Innovation strategies: Does Geographical and Technological *Proximity* Matter

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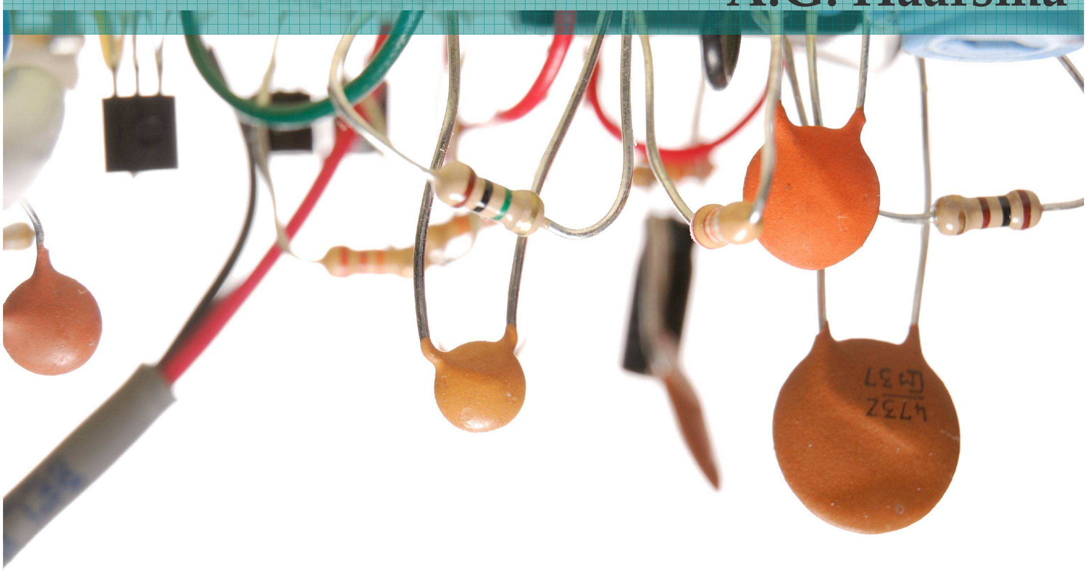

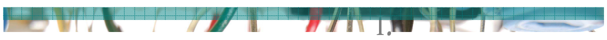

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Does Geographical and Technological Proximity Matter

Innovation Strategies: Does Geographical and Technological Proximity Matter?

An exploration of the influences of cluster and technology characteristics on firm strategy to balance exploration and exploitation.

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Preface

As conclusion to my master Business Administration I present to you this thesis. This study is concerned with innovation strategies pursued by firms to develop and build 'products' that integrate applications of extremely small sizes, as small as the size of a molecule. These products are called chips and they are produced in firms all over the world. When I started this thesis this field of technology sounded as an interesting research context in which innovativeness should be of great importance. Since in the Eindhoven region a number of large and prominent research institutes are situated which could be expected to influence surrounding firms, I was keen to study the actual innovation strategies they employ.
Conducting a structured and purposeful study has been difficult. However, I have gained a lot of knowledge and experience concerning the semiconductor industry, the current state of scientific debate on innovation and most importantly, on how to perform an academic study. But I could not have achieved this without the help of a number of people. Firstly, I would like to thank the two supervisors of this thesis who have been supporting and encouraging me all the way.

Klaasjan, you are a master in listening and postulating the right questions during our meetings. These meetings have helped me enormously to structure my thoughts so that I could write them down in a coherent way. What's more, you are also a really nice person!

Arie, thanks a lot for all your input and your widening but precise view at the research context. Also your willingness to think with me helped me a lot.

And I would like to thank three 'experts' in the field. Two experts have been of great help in getting me more acquainted with the semiconductor industry; Maarten Vertregt and Richard Claassen from NXP. Finally, I would like to thank the third expert: my mother! who spent hours assisting me with my writings.

Jos Haarsma
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Management Summary

Within the last two decades of research in nano-technology, the focus has primarily been on fundamental explorative research. Recently there has been a shift towards a more exploitative approach as firms have been trying to apply nano-technology to enhance their current competences and products. This development is noticeable in nano-electronics and in particular in the semiconductor industry.

Regularly firms of the semiconductor industry and firms from adjacent industries can be found together in one specific geographical region. When other actors, like research institutes and universities involved in development of (nano-) electronics, are located here as well, they are said to form a cluster. One of those clusters is located in the Eindhoven, Leuven and Aachen-Triangle (ELAT). Clusters could influence the innovations strategies of firms.

This study focuses on the innovation strategies firms employ in order to balance exploitation and exploration and on how these strategies are influenced by cluster and technology characteristics. These strategies aim to structure organizational resources and activities. When these activities are typified as exploitative, key notions are “refinement, building and broadening of current knowledge and skills”. When they are typified as explorative, key notions are “search, variation, and departure from existing knowledge to new knowledge”. There are several innovation strategies to balance exploitation and exploration and it is argued that maintaining a right balance between these two is of great importance to be successful in the short- and in the long term. The research questions this study answers are:

Which innovation strategies do firms follow in order to balance exploitation and exploration present in a nano-electronics cluster? In which way are the innovation strategies influenced by cluster and technology characteristics?

To answer the research questions a multilevel approach is adopted. This research is typified as a single-case study with sub-cases. Each sub-case focuses on a particular firm of the semiconductor industry in the ELAT-region. These firms are Océ, NXP, Catena Radio Design, ItoM, SiTel and Cavendish-Kinetics respectively. Experts in the field are interviewed to get an understanding of cluster and technology characteristics. Furthermore, research interviews are held with Research & Development Managers of these firms, and with employees involved in these activities.

To conduct a thorough research, this study is based on current scientific literature about the three main areas of interest, viz. (1) innovation strategies to balance exploitation and exploration, (2) technology regimes and innovations patterns, and (3) cluster characteristics.

Innovation strategies can be divided into three types. There are strategies that aim at pursuing exploitation and exploration simultaneously and those that aim at specializing in either exploitation or exploration. The third type of strategy organizes periods of exploitation and exploration sequentially. The simultaneous approach is subdivided in five strategies, the Internal Corporate Venture, Contextual Ambidexterity, Structural Ambidexterity, Separation and Temporary Separation.

Secondly, the technology regimes and innovation patterns describe how innovations in an industry are accomplished and by whom. It should be noted that there are two types of industries, widening industries and deepening industries. In the former innovations are accomplished by new entrants and existing technology standards are continuously challenged. In the latter innovations are produced by incumbents and require large investments in research, while the technologies are continuously improved and refined.

Finally, clusters of actors can be defined by three variables, proximity in geography, distance in technology and complementarities between actors.

Results - Pursued innovation strategies

Large firms (NXP and Océ) pursue the Internal Corporate Venture strategy that structurally separates exploitative activities from explorative activities. Smaller and medium-sized firms (Catena, SiTel and ItoM) pursue the Contextual Ambidexterity strategy that stimulates personnel to be involved in both. They adopt this strategy because they do not want to or do not see the need to allocate personnel solely to either exploitation or exploration. Cavendish-Kinetics is still in the process of developing their first product and is pursuing the Specialization strategy in exploration. The transition to exploitation is becoming more important but the focus remains on the explorative development of their first innovation.

Results - Technology pattern

The technology pattern of the semiconductor industry is typified as *deepening*. Having an innovation history in technology is for these firms of vital importance. The technology path of the semiconductor industry is distinctive and develops along a predictable path. This path follows distinctive technology trajectories, for example the More Moore and the More than Moore trajectories. Semiconductor industries primarily focus on exploitation and on the integration of the results of exploration in the existing processes and products.

Results - Cluster characteristics

The cluster characteristics of the ELAT-region can strengthen the explorative activities of firms if they utilize the available facilities and knowledge at the research institutes. So far, few effects have been noticed at the firms. NXP and SiTel are the only ones to participate in explorative activities. The other firms do not experience any benefits of the ELAT-region for their explorative and exploitative actions in organizing exploration and exploitation.

Conclusion

Firms allocate the majority of the R&D resources to exploitation. They pursue innovation strategies that support the integration of results of exploration in existing technologies, processes and products. Large firms adopt the Internal Corporate Venture strategy instead of the other simultaneous strategies. The latter are less appropriate in deepening industries since they separate the result of exploration from the existing processes and products. Smaller firms specialize in one technology and primarily organize for exploitation. The few explorative activities are executed by the same personnel.

The ELAT-region has little influence on the innovation strategies of the firms. Complementarities with research institutes or specialist firms do occur, but they are not geographically bounded.

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List of abbreviations

CEO	Chief Executive Officer
ELAT	Eindhoven-Leuven-Aachen-Triangle
HTC	High Tech Campus
IAC	Inkjet Application Centre
ICV	Internal Corporate Venture
IDM	Integrated Device Manager
IP	Intellectual Property
IPR	Intellectual Property Rights
ITRS	International Technology Roadmap Semiconductors
KUL	Leuven university
MEMS	Micro Electro Mechanical Systems
MM	More Moore
MtM	More than Moore
Nm	nanometer
NTRS	National Technology Roadmap Semiconductors
OEM	Original Equipment Manufacturer
PMTO	Product-Market-Technology-Organization
R&D	Research & Development
RBV	Resource Based View
SM-I	Schumpeter Mark I
SM-II	Schumpeter Mark II
TU/e	Eindhoven University

Chapter 1 Introduction

This study is focused on the innovation strategies firms employ to balance exploitation and exploration. It also deals with the influences a regional cluster may have and the underlying technology pattern of the industry. Both could be influencing the innovation strategy of firms.

1.1 Background

In scientific literature two types of innovation are discussed. These two types are innovations resulting from activities which could be labelled exploitation and exploration. With innovation as a result of exploitation is meant an innovation that results from current competences. An innovation as a result of exploration is referred to as an innovation resulting from newly developed, searched, or gathered competences. Exploitative activities are related to current competences and explorative activities are related to future desired competences (He & Wong, 2004; Holmqvist, 2004). It is of great importance for firms to be successful in the short- and in the long term. That is why firms focus on enhancing current competences as well as on innovations developing future desired competences, thus on exploitation as well as on exploration (Benner & Tushman, 2003; Levinthal & March, 1993)

But this comes at a price. Firms must divide and distribute the available resources and knowledge between the two types of innovation. Going for one type of innovation is risky (March, 1991). If firms assign too many resources to exploitation it makes them vulnerable for the long term because there is a lack of resources for successful exploration. On the other hand, assigning too many resources to exploration makes firms vulnerable in the short term because there is a lack of resources for successful exploitation, and that may lead to a loss in current competitive power. Firms know that they have to make a reasoned division in resources between the two types of innovation (March, 1991). This division has to be carefully balanced in order to obtain the desired result in exploitation and exploration. To realize a balance between exploitation and exploration firms, follow various strategies.

The strategies can be distinguished into two groups; strategies to organize exploitation and exploration simultaneously and strategies to specialize in exploitation or exploration (Gupta, Smith, & Shalley, 2006). Strategies to organize exploitation and exploration in a parallel way are already much debated in literature. Strategies that pursue specialization are much less studied.

Strategies to organize innovations in a parallel way are aiming at performing exploitation and exploration activities simultaneously. This kind of strategy to be capable of doing both simultaneously is referred to as an ambidextrous strategy. One way to achieve this is to physically separate exploitation and exploration activities into departments (Benner et al., 2003; Weick, 1976), or to temporary separate explorative activities and reintegrate the activities in the more exploitative activities (Iansiti, McFarlan, & Westerman, 2003; Siggelkow & Levinthal, 2003). The sequential strategy is characterized by a continuous focus on exploitation altered by a short period of intense exploration. After a successful period of exploration further exploitation of the newly acquired technologies and knowledge is organized (Burgelman, 2002; Tushman & Anderson, 1986).
Firms can also pursue a strategy to specialize either into exploitation or exploration. The balance between exploitation and exploration need not be realized within the organization itself but on a higher level in a social system (Gupta et al., 2006). Within such a social system one firm focuses on exploitation and another firm focuses on exploration. In this way firms can become complementary to each other and secure their short and long term viability. Since they become complementary the balance between exploitation and exploration is realized without immediate balancing issues. A good example of such a social system is an industry in which firms are complementary through their sequential position in the value chain. Exchange of exploitative and explorative activities is realized through the custom market principles between the different positions in the value chain (Gupta et al., 2006). It is possible that such complementarities between explorative and exploitative actors are realized in a regional innovative cluster.

Studying innovation strategies in the context of the social system asks for a multi-level analysis. This is an analysis on different levels, on the organizational level and on the higher social system level. Research into balancing exploitation and exploration on multiple levels is still undeveloped but desired. (Benner et al., 2003; Boschma, 2005; Gupta et al., 2006; Mahmoud-Jouini, Charue-Duboc, & Fourcade, 2007; March, 1991) This study seeks to pay attention to this blank spot.

