terms of the number of start-ups 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 start-ups 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 and innovation processes in the semiconductor industry at large could be such a mechanism. Otherwise the number of start-ups could decline in the less attractive conditions (e.g. in terms of fewer exit options) that have developed historically through the increasing completion of the design flow in terms of the tools offered by large EDA firms.

5. Future Research

A theme that emerges from the analysis is the high relevance of reference customers. Reference customer's innovation requirements seem to be between the types of radical supply-pushed innovation and market-pull innovation identified by

Markides and Geroski (2005). With relatively clear and similar market requirements across a larger group of customers there may also be further changes in the workings of the industry that merit analysis in this respect. Furthermore, the limited mention of innovation networks during the interviews and the data at hand only giving information about the acquisition at one point in time make it difficult to test the proposition of a phased appearance of networks and acquisitions (in terms of the creation and exercise of an option). More detailed analysis could help to shed light on this highly interesting question.

Finally, the recent trends towards open and user innovation that have been observed empirically and discussed in the literature raise the question whether openness is or should be a strategy of large EDA incumbents, for example to make the market less attractive for start-ups. The exploratory semi-structured interviews as well as the structured interviews with start-up both indicate that this currently has lower relevance for the EDA industry (even though the software base relates to trends in Open Source Software). It was found that few firms defensively publish or freely reveal their innovations and that compared to this secrecy and patenting prevail. Interestingly, concerning large EDA firms there seems to be considerable variation with regard to openness. For example, in the semi-structured interviews, the OpenAccess database of Cadence was mentioned as one example where open innovation processes get a hold in the industry. Future research could analyse in more detail what differences in perception and motivation relate to differrences in behaviour and whether and if so why there are differences in the software-based EDA industry to other industries where Open Source Software plays a particular role, as for example in the Embedded Linux market (Henkel, 2006).

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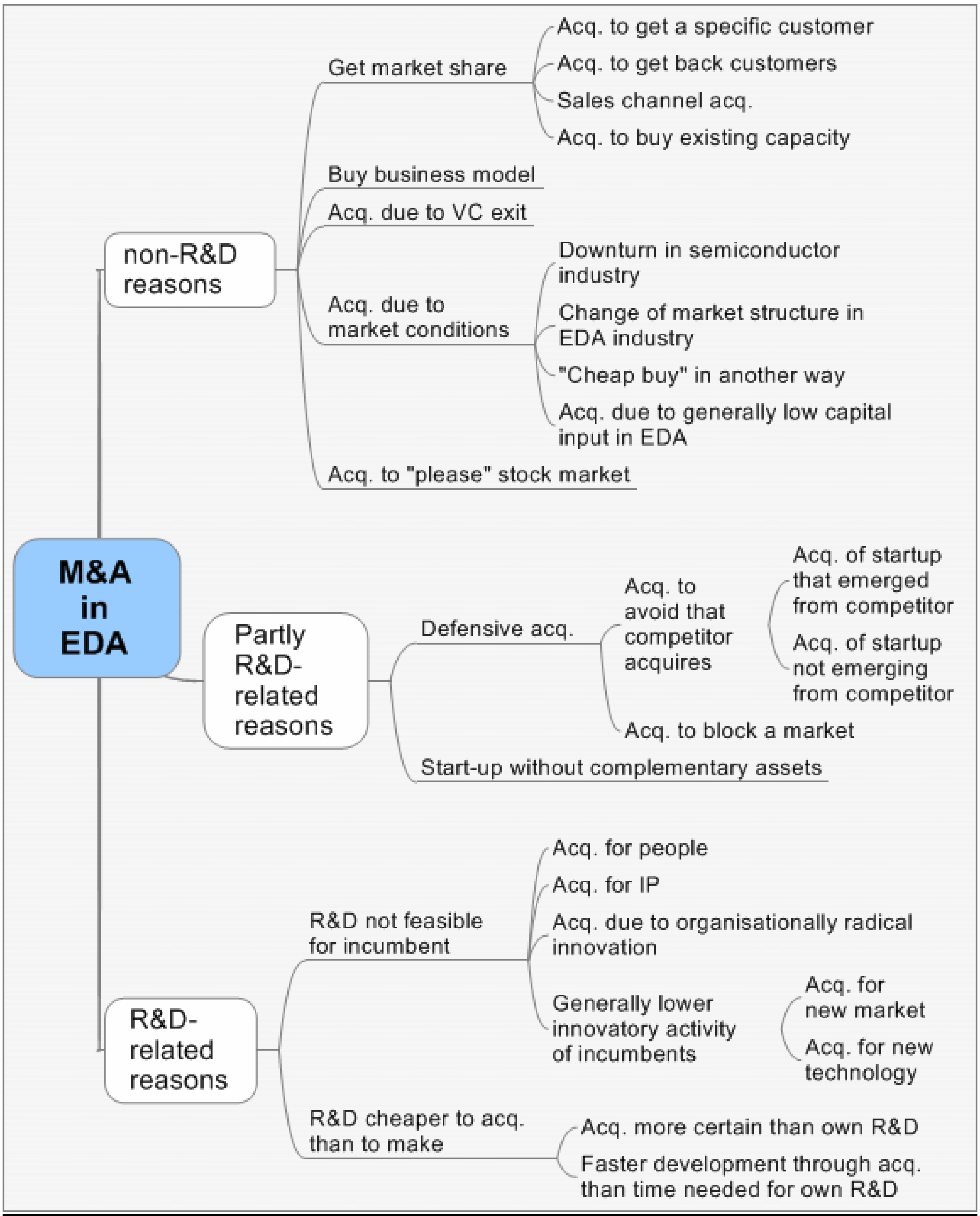
Appendix: Coding scheme developed out of semi-structured interviews with industry experts, further descriptive statistics and marginal effects for ordinal Logit models (Acq.: acquisition)