The object of this multi-level study is a cluster of firms aimed at developing innovations using technologies on nano scale. Within the last 20 years of research activities in nano-technology, the research focus has been mostly on basic research activities which are strongly explorative of nature. But recently firms have been trying to transform the explorative activities into more exploitative activities. This creates the ability to apply nano-technology for developing and enhancing current competences (Bucher, Birkenmeier, Brodbeck, & Escher, 2003).

Therefore the context of nano-technology seems fruitful for studying strategies to balance exploration and exploitation. In addition nano-technology itself brings along some interesting characteristics which might influence innovation strategies.

Nano-technology is an overarching technology. It is an enabling technology, in which new effects and characteristics are created at the nano-scale, that is with at least one dimension between 1 and 100nm. One nanometer is 1/1.000.000.000 of a meter. Since research is focused on such a small scale, borders of scientific disciplines such as biology, chemistry, physics and information sciences are irrelevant. These disciplines are converging in research at this small scale (Avenel, Favier, Ma, Mangematin, & Rieu, 2007; Rocco & Bainbridge, 2003). The convergence of disciplines happens not only in science, but also at industry level. This convergence is noticeable in industries like the biotechnology, information technology and electronics (Bozeman, Laredo, & Mangematin, 2007).

Convergence of industries and science does not imply that nano-technology replaces the converging disciplines into one new absolute discipline. Within the convergence, specific research fields emerge for example in biotechnology and electronics. Research in the biotechnology is characterized by exploration and it is still limited in making the transition from exploration to exploitation. In the electronics industry, exploration as well as exploitation of nano-technology is realized.

Another interesting aspect of nano-technology is the fact that converging technologies draw actors from different disciplines into the research locations. Thus, locations of nano-technology research consist of different scientific disciplines and industrial actors, which is especially visible in nano-electronics clusters like Grenoble (Robinson, Rip, & Mangematin, 2007).

There are a number of arguments in favour of geographic co-location near research activities. An example is the presence of crucial research facilities like clean rooms and the required knowledge for performing research at nano level. Another argument is the possibility to transfer tacit knowledge which is of great importance to realize innovations consisting of different scientific and industrial disciplines (Boschma, 2005). A cluster can therefore be characterized by a shared orientation on nano-technology related to electronics industry (Robinson et al., 2007; St. John & Pouder, 2006). An example of a micro-electronics cluster is the well known Silicon Valley region in the United States where many firms are related to the information sciences (St. John et al., 2006). It is argued that clusters can influence or facilitate innovation activities.

The participants in a cluster which can contribute to innovation activities also differ in their position in the product-value chain. Besides the presence of actors like universities and research institutes firms are present. But how are the firms characterized. Do they have a history in innovating and building knowledge concerning the underlying technology? Is there a great amount of R&D effort required for realizing an innovation? Such technology characteristics are expected to be relevant for firms in a cluster. These characteristics refer to an underlying technology pattern which influences the industry, and therefore also the strategies for balancing exploitation and exploration.

1.2 Problem definition

Firms have the possibility to choose different innovation strategies to balance or specialize in exploitation and exploration. A multilevel analysis of this research field has not been performed yet but can give additional and new insights in the exploitation-exploration debate. Cluster characteristics could be an additional factor influencing the innovation strategies. A cluster with a nano-electronics identity seems to be very interesting for observing these effects. Moreover, the nano-electronics industry is expected to have technology characteristics which could influence the exploitation exploration activities.

In this study the following research question will be answered*: Which innovation strategies do firms follow in order to balance exploitation and exploration present in a nano-electronics cluster? In which way are the innovation strategies influenced by cluster and technology characteristics?*

To be able to answer the main research question the concepts and variables require further explanation. This is given in a literature review and theoretical framework presented in chapter 2. This theoretical framework results in a theoretical model that can be used to answer the main research question. The theoretical model is used in the empirical analysis which results are presented in chapter 5. Chapter 4 describes the context of the nano-electronics and the cluster. The research methodology used for selecting and analyzing the empirical data is described in chapter 3.

Chapter 2 Literature Review and Theoretical Framework

2.1 Introduction

In the past decades scholars emphasized the importance of simultaneously enhancing current internal competences as well as the importance of organizing future desired internal competences. The basic assumption that internal competences create a competitive advantage is grounded in the Resource-Based View (RBV). Firms are able to create a sustained competitive advantage while other firms are less successful with a similar strategy due to inequality in internal resources (Barney, 1991). Resources include all assets, capabilities, organizational processes, firm attributes, information, knowledge etc. controlled by a firm. These resources enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness in the short and the long term (Barney, 1991). Thus innovation capabilities are also internal resources which can contribute to the creation of a sustained competitive advantage. Innovation strategies are therefore constructed to facilitate the allocation of resources to the innovation activities for enhancing current capabilities as well as future capabilities. Learning to enhance current and future capabilities is often referred to as exploitation and exploration (He et al., 2004; March, 1991). Because exploitation and exploration require fundamentally different activities, a sound balance needs to be organized. An innovation strategy is therefore only able to contribute to the creation of sustained competitive advantage when exploitation and exploration activities are balanced.

The result of exploitation and exploration is an increase in knowledge and possibly a service or product to enhance current as well as future performance. In addition, exploitation and exploration create a broader and more solid knowledgebase to anticipate changes in the external environment (Tripsas, 1997). An innovation cluster is a specific environment in which a participating firm can be confronted with (technological) innovations by other cluster actors. Organizing a solid knowledgebase creates the ability to react to these changes, which is a necessity for profiting from innovation and knowledge spillovers of the other clusters actors. The cluster can stimulate exploitation and exploration in different ways, depending on the actors and their knowledge and technological background. Firms should incorporate the external environment characteristics in their innovation strategy because it can influence the way in which exploitation and exploration is balanced.

Besides being present in an innovation cluster, the overall technology characteristics of an industry can also influence the exploitation and exploration activities. The technological regime and innovation pattern in a part of the product-value chain or in a product-value chain as a whole, determines to a large extent how innovations are realized and by whom. Technology patterns can lead to, for example, the predictability of technology development for the forthcoming years, or the opposite, that technology is not predictable and technology standards are continuously challenged. In which way exploitation and exploration contribute to the firms' competitive advantage is therefore heavily influenced by the underlying technological regime.

Balancing exploitation and exploration as an internal issue needs to be related to the external environment and the underlying technological regime of the industry. In this chapter a conceptual model is presented which is used for the analysis of the innovation strategies of firms. This conceptual model incorporates concepts like exploitation, exploration, innovation, cluster characteristics and technological regime. Before presenting the model, an explanation of the concepts is given.

From the analysis further insights are created in the relation between exploitation, exploration and innovation. It is argued that innovations result from a process of exploitation and/ or exploration and that the specific characteristics of exploitation and exploration are present in the process. The result of the innovation process can be an innovation that manifests itself in the different ways in which the underlying knowledge areas and linkages are developed. Eventually this description of the innovation process will lead to a description of two types of innovation strategies and how they relate to the external environment.

2.2 Exploitation and Exploration

The concepts exploitation and exploration are rooted in the organizational learning literature. March (1991) describes exploitation and exploration as two different types of learning. Exploitation is aimed at enhancing and refining existing knowledge. Activities which are related are characterized by "efficiency, production, selection, and execution" (March, 1991, pg. 71). Attention is primarily given to creating a better understanding of current processes. This results in learning effects that facilitate a better and more efficient execution of the processes.
Exploration is aimed at acquiring new knowledge through learning. Related activities are characterized by "search, variation, risk taking, experimentation, play flexibility, discovery,

innovation" (March, 1991, pg. 21). Consequently March asserts that "the essence of exploration is experimentation with new alternatives" (March, 1991, pg. 85).

To realize those two processes of knowledge a type specific approach is needed; exploitation asks for extending the experience with knowledge areas and exploration asks for searching to vary in knowledge and environment. Enlarging the variety of knowledge internally creates opportunities to better respond to unforeseen changes in the external environment. Moreover, it creates a better and more solid base for anticipation (Levinthal et al., 1993).

The characteristics for identifying the type of learning process are readily applicable. For example activities aimed at enhancing the efficiency or activities involving experiments refer to exploitation and exploration respectively. It could be that for one person some activities are a routine, but for another person the same activities are completely new and pure experimentation. If you replace the notion "person" by "firm", in for example an industry chain, it may be seen that the same kind of activities will be perceived as routine or as new. In such a chain every firm has its specific area of expertise that could be largely new and unknown to the other chain members. This is particularly visible in upstream R&D activities and downstream marketing activities. Activities which are unknown to firms will be perceived as explorative. To study the concepts of exploitation and exploration it is of importance to recognize the point of view firms have in identifying activities as exploitative or explorative (Li, Vanhaverbeke, & Schoenmakers, 2008).

The balance is not only required within the organization itself, but also along the value chain. This gives firms an extra balancing possibility, viz. exploitative downstream product-market actors and explorative upstream science actors. This will be discussed in the cluster complementarities section 2.9.4.

2.2.1 Balance between exploitation and exploration

As is argued, exploitation and exploration differ considerably, and they are complementary in their result, i.e. perfection of existing knowledge and anticipation to new knowledge. Therefore March (1991) argued that both types of learning are important, and that one type of learning should not be at the expense of the other. They should be balanced. Achieving this kind of balance is not simple, because exploitation and exploration differ considerably. In the first place there is the problem of allocating available scarce resources like employees, capital and facilities, and since both exploitation and exploration are needed, a division of available resources is required. "They compete for firms' scarce resources, resulting in the need for firms to manage the trade-offs between the two" (He et al., 2004, pg. 482).

The second problem is the self-reinforcing character of exploitation and exploration. In the situation that a firm (or another entity) performs exploitation, the result will be refinement of existing knowledge. It is to be expected that this refinement will deliver a positive result relatively quickly, because the firm is already familiar with the field of knowledge. This positive result stimulates further learning along the same path, which will lead to the so-called success trap. When a firm is focusing on exploration it will undoubtedly get stuck at one moment because it is unfamiliar with this field of knowledge. A natural reaction to this situation is further exploration so that the problem or unfamiliarity with the knowledge can be tackled. This will lead to the so-called failure trap (Gupta et al., 2006). A firm needs to give the right amount of attention to exploitation and exploration, otherwise it may find itself in a vicious circle in succeeding in one and neglecting the other too much.
There is a fundamental difference in mindsets required for performing these two. The differences in mindsets are described by March as "exploiting interesting ideas often thrives on commitment more than thoughtfulness, narrowness more than breadth, cohesiveness more than openness" (March, 1996, pg. 280). For an employee it is not always possible to be narrow as well as broad, or to be simultaneously focused on cohesiveness and on openness. Moreover, employees (and firms) are not interested in developing activities or products which make current activities or products obsolete. Basically this would mean cannibalizing current competences (Christensen, 1997). Since profit in the short term can obscure the potential of the long term, it requires a balanced view on organizing exploitation and exploration. Giving attention to exploration that leads to cannibalism of current competences can be a method of creating the ability to anticipate on the future, but exploitation of current competences is also needed to be viable in the short term.
Finally, the expectations about the results of exploitation and of exploration differ substantially. The returns of exploitation are positive, proximate, and predictable. The returns of exploration are uncertain, distant, and often negative (March, 1991). In other words, the results of exploitation and exploration cannot be assessed on the same dimension.

Thus, obtaining a sound balance between exploitation and exploration is difficult to realize. Table 1 (adapted from (Jansen, 2005, pg. 19) gives an overview of the characteristics of exploitation and exploration.

Table 1 overview exploitation and exploration

	Exploitation	Exploration
Goal Cognitive Content	Build and broaden existing knowledge and skills	Require new knowledge and departure from existing knowledge
Characteristics of activities	Refinement, production, efficiency, and execution	Search, variation, flexibility, experimentation, and risk-taking
Mindset	Commitment, narrow, cohesiveness	Thoughtfulness, breadth, openness
Effect	Success trap	Failure trap
Returns	Positive, proximate, and predictable	Negative, distant, and uncertain

2.3 Continuity and orthogonality

March (1991) seemed very clear in his theorization that, although both exploration and exploitation are essential for the long-run viability, the two are fundamentally incompatible. They compete for scarce resources and can be seen as two ends of a continuum. Another point of view is the orthogonality perception. This view perceives exploitation and exploration not as mutually exclusive but as different types of firm behaviour (Gupta et al., 2006). The division of scarce resources between exploitation and exploration results in balancing issues which can be identified along the continuity approach. But it can be that competing for resources is not a problem, e.g. because availability of information and knowledge may be infinite through public articles or the internet, or because of abundant firm resources. The point of view taken in an organization to analyse exploitation and exploration determines how mutually exclusive they are perceived. In the situation of multiple domains, for example multiple business units, it can be that exploitation and exploration are performed in different units. This makes the balancing issues in mindset and effects far less necessary (Gupta et al., 2006), exploitation and exploration are then seen as different types of firm behaviour. The difference between continuity and orthogonality is of significance to the different innovation strategies firms pursue. An innovation strategy pursued by a small firm consisting of one business unit with few resources will be determined, in part, by the mutual exclusive characteristics of exploitation and exploration. A large firm with abundant resources and a large number of business units, e.g. production, R&D, marketing and sales, can perform exploration and exploitation in different units. The mutual exclusive effect of exploitation and exploration will be less obvious.

In this study it is not tried to see exploitation and exploration as either a continuity or an orthogonality issue but they are both appreciated. The innovation strategies section will discuss the different approaches to balance exploitation and exploration in more detail.

2.4 Results of exploitation and exploration

The notions exploitation and exploration refer to the learning processes in a firm. Results could be innovations (He et al., 2004; Jansen, 2005; Li et al., 2008), but also the absorption of knowledge. This absorption forms a more robust and solid knowledge base that enhances the anticipation capability to changes in the external environment and to incorporate external innovations (Cohen & Levinthal, 1990; Teece, Pisano, & Shuen, 1997; Tripsas, 1997). But the internal innovation process is of interest in this study.

It is possible to state what the result of the learning process will be. Innovations can happen in different areas of an organization. Boer & During (2003) consider innovation as the creation of a new product-market-technology-organization-combination (PMTO-combination). This 'combination' covers four innovation areas. A change in one of those areas, for example a product innovation, always somehow affects the other areas.

Another interesting aspect of the PMTO-combination is the premise that an innovation is of influence on different levels. For example, a product innovation influences the production process, but also the market and the participants of the market domain. Or to put it differently, an innovation can be of influence on a micro, but also on a macro level. An example of this multilevel relation can be seen in a product innovation which makes other products or entire markets obsolete (Geels & Schot, 2007).

How innovations as a result are related to the learning process is discussed in this section. This study focuses on the learning processes, and how these could result in technological innovation.

2.4.1 Technological innovation

A technological innovation is described as "the technology development of an invention combined with the commercialization of that invention" (Garcia & Calantone, 2002, pg. 112). An innovation is thus clearly more than a discovery, "a discovery that goes no further than the laboratory remains an invention. A discovery that moves from the lab into production, and adds economic value to the firm (even if only cost savings) would be considered an innovation" (Garcia et al., 2002, pg. 122). According to this definition an innovation can be a small improvement, but also a very big improvement, as long as it adds value.

2.4.2 Types of technological innovation

A further distinction in technological innovation can be made through taking into account the extent of the impact of an innovation. The impact can be on micro or on macro level (Garcia et al., 2002). A content analysis of the innovation as a result is useful because an innovation can be seen as the result of development and combination of components. These components can be put differently together realizing a change in performance. In addition, the components itself can be enhanced or replaced. Moreover, this analysis is directly applicable during the process of an innovation whereas the level of impact can only be determined in hindsight. First, a description of the level of impact will be given, followed by a description of the content of an innovation.

2.4.2.1 Impact micro – macro

If the impact is on a micro level, an innovation enhances or possibly replaces the current products, technologies or markets without demanding significant changes in behaviour of related actors. Innovation that results in such a type of impact on micro level can also be defined as incremental (Garcia et al., 2002; Henderson & Clark, 1990).

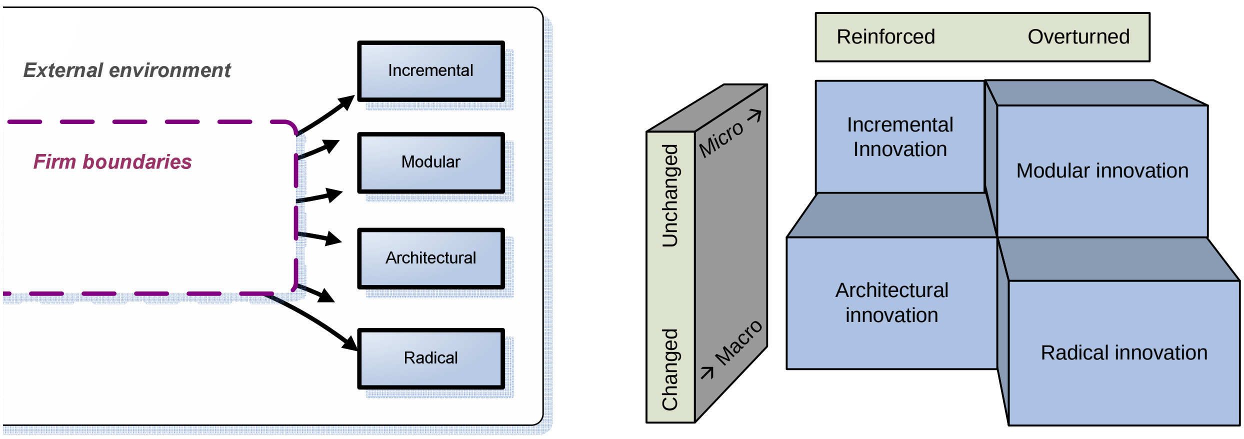
If the impact is on a macro level, all related technologies and markets are more or less affected. A direct result is that related actors in the industry value chains have to redefine their current bilateral relations. Innovations which cause changes in a large part of an industry value chain can be characterized as radical. Incremental and radical are two opposites of a continuum to describe the impact of an innovation. This approach to characterize innovations has the problem that it is retrospective. It can only be defined after identifying the level of impact on market, firm and industry chain. This typology of the innovation can be useful for identifying the effects on the industry value chain, but it is less applicable in connecting the internal innovation processes to the innovation as a result. A content analysis of the innovation is needed to actually be able to make a better grounded expectation of the result of the process.

2.4.2.2 Typology in linkages and components of innovations

Henderson and Clark (1990) use two dimensions to characterize the content of an innovation as a result. Their model is derived from earlier work from Abernathy and Clark (1985) which discusses the linkage between technology and markets. Abernathy and Clark (1985) propose a framework which describes the impact of technological innovations on the markets and industries. Henderson and Clark (1990) use similar notions to typify innovations but are much more focussed on the product itself and how technological innovations are performed in the content of the product. The notion content refers to incorporated technology and knowledge in components to realize the innovation. They note that a product consist of various components. Innovations can occur within one component and in the way the components are put together. The first dimension relates to the extent in which the change in component enhances or replaces the component currently used. In the situation that a component is only enhanced, this can be defined as incremental. But, when the change is characterized by a total replacement of the old component, then this innovation can be defined as modular. The second dimension relates to the extent of changes in linkages between components in the innovation. Component innovation can enhance current linkages, this can also be defined as incremental. Component innovation however can also replace current component linkages. This kind of innovation is defined as architectural. Architectural innovations are performed when a dominant design in the industry is absent (Henderson et al., 1990). When a dominant design emerges, innovations are more realized within components, thus incremental or modular. But, an innovation in component can precede an innovation in component linkages. When an innovation is replacing current component as well as current component linkages, the innovation is defined as radical.

A radical innovation is strongly related to effects on macro level. This is caused by a change in component and linkages which influences internal processes as well as external relations and as a result makes current components and linkages obsolete (Garcia et al., 2002; Henderson et al., 1990). Figure 1 visualizes the possible types of impact of an innovation. The two dimensions relate not solely to component and linkage innovations, but also to the underlying knowledge required for realizing an innovation. These two dimensions are very helpful in mapping an innovation in relation to exploitation and exploration, as the types of learning result in some kind of knowledge accumulation and linkages. This can also be projected on the two dimensions. In section 2.5 a further explanation of the relation between the learning types and the two dimensions will be given.

Figure 1 Content of innovations

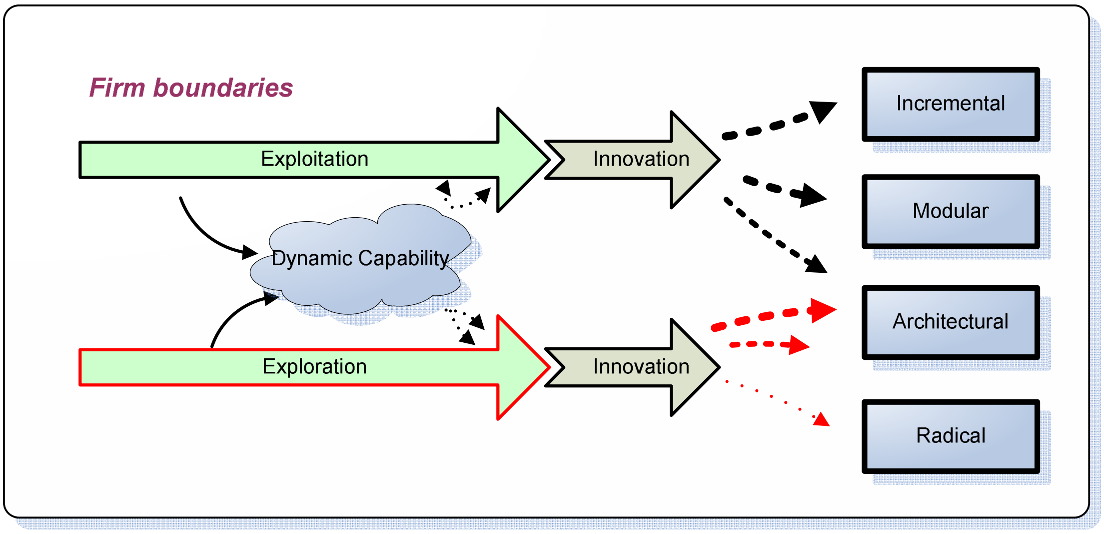


2.5 Results of the process

Technological innovations and the enhancement of dynamic capabilities are the results of learning processes. Yet the question remains which type of innovations are a result of exploitation and which are a result of exploration. The relation between the learning process and the result will be made through identifying the underlying changes and improvements in components.
Exploitation is related to refinement of existing knowledge. The technological innovation coming from these exploitative activities should be an improvement of the existing technology and can be typified as incremental. When these exploitative activities result in a strong improvement or even in a replacement of technology, they are called modular innovation. It is unlikely that exploitation will result directly in an architectural innovation, because this requires a change in the way components are put together. Architectural innovations are especially apparent when there is no dominant design and there has not been enough time to establish routines to exploit. Yet although architectural innovation is unlikely, modular innovations quite often lead to architectural innovations (Henderson et al., 1990). Radical innovations cannot be expected to result from an exploitative activity. It is very unlikely that radical innovations, viz. innovations that consist of new components and new component linkages, are the result of activities aimed at refining existing technology. But as was said earlier, modular innovation can lead to architectural innovation and therefore possibly to radical innovation.

The explorative process is characterized by search, variation and experimentation. An innovation as a result of these activities can be incremental, modular, architectural or radical, because the search can end anywhere. In current literature exploration is often directly related to radical innovations (Benner et al., 2003; Jansen, Van Den Bosch, & Volberda, 2006). It is argued that the intentions of exploration activities are aimed at organizing radical innovations or at creating absorptive capacity to deal with radical external innovations. A more open perception of exploration is appropriate since the result is not known beforehand. In the explorative search for new technology it is to be expected that current products, processes or services are improved (when possible) with newly found technologies or with changes in the way the components are put together. Architectural innovations could be a result of exploration. In figure 3 the relation between exploitation, exploration and the results is visualized.

Figure 2 Relations between results, dynamic capability and exploitation/ exploration



2.6 Innovation strategies

Firms can achieve sustained competitive advantage when they implement a value creating strategy not simultaneously being implemented by any current or potential competitors, or implemented with less results (Barney, 1991). An innovation strategy can contribute to this overall strategy because it is aimed at the organization and division of internal resources to realize innovations which could add value. In order to realize this, balancing exploitation and exploration can be required. The innovation strategy may overcome balancing issues like the division of resources provided to enhance current performance and future performance. Also the more indirect result of exploitation and exploration, i.e. the dynamic capability, contributes as an internal resource to the competitive advantage.

Scholars have proposed various strategies to balance conflicting tasks, e.g. investments in current versus future projects, differentiation versus low-cost production and exploitation versus exploration (Gibson & Birkinshaw, 2004). Although these strategies differ in their context, they all have in common that they strive for organizing a balance between conflicting tasks. These strategies are often related to achieving a sound balance between exploitation and exploration. The various strategies differ in three variables. First, there is the moment of time on which exploitation and exploration are performed, which can be simultaneously, temporary simultaneous or specialized. Secondly, exploitation and exploration are organized in a parallel manner or sequentially. And thirdly, innovation strategies differ in the organizational structure. Basically, the strategies can be divided in three (Gupta et al., 2006):

1. Strategies to organize exploitation and exploration parallel,
2. Strategies to specialize in exploitation or exploration,

3. Strategies to organize exploitation and exploration sequentially.

The three variables differ in the various strategies of which eight can be distinguished.

2.6.1.1 Parallel strategy within business unit – contextual ambidexterity

Gibson and Birkinshaw (2004) argue that employees are capable to decide for themselves which activities should be performed if management has communicated clear targets and organized the facilities to be flexible in performed activities. They state that employees within an organization or one business unit can be involved in exploitative as well as in explorative activities. This strategy is appropriate for smaller and medium sized firms. Large firms have the resources to allocate employees and facilities to both areas (Lubatkin, Simsek, Ling, & Veiga, 2006).