Coding scheme



Descriptive statistics of standardised questionnaire

What is currently the company's primary technical design

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Analog / Mixed Signal	2	6.5	6.5	6.5
	Manufacturing / Foundry	1	3.2	3.2	9.7
	ASIC / ASSP	2	6.5	6.5	16.1
	DSP	1	3.2	3.2	19.4
	System-on-Chip	3	9.7	9.7	29.0
	Test/Validation	1	3.2	3.2	32.3
	Verification	3	9.7	9.7	41.9
	Other	3	9.7	9.7	51.6
	More than one	15	48.4	48.4	100.0

Did you patent the innovation behind your new product?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	20	64.5	64.5	64.5
	no	10	32.3	32.3	100.0
	unknown	1	3.2		

Did you use secrecy to protect your innovation?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	13	41.9	72.2	72.2
	no	5	16.1	27.8	100.0
	unknown	13	41.9		

Defensive publishing?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	4	12.9	22.2	22.2
	no	14	45.2	77.8	100.0
	unknown	13	41.9		

Free revealing?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	1	3.2	5.6	5.6
	no	17	54.8	94.4	100.0
	unknown	13	41.9		

Does your product enables cost savings either in the design process itself or for the product it designs that render existing products uncompetitive (assuming no change in performance)?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	22	71.0	71.0	71.0
	no	9	29.0	29.0	100.0

Does your product use a different technological principle that results into much better performance (in the performance categories commonly considered for this product group) or that is capable of providing an additional feature that existing products do not provide (but possibly at higher cost)?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	28	90.3	90.3	90.3
	no	3	9.7	9.7	100.0

Does (compared to the competences of the top 3 firms in the industry) innovating your product requires new capabilities or skills of researchers (e.g. only recently taught at universities) or a different structure of R&D in a firm?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	14	45.2	45.2	45.2
	No	17	54.8	54.8	100.0

Marginal effects for ordinal Logit model predicting probability of acquisition in next 12 months and five years

Table A1. Factor change for probability of acquisition in next 12 months

Variable	*Logit Coef.*	*Z*	*Factor Change*	*Std Factor Change*
Low risk / day-to-day	-1,182	-1,780	0,307	0,307
No fit / irritation	0,111	0,250	1,117	1,117
Age	0,559	1,690	1,749	32,706
Age squared	-0,026	-2,060	0,974	0,018
Patenting (Tech. rad).	1,643	1,270	5,171	2,198
Econ. rad.	-1,654	-1,050	0,191	0,463
Org. rad.	-3,721	-2,550	0,024	0,151
Small start-up	0,343	0,350	1,409	1,190