2.6.1.2 Parallel strategy within internal corporate venturing (ICV)

In the R&D department explorative as well as exploitative activities are performed, in which the explorative R&D activities are the frontier of corporate technology. If the new technology seems to be able to fulfil a technological and economical need, an internal corporate venturing unit is organized and held responsible for further development of the technology (Burgelman, 1983). After a period of development of the technology, the main objective alters from exploration into exploitation. To support this shift, the organizational structure should support this transition through adding functional exploitative specialisms to the internal corporate venturing unit like employees of engineering, manufacturing and marketing (Kazanjian & Drazin, 1990). This strategy underlines that the development of technology requires different capabilities at the different phases of the development. The organizational structure should be contingent with the requirements for technological development. This strategy is appropriate when the explorative activities will be aligned with existing activities and multidisciplinary teams are required. This strategy is of use to larger multidisciplinary firms.

2.6.1.3 Parallel strategy between business units – structural ambidexterity

Several scholars argue for structural separation of explorative activities from exploitative activities. Exploitative and explorative activities are separated into distinctive business units. At management level, the coherence of the multiple business units is organized and coordinated. O'Reilly and Tushman (2004) phrase this kind of strategy as follows: "The structure of ambidextrous organizations allows cross-fertilization among units while preventing cross contamination. The tight coordination at the managerial level enables the fledgling units to share important resources from the traditional units-cash, talent, expertise, customers, and so on-but the organizational separation ensures that the new units' distinctive processes, structures, and cultures are not overwhelmed by the forces of business as usual" (Tushman & O'Reilly Iii, 1996, pg. 77). This strategy is specifically useful when the environment of business unit developing the innovation is unstable and when the result of the explorative process is not integrated in existing processes and products (Siggelkow et al., 2003). The structural ambidexterity strategy is not appropriate for smaller firms which cannot allocate personnel solely to exploitation or exploration (Lubatkin et al., 2006).

2.6.1.4 Parallel strategy – exploitation and exploration separated outside the organization

The innovation strategy which separates the activities the most builds on the analysis of Weick (1976) who argued that strongly related but diversified business units are not capable of handling radical changes. Therefore scholars have proposed to separate activities that are oriented on new products and markets outside the organization (Christensen & Bower, 1996; Markides, 2006). In a way, this refers to a strategy to specialize into exploitation, but because this strategy makes it possible to organize exploitation as well as exploration in parallel, (although not in one organization, but originating from one organization), the strategy is typified as parallel. Spin-offs specializing in exploration are small and separated from large firms. The spun-outs focus is on technology development and is typically used in unstable environments with periods of intense technology competition and absence of dominant designs. Because of the uncertainty in these unstable environments, large firms focus on their core business and focus on exploitation.

2.6.1.5 Parallel strategy – exploitation and exploration temporary separated

Siggelkow and Levinthal (2003) point out that explorative activities can be best organized outside the existing organization. They argue that explorative activities in the developing stages require flexibility and a non-interference of established routines. This non-interference can be organized through separating the explorative activities organisationally. After a period of development, exploitative activities become important. Because the parent organization has routines and exploitative knowledge, the separated explorative activities and the result should reintegrate to benefit from the parent organizational strengths. The Temporary Separation strategy is suggested to be the right strategy in a dynamic and changing environment when interaction between firm activities and technologies is important and pervasive, for example, interactions between exploitative and explorative activities (Siggelkow et al., 2003).

2.6.1.6 *Specialization strategy – exploitation and exploration*

Firms can also choose to specialize in exploitation or exploration. Firms that pursue exploration search for new knowledge areas and may organize a balance through a relation with an actor focusing on exploitation in the same social system. Their relation is characterized by a certain amount of mutual interdependence. This strategy is appropriate when the explorative actor is active in a dynamic and changing environment, whereas the exploitative actor is active in a stable environment (Gupta et al., 2006).

2.6.1.7 *Sequential strategy*

The strategy to specialize in exploitation is often pursued without securing a balance with a specialized explorative actor. Tushman (1986) described the behaviour of firms who choose to focus on these activities which has proved themselves successful. These firms stick to what works well and are able to adapt to minor changes in the environment and the technology, the focus is on exploitation. When major environmental or technological changes occur, firms cannot adapt their existing technology and processes sufficiently enough, firms are forced to explore and search for radically different activities and technologies. These periods of exploration are typically uncertain. When a dominant design emerges, the focus shifts from exploration to exploitation. The explorative activities required to adapt to the major changes can be realized within the internal organization as the result of autonomous innovation (Burgelman, 2002), or as the result of a take over (Vermeulen & Barkema, 2001).

2.6.1.8 *Contingency*

The availability of abundant resources, e.g. in information, knowledge, personnel or finance, influences the strategy choice to balance exploitation and exploration. In the described strategies, firm size is the most prominent and obvious contingency variable. Also the stability of the firm environment is an influencing variable. The relation between firm size, technology regimes and innovation strategies is discussed in more depth in section 2.8.

2.7 Clusters

Firms can position themselves with regard to their innovation environment. An innovation cluster can be such an environment and the internal innovation process can benefit from the innovations being developed elsewhere in the cluster (Knoben & Oerlemans, 2006). A cluster can also contribute because of the resources available from the several actors, e.g. skilled personnel, machinery and knowledge. These resources may support the internal resources and as such enhance the internal innovation processes (Mathews, 2003).

2.7.1 Cluster definition

In the literature there are several approaches to characterize clusters. The first approach is geographical which starts with the actual presence of firms in a certain geographical area (Oerlemans & Meeus, 2005). The importance of geographical proximity lies in the fact that small geographical distances facilitate face-to-face interactions (both planned and serendipitous) and, therefore, fosters knowledge transfer. The main reasoning behind these effects is that short geographical distances bring organizations together. It favours interaction with a high level of information richness and facilitate the exchange of, especially tacit, knowledge between actors. The larger the distance between actors, the more difficult it is to transfer these tacit forms of knowledge (Knoben et al., 2006).
A common technology can attract firms with a specific actor and location, like for example the nano-technology development in Grenoble, France. The technological difference between cluster actors is influencing their relationships. Technological difference refers to the differences in knowledge actors possess about the technologies that mediate between their input and their output. Technological difference states that actors must have comparable knowledge bases in order to be able to recognize the opportunities offered by others, but a different specialized knowledge base in order to permit utilization of new knowledge (Knoben et al., 2006). The technology background of cluster actors influences the benefits a firm can have in their innovation activities, and may strengthen exploitation and exploration differently.
Occurring complementarities between cluster actors is connected to the differences in technology background. In general, complementarities between actors are a well known advantage of geographical regions. An actor within a cluster can often more rapidly source the new components, services, machinery and other elements necessary to implement innovations (Porter & Stern, 2001). The presence in a cluster of upstream activities, e.g. a R&D, and downstream activities, e.g. production/ marketing, may support firms to collaborate with these actors.

The three approaches to characterize clusters create insights in how exploitation and exploration activities at cluster actors are strengthened.

2.7.2 Technology

A cluster allows firms to learn from each other. Dynamic capabilities of the firm support the ability to deal with external technology. There are limits to the learning capability of the firm in a cluster, which is determined by the differences in technological background of the firms. Some difference in technology is needed, otherwise there is nothing to be learned. When the difference becomes too large, the dynamic capabilities of the firm are not sufficient to integrate the external knowledge. Is the difference too small, nothing will be learned (Knoben et al., 2006; Nooteboom, Van Haverbeke, Duysters, Gilsing, & van den Oord, 2007). In addition, a further distinctive aspect is in how exploitation and exploration are strengthened. Exploitation is supported when there is uniformity in technological background. Exploration is supported when there is a diversity in technological background, so that there are opportunities for exploring new knowledge and technology (Boschma, 2005; Nooteboom et al., 2007).

2.7.3 Geography

Geographical proximity is defined as the spatial and physical distance between the actors (Boschma, 2005). Learning and innovating depend on geographical proximity, because knowledge in development is to a large extent tacit and location-bound. This underlines the importance of being able to transfer and communicate acquired knowledge (Tripsas, 1997), in the internal organization as well as in the relation with external partners. Geographical proximity between actors can help in facilitating the transfer of tacit knowledge (Boschma, 2005; Tallman, Jenkins, Henry, & Pinch, 2004), it facilitates in a sufficient transfer of tacit knowledge and as such stimulates innovating activities. Exploration searches for and acquires new and unknown technologies. The new acquired knowledge is in the beginning still not well understood and is difficult to codify. Explorative activities can be strengthened by being present in an innovation cluster, since tacit knowledge can be more easily transferred.

Because exploitation is the refinement of existing knowledge, there have been more possibilities to codify the existing knowledge. Refinement of this knowledge is therefore possible over a larger geographical distance. But, for the correct interpretation of codified knowledge, tacit knowledge is needed. Thus, the required transfer of tacit knowledge for exploitation is also supported by geographical proximity (Boschma, 2005).

2.7.4 Added value through complementarities

In the perspective of exploitation and exploration, the interesting complementarities are the presence of upstream and downstream activities, in which upstream refers to R&D activities, and downstream refers to product development and commercialization. An actor which focuses on downstream activities could find an actor in the cluster with upstream activities. They could cooperate together and as such become complementary. Upstream activities are exploratory, and downstream activities exploitative (Li et al., 2008). To utilize these complementarities in a cluster fully, so that one actor focuses solely on exploration and another actor solely on exploitation, three conditions have to be fulfilled (Gupta et al., 2006). [1] Actors have to be complementary to each other in which one actor focuses on exploration and the other actor focuses on exploitation. [2] The complementary actors have to be present in different domains, in which one is characterized as dynamic, and the other as stable. [3] There is a low necessity to co-specialize which makes it possible to compensate through the complementarities. If these three conditions are fulfilled, firms can choose to follow a specialization strategy.

But complementarities can also be realized without specializing fully in exploitation or exploration. One cluster actor can perform exploration but may find support in their explorative activities by an upstream R&D actor, e.g. university or research institute.

Table 1 Cluster characteristics and influence on exploitation exploration

	Exploitation is stimulated by:	**Exploration** is stimulated by:
Technology	Close distance in technology background	Larger distance in technology background
Geography	Knowledge transfer is less hampered or stimulated by proximity	Geographical stimulates transfer of tacit knowledge
Complementarities	Presence of downstream actors	Presence of upstream actors

2.8 Technology regimes and innovation patterns

The technology regime can be a determinant for a specific pattern of innovations in an industry. There are two types of specific innovations patterns, the first is known as creative destruction and the second as creative accumulation (Breschi, Malerba, & Orsenigo, 2000). The first pattern refers to the fact that innovations in an industry are mainly produced by new entrants with no history in innovation within the industry and is heavily linked to the early claim of Schumpeter. In such an industry a great diversity of innovations is realized, which causes the industry to expand in technology (widening). The second pattern refers to deepening, where innovations are realized by incumbents with an innovation history within this industry and technology, this claim is heavily related to an latter proposition of Schumpeter who stated that large firms are more able to accumulate tacit knowledge in R&D departments and are as such more able to realize innovations (van Dijk, 2000). These two innovation patterns, which are derived from the claims of Schumpeter, occur within industry value chains (Breschi et al., 2000; van Dijk, 2000). A part of the chain can differ in type of technological pattern, these differences along the chain might help to understand the specialization strategies which could occur in the industry.

2.8.1 Deepening and widening

If parts of the industry chain are characterized as widening or as deepening, depends on certain aspects. These aspects grouped Breschi et al. (2000) in Schumpeter Mark I (SM-I) or Schumpeter Mark II (SM-II) type. SM-I and SM-II refer to the two claims of Schumpeter described in the previous section. Breschi et al. (2000) further distinguish the two types in four respects; technological opportunities, appropriability, cumulativeness and knowledge conditions. Technological opportunities reflect the likelihood of innovating for any given amount of money invested in research. The larger the likelihood for innovations coming from an investment, the higher the incentive to innovate. Appropriability of innovations summarizes the possibilities of protecting innovations from imitation and of reaping profits from innovative activities. The better the innovations are protected, the higher the incentive to innovate. Cumulativeness of knowledge is related to the necessity of having an innovation history to be able to realize innovations. In case that there is the necessity of an innovation history, the technology will develop along a line of continuous improvements. If an innovation history is not needed, the technology in the industry will develop with a greater diversity and along a less continuous path. Knowledge conditions are related to the character of knowledge underlying the bases of innovations. The knowledge can be distinguished into specific and generic. Specific knowledge is required for specific applications and generic knowledge for generic applications. Fundamental knowledge can be seen as generic knowledge and applied research more to specific knowledge. These four aspects grouped together form either the Schumpeter Mark I or Mark II innovation pattern.

Table 2 Characteristics of widening and deepening industries

	SM-I Widening	**SM-II Deepening**
Technological opportunities	High	Low
Appropriability	Low	High
Cumulativeness	Low	High
Knowledge Conditions	Limited role of generic knowledge	Generic knowledge base

2.8.2 Schumpeter Mark I Widening

The knowledge characteristics of a(n) (part of the) industry in which new entrants produce innovations can be typified by high “technological opportunities”. This refers to a higher likelihood to produce innovations form investments. There is also a low “appropriability” which creates the opportunity for others to benefit from externalities of innovations. Being able to benefit from externalities is related to the low necessity to have an innovation history in the industry. So the “cumulativeness” of knowledge is low and the knowledge conditions ask for more specific applications. Because the cumulativeness of knowledge is less of importance, the dynamic capabilities (Cohen et al., 1990) of a firm are of less importance in a Schumpeter Mark I industry. These knowledge characteristics should imply the presence of several small firms that continuously challenge technology standards and produce a constant stream of fresh ideas, processes and products (Breschi et al., 2000).

2.8.3 Schumpeter Mark II Deepening

The knowledge characteristics of an (part of the) industry in which incumbents realize innovations can be typified by low “technological opportunities”. Therefore, the possibilities for small entrants to produce innovations are very slim because they lack the resources. In addition, the industry can be characterized by a high “cumulativeness” caused by the necessity to have an innovation history to produce innovations. Incumbents have the advantage over new entrants who have not had the opportunity to build an innovation history. The “appropriability” is high, because innovations are the result of a complex and costly innovation process which makes the possibility for imitation and/ or benefiting from externalities lower. This group of characteristics results in an industry, or part of the industry value chain, which can be typified as Schumpeter Mark II. In such an industry, it is easier for incumbents to realize innovations than it is for new entrants. This results in an industry with high entry barriers to entrants (Breschi et al., 2000).

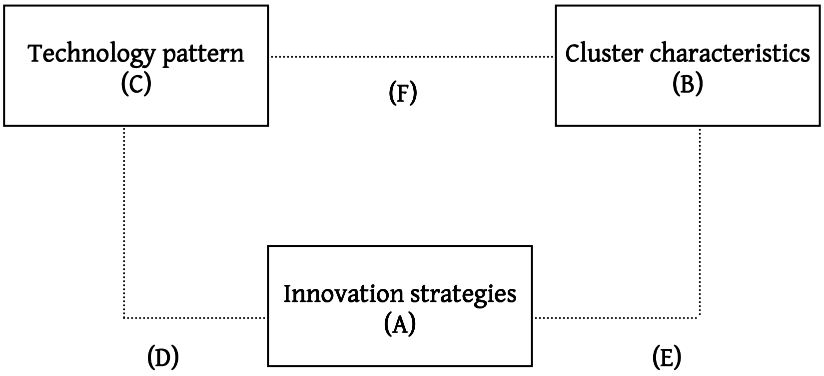
2.8.4 Contingency

Technological regimes influence the source of innovations in an industry. Organizing exploitation and exploration at large incumbents in SM-1 industries requires a different strategy opposed to SM-2 industries. In order to create the flexibility to deal with the dynamic environment in a SM-1 industry, incumbents prefer strategies which (structurally) separate explorative activities from exploitation. Since technology development happens along a continuous path in SM-2 industries, incumbents prefer linkages between explorative and exploitative activities. Innovation strategies which facilitate integration of explorative and exploitative activities are preferred.

2.9 Integrated approach

Until now, the different aspects of balancing exploitation and exploration and innovations in a cluster have been described separately. Firms’ strategies are influenced by the overall situation, in which cluster characteristics and technology characteristics have received specific attention. In figure 4 the three concepts and the studied relations are visualized. The figure suggests causality, the relation between technology and cluster characteristics has not been described and it is to be seen if this causality can be noted.

Figure 3 Strategy, cluster en technology



(A) The innovation strategy to balance exploitation and exploration is described by the moment and structure in which exploitation and exploitation is performed. (B) Cluster characteristics could enhance exploitation and exploration, this is described with the proximity in geography and technology, but also in how complementarities are organized between explorative and exploitative actors. (C) Description of the technology patterns of the industry and (D) how these influence the innovation activities. (E) Cluster characteristics could enhance or influence the innovation strategy of firms, and (F) the technology pattern and cluster could be of influence to each other.

Chapter 3 Study design and methodology

This chapter presents the research model and research logic accompanying the research questions. In addition, attention is given to the research design and method of data collection and analysis.

3.1 *Research question*

The main research objective is formulated as:
Which innovation strategies do firms follow in order to balance exploitation and exploration present in a nano-electronics cluster? In which way are the innovation strategies influenced by cluster and technology characteristics?

The research objective comprises three distinct questions to be studied. The first question is related to the possible strategies firms have to balance exploitation and exploration. The second question is related to (possible) contingency variables of the cluster, and the third question is related to contingency variable of the underlying technological regime in the industry. These three conceptual questions are represented in the research questions. The research objective is strongly explorative of nature and (in some extent) descriptive. The part of identifying the research strategies is explorative and the research on cluster and technology characteristics and their possible contingency variables are descriptive.

3.2 *Definition of core elements*

The main research objective consists of a set of theoretical concepts.
Exploitation and exploration, exploitation refers to the process of refining existing knowledge and exploration refers to the process of searching for new knowledge.
Strategy is related to the long-term goals of the firm, and how resources are allocated to the various processes to reach these goals. An innovation strategy is related to the division of resources to innovation processes which could enhance the current capabilities through exploitation, but also on processes to anticipate through exploration on the future
Nano-electronics - refers to technology development within the electronics industry at nano scale. Nano is the expression of technology which is generally defined as utilizing technology less than 100nm in size. This is 1/1.000.000.000 of a meter.
Cluster is a concept which relates to the point of view that firms and other actors are linked to each other, which could be caused by a for example shared culture, technology, goal, supplier, industry or geographical proximity. In this study clusters are defined through three variables, difference in technology background, proximity in geography and complementarities in exploitation and exploration between actors. In this study the

Eindhoven – Leuven – Aachen-region (ELAT) is the geographical cluster, nano-electronics as the core technology and exploitative and explorative activities as complementarities of actors in the ELAT-region concerned with nano-electronics. The ELAT-region is the research domain (Geurts, 1999) of this study and firms of importance to this study have the following characteristics:

- Firms and other organizations related to the development of nano-electronics technology
- These actors are located in the ELAT-region

3.3 Research questions

To answer the main research objective, six research questions are drawn up. The first, second and third research questions are aimed at comprehending the current theoretical and scientific debate and to build a model theoretical framework to structure the empirical analysis. The fourth, fifth and sixth research question are related tot the empirical analysis and will create the data to answer the three theoretical questions.

Conceptual research questions

1. Which innovation strategies can be distinguished to balance exploitation and exploration?
2. Which cluster characteristics relevant to exploitation and exploration can be identified?
3. Which technology characteristics can be identified? And what developments in nano-electronics, and more specific within the ELAT-region can be identified?

Empirical research questions

4. Which innovation strategies are followed by firms present in the ELAT-region?
5. In which way are innovation strategies influenced by technology characteristics?
6. In which way are innovation strategies influenced by cluster characteristics?

3.4 Logic behind the research questions

The first, second and third research question attempt to clarify the three distinct areas of the main research objective. The first research question clarifies the possible innovation strategies to balance exploitation and exploration, and forms the foundation of this study. The second and third research question attempt to clarify how cluster and technology characteristics can influence the innovation strategies. The fourth research question will clarify the explorative part of this study, the actual followed innovation strategies to balance exploitation and exploration in the ELAT-region. The fifth and sixth research question will clarify in which way cluster and technology characteristics influence the innovation strategies of the firms. By using these six research questions, a solid theoretical and empirical analysis of the main research objective will be realized.

3.5 Study design

The study design is set up to create insights at firm and cluster level. So, an understanding of the various interrelations between cluster characteristics and internal innovation processes is realized. As this study is explorative of nature and tries to understand interrelations, a qualitative research approach is used (Creswell, 1994) . The ELAT-region is the context of the analyzed firms, and it is tried to understand the influence of the ELAT-region on the firms. Scientific literature is insufficient and not developed far enough to propose hypotheses about the expected relations between a cluster and innovation strategies adopted. Therefore an explorative case study is required and appropriate (Yin, 1987). A direct result of the explorative nature of the study is that the results will be primarily descriptive, but with some causal characteristics because it is tried to explain the possible relations between firm strategy, cluster and technology characteristics. Due to lack of data and time a cross-sectional study is executed.
The case study can be typified as a single-case study with sub cases (Yin, 1987). The rationale is the fact that the ELAT-region is the case to be studied, but to understand the influence of the ELAT-region, underlying sub-cases need to be studied.

3.6 Unit of Analysis

There are two types of unit of analysis, the cluster and the participating firms. The first unit of analysis is the nano-electronics cluster in the ELAT-region. The second unit of analysis consists of the actual firm strategies of participating firms in de ELAT-region.

3.7 Research Methods

To answer the first, second and third research question, an analysis is made of the scientific debate concerning the three distinct theoretical concepts. The second and third research questions are also aiming at creating better insights in the actual ELAT-region and nano-electronics industry. Besides the literature review, context interviews are held to get insights. These interviews are in-depth, since they are held to understand what the context is and how this has to be interpreted (Cooper, 2003). They are held with experts in the field of semiconductor technology, cluster activities and innovation activities at firms.

Semiconductor technology:

- Prof. dr. Jurriaan Schmitz Twente University, Electrical Engineering

Cluster:

- Clement Goossens, Director Point One
- Jo de Boeck, CEO IMEC/ Holst Centre

Innovation activities at firms:

- Maarten Vertregt, Senior Research Principal NXP
- Thomas Grosfeld, Director Government Relations Netherlands NXP
- Richard Claassen, Senior Test & Product Engineer NXP

The fourth, fifth and sixth research questions are answered through semi-structural interviews with Research & Development Managers or employees responsible for these activities. Since the research questions are of an explorative nature but need to be in some extent comparable, semi-structured interviews are appropriate for discussing possible influencing or causal relations. The interviews are held with:

NXP - Mr. F. Van Roosmalen (Vice President, Manager Corporate Government & Industry Relations)

Océ - Mr. A. Gelderblom (Relation Manager R&D)

Catena - Mr. Ten Pierik and Mr. Pol (System Architects)

Sitel Semiconductors – Mr. R. Kohlmann (Chief Technology Officer)

Semiconductor Ideas To the Market - Mr. P Langendam (Chief Executive Officer)

Cavendish-Kinetics - Mr. Cor Schepens (Marketing & Relation Manager)

3.8 *Selection of Cases*

The selection of the ELAT-region as a unit of analysis is the result of the objective to analyze the scientific debate in the situation of a multilevel context, and to create a better understanding of the influence of technology characteristics on the innovation strategy. The selection of the ELAT-region can therefore be typified as purposive sampling (Cooper, 2003).

The selection of the sub-cases is, as is said, the result of two selection criteria:

- Firms and other organizations need to be related to the development of nano-electronics technology
- The actors are located in the ELAT-region

Six firms are selected, namely:

1. NXP - is a large multinational semiconductor manufacturer with a long history of innovations in the industry. The headquarter and main research location is situated in Eindhoven.
2. Océ – is a large multinational in document processing and has just recently begun to integrate nano-electronics technology into their products. Océ is headquartered in Venlo, as is the main research location.
3. Catena - is a medium sized company which operates as a technology specialist in designing radiofrequency applications for the semiconductor industry. Catena is headquartered in Delft and also located in Eindhoven.
4. Sitel Semiconductors - is a medium sized company which designs and produces chips applicable in the telecommunication industry. It is located in Den Bosch
5. Semiconductor Ideas To the Market (ItoM) - is a small sized company which operates as a technology specialist in designing receiver and transmitter chip applications for communication applications. It is located in Eindhoven.
6. Cavendish-Kinetics - is a small sized company which develops a highly innovative integrated memory chip application. It is headquartered in San Jose, USA and located in Den Bosch.

3.9 Validity and reliability of empirical analysis

Four tests may be considered relevant in judging the quality of a research design. These four tests are construct validity, internal validity, external validity and reliability (Yin, 1987).

Construct validity is all about establishing correct operational measures for the concepts to be studied (Yin, 1987). The operational measures are the result of the literature review and the interviews about the context and technology. These interviews are held with experts in the technology and industry. This enhances the content validity strongly. The analysis of the context and technology is written in a continuous dialogue with experts in the field. The operational measures derived from literature are enhanced by the context and technology analysis. Attention is given to what the concepts of exploitation and exploration actually mean in the semiconductor industry. The result of these activities is enhanced construct validity.

The internal validity relates to the possibility to make causal relations (Yin, 1987). Although this study is primarily explorative, it tries to understand the influence of the technology and the cluster on the firm strategy. Proposing conclusions and causal relations as a result of an understanding of the influences on the firm strategy is possible, but requires attention. To support the validity of these causal claims alternative rival explanations are studied. In the discussion section the proposed causal relations are debated. So, the internal validity of these relations is enhanced.