Table A2. Discrete change for probability of acquisition in next 12 months

Variable	*Change*	*Average Δ*	Not at all	1-25%	25-50%	50-75%
Low risk / day-to-day	*Marginal*	---	0,263	-0,075	-0,122	-0,065
	Δ Range	0,399	0,798	-0,101	-0,310	-0,387
	Δ 1	0,129	0,258	-0,070	-0,120	-0,068
	Δ σ	0,129	0,258	-0,070	-0,120	-0,068
No fit / irritation	*Marginal*	---	-0,025	0,007	0,011	0,006
	Δ Range	0,045	-0,091	0,028	0,041	0,022
	Δ 1	0,012	-0,025	0,007	0,011	0,006
	Δ σ	0,012	-0,025	0,007	0,011	0,006
Age	*Marginal*	---	-0,124	0,036	0,058	0,031
	Δ Range	0,499	-0,975	-0,022	-0,002	0,998
	Δ 1	0,062	-0,124	0,035	0,058	0,031
	Δ σ	0,330	-0,661	0,117	0,292	0,252
Age squared	*Marginal*	---	0,006	-0,002	-0,003	-0,001
	Δ Range	0,487	0,975	-0,148	-0,280	-0,547
	Δ 1	0,003	0,006	-0,002	-0,003	-0,001
	Δ σ	0,363	0,726	-0,110	-0,307	-0,309
Patenting (Tech. rad.)	*Marginal*	---	0,258	-0,070	-0,120	-0,068
	1-->2 (no)	0,177	-0,353	0,256	0,070	0,028
Econ. rad.	*Marginal*	---	0,368	-0,105	-0,171	-0,091
	1-->2 (no)	0,195	0,178	0,213	-0,136	-0,255
Org. rad.	*Marginal*	---	0,827	-0,237	-0,385	-0,205
	1-->2 (no)	0,319	0,063	0,282	0,293	-0,638
Small start-up	*Marginal*	---	-0,076	0,022	0,036	0,019
	0-->1 (yes)	0,038	-0,076	0,022	0,035	0,019

Table A3. Factor change for probability of acquisition in five years

Variable	*Logit Coef.*	*Z*	*Factor Change*	*Std Factor Change*
Low risk / day-to-day	-0,224	-0,320	0,799	0,799
No fit / irritation	-0,242	-0,640	0,785	0,785
Age	0,010	0,040	1,011	1,067
Age squared	-0,009	-1,130	0,991	0,232
Patenting (Tech. rad.)	-0,605	0,760	0,546	0,748
Econ. rad.	0,808	-0,890	2,242	1,457
Org. rad.	1,828	-1,970	6,220	2,528
Small start-up	0,837	-0,690	2,308	1,529

Table A4. Discrete change for probability of acquisition in next five years

Variable	Change	Average Δ	Not at all	1-25%	25-50%	50-75%	75-100%
Low risk & day-to-day focus	*Marginal*	---	0,021	0,017	0,018	-0,018	-0,038
	Δ Range	0,088	0,086	0,067	0,066	-0,069	-0,151
	Δ 1	0,022	0,021	0,017	0,017	-0,018	-0,038
	Δ σ	0,022	0,021	0,017	0,017	-0,018	-0,038
No fit / irritation	*Marginal*	---	0,023	0,019	0,019	-0,020	-0,041
	Δ Range	0,087	0,080	0,065	0,071	-0,062	-0,155
	Δ 1	0,024	0,023	0,019	0,019	-0,019	-0,041
	Δ σ	0,024	0,023	0,019	0,019	-0,019	-0,041
Age	*Marginal*	---	-0,001	-0,001	-0,001	0,001	0,002
	Δ Range	0,026	-0,024	-0,020	-0,022	0,020	0,045
	Δ 1	0,001	-0,001	-0,001	-0,001	0,001	0,002
	Δ σ	0,007	-0,006	-0,005	-0,005	0,005	0,011
Age squared	*Marginal*	---	0,001	0,001	0,001	-0,001	-0,002
	Δ Range	0,368	0,921	-0,026	-0,162	-0,288	-0,445
	Δ 1	0,001	0,001	0,001	0,001	-0,001	-0,002
	Δ σ	0,140	0,144	0,106	0,100	-0,103	-0,246
Paten-ting	*Marginal*	---	0,021	0,017	0,017	-0,018	-0,038
	1-->2 (no)	0,056	-0,083	-0,047	-0,009	0,065	0,074
Econo-mically rad.	*Marginal*	---	0,077	0,062	0,063	-0,065	-0,137
	1-->2 (no)	0,073	0,045	0,046	0,091	-0,002	-0,181
Organ-isation. radical	*Marginal*	---	0,173	0,140	0,143	-0,148	-0,309
	1-->2 (no)	0,159	0,036	0,044	0,144	0,175	-0,398
Small start-up	*Marginal*	---	0,079	0,064	0,065	-0,068	-0,142
	0-->1 (yes)	0,082	0,079	0,063	0,065	-0,063	-0,144

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