External validity is about the domains to which the study's findings can be generalized (Yin, 1987). The ability to generalize the findings of this research to other domains is enhanced by a number of aspects. The selection of this domain of analysis, the ELAT-region, is the result of the wish to study exploration and exploitation on multiple levels. This is possible in an innovative cluster like the ELAT-region. The sub-cases are selected by their presence in the ELAT-region, their relations to a single industry and technology, and their relation to innovation activities of this industry. The selected sub-cases differ, but are all involved in similar activities, viz. they all design chips. Therefore the ability to generalize across other nano-electronics clusters and participating firms of the semiconductor industry is enhanced. Since in nano-electronics clusters various types of firms are present, from the semiconductor industry as well as from adjacent industries, generalizing the study's findings to all firms in a nano-electronics region is not appropriate. Attention has to be given to their industry background.

3.10 Intended Result

The intended result is a theoretical foundation and a model to analyze the innovation strategies aimed at balancing exploitation and exploration in a cluster. Moreover, it will be used to identify the innovation strategies in the ELAT-region. Since this study uses a multilevel approach, it contributes to the current scientific debate on exploitation and exploration. The analysis also contributes to a better grounded societal expectation concerning innovation hot-spots or innovative regions. Since the ELAT-region was only recently supported by national governments just recently (2006), the actual perceived value of the ELAT-region of participating firms is of significance. This gives better understanding of the actual added value of the region in relation to innovation.

Chapter 4 Context - Nano-technology - Semiconductors

Before the theoretical model can be applied to the analysis of the firms in the ELAT-region, it is necessary to understand in what kind of context these firms are situated. A summary of the semiconductor as a technology and the accompanying industry is given. Subsequently, the exploitative and explorative activities in the industry can be defined, which is necessary to understand the innovation activities of the studied firms in the ELAT-region. This chapter concludes by identifying possible cluster characteristics for the semiconductor industry and the technology patterns within the industry.

4.1 Semiconductor

When a Google search for the word *semiconductor* is executed, the results are often related to the word *chip.* These two words are virtually inseparable and that is not without a reason. Chips are made of a material called silicon. Silicon is a specific material which conducts electricity a little, but not very well, that is why it is called a *semi*conductor. Given that silicon conducts electricity a little, it is extremely useful for a wide range of applications. These applications can be a transistor, a capacitor, an inductor or a resistor. All of these can be integrated in chip. The more of these applications are integrated on a chip, the more powerful the chip will be, or the higher the capacity for storing data. The specific set of transistors, capacitors, resistors etc. with the accompanying software systems determines the functionality of the chip.

4.1.1 Semiconductor industry

When is spoken of the semiconductor industry, one actually refers to the industry related to the design, the production and the sales of chips. This industry began with the invention of the transistor in 1947. Since 1947, the original invention has developed enormously. Nowadays, the industry has grown to a global, multibillion industry, and the year 2007 was responsible for a turnover of $ 255 billion (WSTS, 2008). The global turnover has an average growth of 6,8% a year[1].

Chips are available in various specifications and applications and supply a number of markets. The chip application types are visualized in the figures 6 and figure 7. Figure 6 visualizes the percentage of types of chips produced. It is clear that *Discretes* is responsible for the majority of chip production, but this is to be expected since this application type consists of transistors, capacitors, inductors and resistors, and these are integrated on chips

1 http://seekingalpha.com/article/19711-world-semiconductor-trade-projections-overly-optimistic-for-2007-and-beyond

in various ways. Such chips could be Memory, Logic or Microprocessors, the amount of these types of chips is far less in comparison to Discretes. Figure 7 visualizes the financial contribution of the different chip types. Now it becomes clear that Microprocessors, Memory and Logic are responsible for the largest contribution. This is not surprising, since these chips are much more complex.

Figure 4 Total unit volume contribution

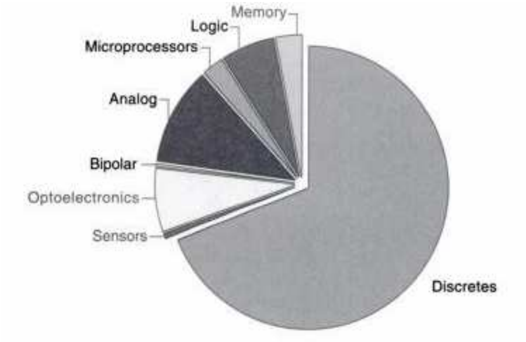
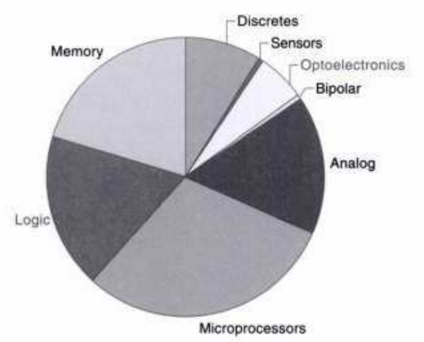
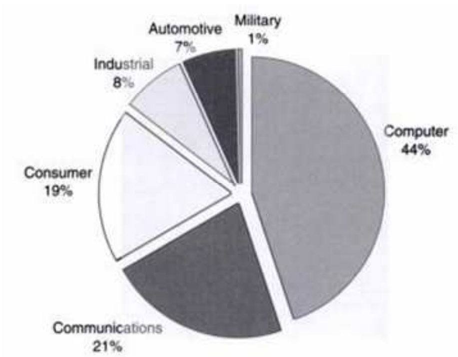


Figure 5 Total Financial contribution



The next step is the division of these chips on the different markets. In figure 8 these markets are visualized and the percentages refer to their financial contribution. The figure points out that the application of chips in the Computer market is responsible for the largest contribution, since this market comprises the consumption of the most complex chip applications such as Memory, Logic and Microprocessors.

Figure 6 Relative consumption by industry



The communication market is an important market. This is primarily due to the high amounts of memory applications required in communication products, like mobile phones. The communication industry is steadily growing and will continue to grow for the forthcoming years as opposed to the stabilization of the computer market.

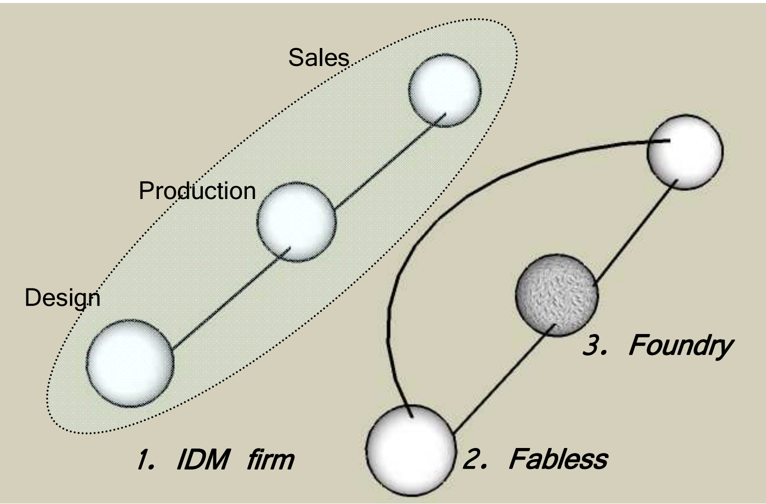
So, firms of the semiconductor industry produce products which are subsequently integrated in other products, like computers, phones, TVs, pacemakers, GPS or any other electronic system. Therefore, the semiconductor firms who design, produce and sell chips are so called original equipment manufacturers and they supply to producers of electrical systems.

The previous section has given some insights in the industry and it can be concluded that the industry reaches multiple markets with various applications integrated in electronic systems. The semiconductor industry is a large and multibillion market in which a great variety of actors is involved. Which type of actor is responsible for innovations in the industry is described in the next section.

4.1.2 Industry value chain

The production of chips involves multiple phases which are executed in more or lesser extent at different firms. In general, three distinctive business models can be identified to organize the value chain of the industry. These models are structured around three core processes, viz. design, production and sales. In figure 9, the business models are visualized.

Figure 7 Business models in the industry



Integrated Device Manufacturer (IDM). In the situation that design, production and sales of chips are performed in one firm, these firms follow the IDM business model. Well known examples of this type of firms are INTEL and IBM. Sometimes, the firms do even more than only the chip, they also integrate it in an electronic system, take for example the IBM chips in their production of IBM personal computers.

Fabless firms. When a firm designs and sells a chip, but does not produce them, these types of firms are typified as *fabless*. For the production of the chips, firms can cooperate with an IDM. An example of a fabless firm is Xilinx, who designs and sells their chips but produces their chips at the IBM manufacturing site.

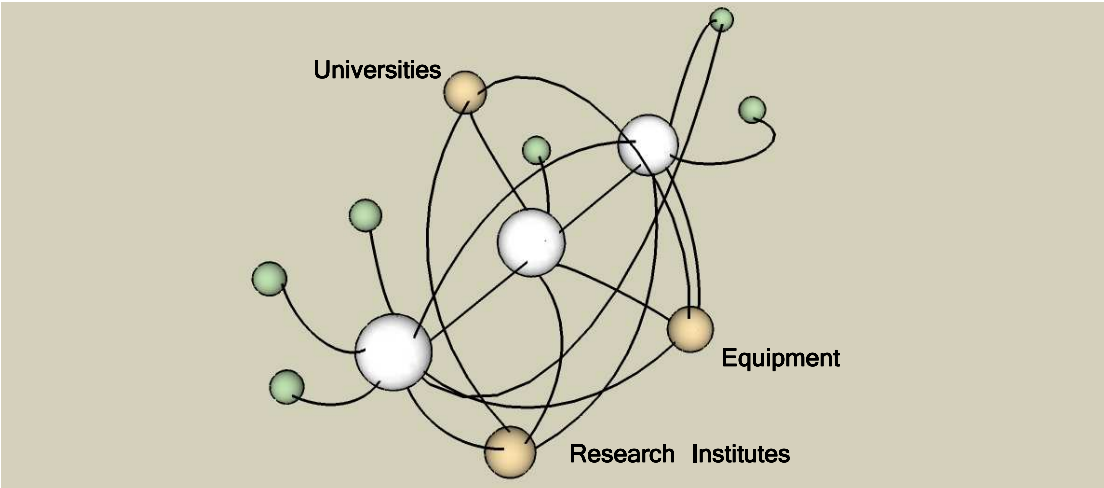
Foundry. In the situation that a firm does not design or sell a chip, but only produces a chip, these firms can be typified as a *foundry*. Xilinx could have chosen to produce their chips at such a dedicated foundry firm, for example, TSMC in Taiwan.

4.1.3 Networks related to the three core processes

To produce a chip, linkages between the three core processes are very important and they are used intensively. The actors who are responsible for the three core processes are well known to each other, therefore the linkages could be characterized by their strong ties (Granovetter, 1983). To each of the three core processes, a specific set of suppliers of knowledge, products, machinery etc is linked. These suppliers all have linkages which are mostly strong, but the relation of these specific suppliers to the other two core processes could be much weaker. In addition, the semiconductor industry has developed into an industry with many specialized suppliers. This specialization occurs even within the three core processes, in which part of the processes are performed by specialists. For example, a part of the design of a chip is performed by a design specialist, and his part is subsequently integrated in the design activities of the chip as a whole at an IDM or Fabless firm. Other specializations can take place at manufacturing sites and machinery producers, which for a large part determines the production possibilities of designs. These machinery specialists, e.g. ASML, Canon, ASMI, FEI etc., have their specialist technology and knowledge suppliers. Although these suppliers are not directly related to the design core process, they influence the ability to produce the designs. So these suppliers are less related to the design core process but stronger to the production process.

A result of the specialization in the industry is the necessity to integrate the individual knowledge areas to be able to develop and produce the chips in a cohesive way. Moreover, weak linkages between the different types of firms could stimulate the innovation activities since firms are confronted with activities of firms they normally do not encounter (Granovetter, 2005). In general, universities are such integrating actors, but other actors like research institutes or equipment and machinery suppliers are also integrating actors. Hence, these actors have stronger ties to the different specialisms. In figure 10, the linkages between the three core processes and suppliers are visualized. In the case of research institutes and universities, linkages exist that could be outside the semiconductor industry, but that could become relevant. Thus, integrating actors in the semiconductor value chain could be a source of potential innovations. Therefore it is of interest how the different firms are related to such integrating actors.

Figure 8 Integrating actor



4.2 Innovation in the semiconductor industry

To understand how firms organize innovations and how the overall technology pattern in the industry has been, an analysis of the innovation path of the industry is given in the following section. This analysis will contribute to the understanding of the specific exploitative and explorative activities organized at the different firms.

4.2.1 Innovation path of the semiconductor industry[2]

The semiconductor industry started with the invention of the transistor in 1947. The first microchip was developed by Jack Kilby at Texas instruments Inc. and Robert Noyce of Fairchild in 1958. Later, Robert Noyce would become one of the co-founders of Intel. In addition, an innovation of the production process was developed by Martin Atall at the Bell Labs in 1959. This created the possibility to produce microchips in bigger volumes. In the following years, the semiconductor technology continued to develop at United States based firms primarily. Within the American semiconductor industry, the competition was fierce, which led to many innovations and technology competition. Firms had encountered difficulties to be competitive in all the activities required for producing chips. Until then, the majority of the firms had had everything they needed to produce chips within their organization (Macher & Mowery, 2004). Fierce competition in technology forced firms to focus on specific technology areas, and so the value chain specialized vertically, and firms specialized in machinery, materials, sales etc. Although firms spun out several activities, the majority of the activities remained in the organization and the firms maintained the IDM business model (Macher et al., 2004).

[2] Innovation path description is based on interviews with senior research employees at a large IDM, NXP

In this decade, the '60s-'70s, firms began to focus on technology improvement in which the amount of integrated transistors on chips increased and the costs of production declined continuously. This led to the well known law by Gordon Moore, which postulates that the number of transistors on a chip will double about every two year[3]. In addition, it was argued that the costs of delivering digital functions on silicon wafers, a round plate from which the single chips are cut, would halve every two years. Since this period, Moore's Law has been a target for the industry.

In the following decade, the focus of the industry remained on Moore's Law. Moreover, the industry reached a major consumer market time with the development of the personal computer. This market proved to be a big success, and prominent firms of the industry tried to get a position in this market. This was not without a reason because the market for personal computers developed into the biggest purchasers of semiconductor products until now, as was visualized in figure 6 en figure 7.

To be able to keep up with Moor's Law and the technology leaders of the industry, technology development requires increasingly higher R&D investments, in particular in the leading-edge applications like Microprocessors and Memory. To stay on top, firms have to update their production facilities and equipment every year (Turley, 2003). This requires huge investments, because firms have a state-of-the-art production facility (n = current technology generation). In addition, firms have to test the upcoming production facility which will be used for the production of the next technology generation (n +1) in the next year. Moreover, firms have to organize research at future facilities and production processes to be able to produce the future technology generation (n+2). Thus firms need to invest in three technology generations and this became too costly. So in the mid '80s, firms searched for alternative ways in research investments in order to keep the technology development affordable. They began to develop technology in cooperation with competitors, equipment suppliers and research institutes in a precompetitive phase, the development of the so called n + 2 technology generation. The research institute IMEC located in Leuven (started in 1984) is an example of an institute which performed precompetitive n + 2 technology research.

Besides the first steps in precompetitive technology development, the business model of some firms changed from IDM to the fabless and foundry business model to keep technology development affordable.

[3] http://www.intel.com/technology/mooreslaw/

Besides the personal computer market, the communication market presented itself as another important technology driver in the early ‘90s. Especially the application of the memory technology presented itself as an important driver for firms to hold on to Moore’s Law. But besides the continuous drive to fulfil Moore’s Law, firms started to search for opportunities to use their existing technology. This resulted in a new technology trajectory, the integration of other functionalities on the chips. A well known and groundbreaking example is the airbag sensor integrated on a chip. The performance and the production costs of these chips were exceptional, because airbag sensors were large heavy products and had a cost price of around $20, but the sensor integrated on a chip had the size of a dice and a cost price of a few dollars. [4] The technology development in which other functions are integrated on a chip is known as More than Moore (MtM).

Besides the changes in business models, technology direction in MM or MtM and vertical specialization of the industry chain, the industry also met with uncertainty as to how to develop technology in the forthcoming years (Macher et al., 2004). Moreover, the industry is globalizing increasingly, take for example, the displacement of production facilities and dedicated foundries from Europe and Unites States to Asia. Prominent firms of the American semiconductor industry acknowledged that this uncertainty was not beneficial. Therefore they worked together to define the expected technology trajectory for the forthcoming 10-15 years. The result of this cooperation is the technology roadmap (NTRS) presented in 1991 (Gehani, 2007). Since the introduction of the roadmap, it has been updated every two years and it expanded even further as an international cooperation realized by firms from all over the world to define the technology trajectory in 2001. This roadmap is called the International technology Roadmap Semiconductors (ITRS). Since the first publication of the NTRS roadmap, these documents have become very important to point out the general technology development. In these documents, the targets of technology development are described, but also the technological barriers which need to be overcome to reach the desired technological targets.

At the end of the ‘90s, the cost of state-of-the-art production facilities has increased so much that many firms choose not to invest in the newest facilities anymore. For example, the cost of building a new production facility has risen to 1 billion dollars and has to be depreciated in 5 years anno 2000 (Turley, 2003). The success of chips like e.g. the airbag sensor, the slowing down of the personal computer market and the increasing costs of developing technology in accordance to the MM trajectory, forced some firms to invest and

[4] http://www.delta.tudelft.nl/nl/archief/artikel/silicium-gatenkaas/3758

develop technologies in the MtM trajectory. The MtM trajectory does not require state-of-the-art production facilities, but exploits existing facilities for new purposes. Hence, the production facility has an extended life span, which makes technology development much more affordable.

Since 2000, firms have acknowledged that the MM trajectory is not only becoming more and more costly, but the technology development is also approaching its physical limits. There comes a point that technology cannot miniaturize any further. Moreover, firms ask themselves if it is useful to reach these limits, since the demand for such miniaturized technology is expected to decline (at the moment) (Christensen, Anthony, & Roth, 2004).

To summarize, in the last 50 years the industry focus was primarily on technology development to reduce the costs of production and to miniaturize the technology. In the '90s, another technology trajectory arose, namely the MtM technology. This shifted the focus of a part of the industry from miniaturization towards functional integration and usage of existing technology. However, MtM technology development requires a different mindset and integration of functional technologies into the semiconductor technology.

4.3 Exploitation and exploration

The technology development of the industry seems to have a clear technology path in which firms are aimed at miniaturizing technology and reducing costs continuously. Although the development of each technology generation requires a lot of research and investments, it is continuously improving existing technologies. More explorative developments are also noticeable in this MM trajectory, because the change from one technology generation to a new technology generation may ask for new production machinery or materials, but it is never totally different from the previous technology generations. In addition, the technology development is strongly related to a technology target. Research knows what the technology is capable of, but does not fully comprehend how to get there. Although the MM trajectory is continuously developing, the explorative developments are related to concrete targets and expectations.
The MtM trajectory seems to have a distinctive explorative and exploitative part. The integration of functionality into the semiconductor chips clearly relates to explorative activities. But this technology is integrated in existing technology and production facilities, which refers to exploitative development. Besides the MtM trajectory which uses existing semiconductor technology, there is another MtM trajectory which combines development in the MM trajectory with the integration of functionality, for example, in the bioelectronics industry. This kind of development is truly explorative of nature because it

requires the development of new semiconductor technology and the integration of new functionalities.

4.3.1 Structure

The section which deals with the innovation path describes why firms might change their business models and why they might start cooperative (pre competitive) technology development. In the '80s, technology development was primarily organized within the organization since most of the firms had the IDM business model. But in the '90s, firms chose to specialize in a specific technology area. Consequently they could only develop a part of the total chip technology. The fabless and foundry business model has even become more popular in the 21st century and this has caused firms to cooperate even more intensively. Since production technology is developed at foundries and research institutes, and chip designs are developed at fabless firms or so called specialist design houses, firms are more and more cooperating with suppliers and industry partners to organize a cohesive technology development.
Hence, the structure for the organization of technology development, exploitative as well as more explorative, has shifted from solely at the internal organization, towards technology development with external partners.

4.3.2 Moment of exploitation and exploration

The structure to organize innovations changed in the last two decades. This change also affects the *moment* of firms to organize exploitation and exploration. The IDM business model brought about continuous exploitation and exploration in the internal organization. But the specialization of firms in technologies entails that firms develop their existing technology and source more explorative activities from external partners. They can, for example, source more explorative technology at research institutes. It is expected that firms in the semiconductor industry will specialize in exploitation of their technology.

4.4 Cluster

In the semiconductor industry, firms often cluster within a geographical region. Well known examples of geographical regions with a strong semiconductor technology character can be found in Silicon Valley, the United States, Grenoble, France and Silicon Saxony, Germany. Since Silicon Valley is seen as a region responsible for a large amount of innovations and this format seems to work. Other regions attempt to organize similar innovative regions.

The Eindhoven-Aachen-Leuven (ELAT) region can also be seen as a geographical region with firms related to the semiconductor technology. In particular, the application of semiconductor technology into electronic systems is well presented in this region as is the equipment industry for producing semiconductor and electronic systems. Besides these firms, the three cities also have Universities with research programs in electronics or adjacent technologies. These universities are responsible for a number of spin-offs in the electronics industry. In addition, there are large research institutes, for example, IMEC Leuven and the research facilities of Philips and NXP at Eindhoven. Hence, the ELAT-region consists of firms, universities and research institutes and this fact should result in exploitative and explorative development.

4.4.1 ELAT-region

The ELAT-region refers to the convergence of three regions situated around Eindhoven, Leuven and Aachen. Each of the three regions has competences in specific technologies. The three regions have grown over the years and have become increasingly closer to each other. Local governments acknowledge the growth of the three regions and support a closer cooperation to form one innovative region. This newly formed innovative region has the potential to become one of the best R&D regions of Europe.[5]

The industries located in the ELAT-region vary from automotive, semiconductor, electronics to bio-medical. The semiconductor technology is much applied in these industries. Although not conspicuously, the semiconductor firms are present in this region.

4.4.2 Eindhoven

The Eindhoven region is located in the southeast of the Netherlands. This region has been host to several prominent firms for many years. The industries present in this region are:

Industries and Firms in Eindhoven region		
	Industries	*Firms*
1	Medical Technology	Philips
2	Automotive	DAF, VDL, VDO Siemens
3	ICT	Atos Origin, SNT, HVL
4	Mechatronics	Philips, DAF, ASML, FEI, Stork
5	Design & Food	Campina, Friesland Foods

Besides these industries, the convergence of traditional separated industries has led to the start of new upcoming technologies, like embedded systems, nano-technology and life-sciences. In addition, Eindhoven University is located in this region. The Eindhoven region is responsible for investments of €2.3 billion in R&D activities each year. This number

[5] http://www.elat.org/

comprises 30% of the total Dutch R&D expenditure and 45% of the R&D expenditure of Dutch based firms. Of the €2.3 billion, 85% is invested by firms, and 15% by research institutes and universities (SRE, 2004). The Eindhoven region is considered to be a more innovative region than other regions in the Netherlands.

4.4.3 Leuven

The Leuven region is situated around Leuven University (KUL) and the IMEC research institute. These two important research actors have 'produced' and attracted a number of high-tech firms. Leuven University is ranked among the top 10 universities in Europe and excels in the transition of academic research into development in firms. The competences of the Leuven region are life sciences, micro and nano-electronics.

	Industries in Leuven region
	Industries
1	Life- Sciences
2	Feed-Food-Health
3	Mechatronics
4	Telematics and communication
5	E-security

4.4.4 Aachen

The Aachen region stretches from the German border near Venlo to halfway the Belgian border. The region has expertise in life-sciences, medical engineering and biotechnology. The Aachen region also has a history of development in materials, production technology and mechatronics. Aachen has only recently started to become a region of high-tech development. The competences are the result of a cooperation between universities, governments and firms. This has resulted in multiple public-private research institutes in which high tech development is organized.

	Industries in Aachen region
	Industries
1	Life Sciences, medical engineering and biotechnology
2	Automotive and rail engineering
3	ICT
4	Production technology
5	Materials

4.4.5 Semiconductor technology in the ELAT-region

The ELAT-region is characterized by the presence of different industries that overlap each other to some extent. The semiconductor industry delivers an enabling technology to these various industries. The most visible semiconductor actors in the region are the research institutes IMEC Leuven and IMEC/ Holst Centre Eindhoven, the IDM NXP headquarters and research facilities in Eindhoven, the High Tech Campus in Eindhoven and equipment suppliers such as ASML and FEI. And then there is Philips Eindhoven, a large buyer of semiconductor technology.

Besides these large and visible actors, there are more firms of the semiconductor industry situated in the ELAT-region. They can be typified by means of their business model and position in the value chain.

4.4.5.1 IDM

In the ELAT-region, several IDMs are located. These firms design, produce and sell chips.

- NXP (turnover $6.32 billion[6], in top 10 semiconductor, HQ Eindhoven)
- ON-Semiconductors (turnover $2.18 billion[7], in top 50 semiconductor, HQ Phoenix, USA)
- Melexis (turnover €200 Million[8], HQ Ieper, Belgium)

Apart from all being an IDM, these three firms differ in the activities they perform in the region. NXP is a large multinational, which is involved in MM as well as MtM technology development. This technology development is partly organized in the ELAT-region. ON-Semiconductors is a similar firm, but it has only a production site in the ELAT-region (Oudenaarde, Belgium). But since its research activities are organized at other locations, ON-semiconductors is not really active in the region. The Melexis firm focuses on MtM technology development in which existing semiconductor technology is integrated with other functionalities. Melexis is a prominent player in the airbag sensor chips. Melexis is not participating in explorative MM or MtM technology development. NXP is the only one who contributes to explorative development in the region.

4.4.5.2 Fabless

Not only IDMs, but also a number of fabless firms are located in the ELAT-region. They are mainly spin-offs from the IMEC institutes and NXP and Philips research departments. These firms design and sell chips and they vary in size and specific technology expertise.

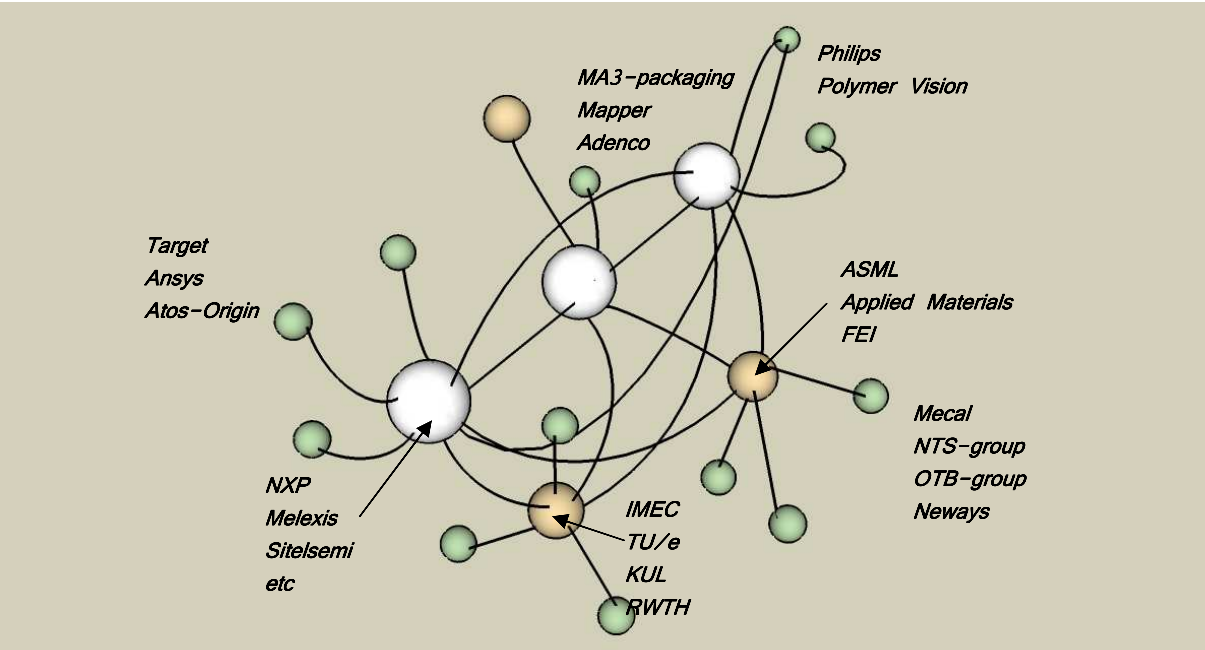
Fabless firms	
Bruco (NL)	ItoM (NL)
Silicon Hive (NL)	ANSEM (BE)
Cavendish-Kinetics (NL)	Easics (BE)
Catena (NL)	Medtronics (NL)
Sitelsemi (NL)	(Oce (NL))

[6] http://www.nxp.com/profile/
[7] http://www.onsemi.com/PowerSolutions/content.do?id=1116
[8] http://www.melexis.com/prodfiles2/0002995_2007_Annual_Report.pdf

4.4.5.3 Suppliers to the semiconductor industry

In the ELAT-region, a number of firms linked to one of the core processes can be found. Firms related to the design of chips are, for example, Ansys Software, Atos-Origin and Ordina. In the Eindhoven region a number of firms are related to the development of production equipment for the industry, such as ASML and FEI. ASML has its own network of suppliers nearby. These could be firms of the mechatronics, sensors, materials industry. Examples of suppliers are MA3-packaging, Boschman packaging, QPI-group wafer testers, Mapper lithography en PGE Adenco lithography. In figure 11 the different firms and their relation to the three core processes are visualized.

Figure 9 Firms in the ELAT-region and their relation to the core processes



4.4.6 Research Institutes IMEC and Holst centre/ MiPlaza

In the innovation path section 4.1.2, changes in research activities of the firms were described. A shift could be seen in the organization of research activities from internal to external i.e. cooperating with competitors and precompetitive research at outside research institutes. IMEC Leuven, and Holst Centre at the HTC are such institutes which perform precompetitive research activities.

4.4.6.1 IMEC Leuven[9]

IMEC, short for InterUniversity MicroElectronics Centre, was founded in 1984 to perform precompetitive research. IMEC sees it as its mission to carry out scientific research that is 3

[9] IMEC and Holst Centre sections are based on an interview with the CEO of the Holst Centre

to 10 years ahead of industrial needs. This research is carried out in the field of microelectronics, nano-technology, development methods and technologies for ICT systems. IMEC is the largest European independent research institute of this kind and it has approximately 1300 employees. The technology development is both in the MM trajectory and the MtM trajectory. IMEC develops technology that is 2 technology generations ahead of the current technology generation. IMEC Leuven is particularly involved in the MM trajectory in technology development with firms in the semiconductor industry. The research facilities and equipment at IMEC Leuven are capable of facilitating this kind of explorative technology development. Many prominent firms in the semiconductor industry co-develop technology with IMEC.

Besides performing technology development, IMEC stimulates the commercialization of developed technology through advising and funding spin-offs. This results in a geographical region with a number of firms specialised in a specific part of semiconductor technology, or adjacent technologies from other IMEC fields of expertise.

4.4.6.2 IMEC Holst Centre and MiPlaza High Tech Campus

A great diversity of firms is located at the High Tech Campus (HTC). These firms are related to the electronics industry. The HTC is basically an extended industrial park originating from former Philips research facilities. As a result, at the HTC, Philips and former Philips activities, e.g. NXP and ASML, are heavily presented. Other firms and institutes are also located at the HTC, for example, Atos Origin, Accenture, IBM, Silicon Hive, Polymer Vision, VDL. One of the institutes is the Holst Centre, which is a cooperation between IMEC Leuven and TNO Delft. The Holst centre conducts research in the MtM trajectory. A great number of the research activities are developed and tested at the MiPlaza facility at the HTC. MiPlaza is a part of the Philips Research facilities, and it is open for other firms and institutes to make use of these facilities[10]. The Holst Centre is one of those users. The MiPlaza research facilities focus especially on Microsystems and linkages between traditional semiconductor technology and the integration of new functionalities. MiPlaza facilitates equipment, machinery and personnel to organize this technology development.

So, the HTC consists of a variety firms, MiPlaza research facilities suitable for MtM technology development and the Holst research institute. The HTC is a geographical region which could be of use to explorative MtM semiconductor technology development.

[10] http://www.miplaza.com/miplaza_flyer.pdf

4.4.7 *Cluster technology distance*

In the previous sections, a description is given of the firms and research institutes in the ELAT-region. It is noted that the firms in the region are primarily involved in design and sales of chips. Moreover, there is also a network of suppliers to equipment producers in the region. Besides the firms of the semiconductor industry, various firms of adjacent industries can be found here. The technology distance of the firms in the ELAT-region differs, from close to each other in the IMEC MM technology development to further away in, for example, the HTC MtM development. So, the firms in the ELAT-region could be supported in exploitation as well as exploration. An example of an MtM trajectory which presents the opportunities of adjacent technologies to the semiconductor industry is given in the Press Release below. In the press release, a description is given of a product of Polymer Vision, which is a spinout of Philips Research, and of how it relates to the traditional semiconductor industry. Although the technology is not directly related to the existing semiconductor industry based on silicon, it is semiconductor technology applied to other materials. Firms of the semiconductor industry could be stimulated in explorative technology development in cooperation with adjacent industries and technologies.

Explorative More than Moore Example

Press Release: Polymer Vision participates in Holst Centre open innovation program on systems in foil - Release date: 21 Dec 2007[11]

EINDHOVEN - December 18, 2007 - The Dutch rollable display company Polymer Vision joins Holst Centre, an initiative of the Flemish and Dutch research centres IMEC and TNO. During the partnership Polymer Vision will research and develop organic transistor technology and patterning processes in the open-innovation setting of Holst Centre.

Flexible, large-area, low-cost electronics have a huge market potential. Some studies indicate that the organic-electronics market will even exceed the size of the Silicon semiconductor market as it is today. Rollable (or flexible) displays and low-cost electronic labels (e.g. RFID tags) are only two of the 'killer applications' associated with organic transistors. To comply with this promising future, the effort in research and development at Holst Centre is focused on novel materials, device structures and processing methods that will further enhance the breakthrough of the organic-electronics industry.

...

[11] http://www.leuveninc.com/pooled/articles/BF_NEWSART/view.asp?Q=BF_NEWSART_297457

4.4.8 *Cluster geography proximity*

Different types of firms are present in the region, but the importance of geographical proximity of these firms seems to vary. Geographical proximity seems to be of importance to absorb the developed knowledge at the MM technology development in IMEC Leuven. But this absorbed knowledge can be transferred by co-locating the employees back to the organization wherever that may be. So, a close geographical proximity is useful for technology development, but it is not required for knowledge transfer to the firm. To what extent geographical proximity supports the MtM technology development at the HTC is difficult to predict. It could be argued that being physically co-located at the HTC supports benefiting from unintended knowledge spillovers of adjacent firms and technologies. But if this truly supports the explorative activities of firms of the semiconductor industry remains to be seen.

For exploitative technology development, geographical proximity was argued to be of less importance, but it might be supportive. Since the semiconductor industry has been globalized (Macher, Mowery, & Di Minin, 2007), exploitative technology development does not seems to be hampered by this globalization. Therefore it is difficult to predict what geographical proximity can offer to the firms in the ELAT-region.

4.4.9 *Cluster complementarities*

In the previous sections attention is given to the research institutes in the ELAT-region and the roles they play in relation to the firms. It can be argued that the research institutes are typically upstream activities that are complementary to firm technology development. The transition of these upstream activities in more downstream activities is realized through co-locating the research employees to the firms, which are primarily located outside the ELAT-region. But the transition is also realized in the various start ups and spinouts located in the Leuven and Eindhoven region. As such, the complementarities which are realized are between the upstream activities at IMEC and HTC to firms all over the world and a little to spinouts. It can be expected that the explorative knowledge is also complementary to incumbent firms like NXP or fabless firms in the ELAT-region.

Complementarities from downstream activities to the firms are less frequently noticed. This is due to the lack of firms which have an up-to-date exploitative production facility in the region.

When the activities in the ELAT-region are seen from a more global perspective, complementarities between firms of the ELAT-region and outside the region are to be expected to occur. This is further supported by the fact that the industry has globalized the last two decades, which caused the displacement of production facilities to the Southeast of Asia. The explorative research activities performed at IMEC Leuven on production processes have complementarities with these firms, for example, dedicated foundries like TSMC which are involved in technology development at IMEC.

The fact that the ELAT-region consists of a number of semiconductor firms which are primarily fabless and that it lacks firms with up-to-date production facilities hampers the possibility for specialisation strategies between firms to be complementary within the ELAT-region as a social system. These kinds of complementarities are realized more globally. But this line of reasoning applies primarily to firms of the semiconductor industry. Complementarities between firms of adjacent technologies and industries may very well be supported by the presence of the fabless firms and not so up-to-date production facilities in the ELAT-region, since the MtM trajectory does not always require the most sophisticated production facilities.

4.5 Technology characteristics

The industry is continuously developing technology and the goal of the development is known. Another important aspect of the technology development is the relation between existing technology and future technology. Firms develop technology in such a way that the current technology can be improved to reach the targets set for the forthcoming years. Therefore it seems to be that a history in technology development is required for technology development and innovations. In addition, the fundamental explorative technology development performed in precompetitive research activities is of generic nature, and is subsequently integrated in the different firms. The firms involved in this kind of technology development are the prominent and leading firms of the industry, such as INTEL, NXP, Samsung, TSMC etc. This resembles the Schumpeter Mark II pattern of innovations, and the industry can therefore be typified as *deepening*.

To typify the total industry as *deepening*, however, might be a bit premature. There could be opportunities for smaller firms, especially when they develop MtM technology which is not too explorative of nature, but aimed at utilizing existing technologies for new applications. Precompetitive technology development of this kind of MtM technology does not seem to be necessary since it is much more application driven. There are a number of firms in the ELAT-region involved in this kind of technology development. The innovation pattern of these firms could be more *widening* in nature.

4.6 Conclusion

Since the start of the industry in 1947, the industry has grown into a global and multibillion market. Technology development has been aimed at miniaturizing technology, reducing costs, and improving performance following Moore's law. The industry has changed in business model and has become more vertically specialized to be able to afford technology development. Subsequently, in the 90s an additional technology trajectory presented itself in the integration of functionalities on chips. This resulted in a more horizontal specialization of firms on specific applications.

Besides the change in business models, firms increasingly cooperate in technology development. This development is also realized at research institutes. The ELAT-region seems to be able to facilitate in explorative technology development, especially at the technology platforms of IMEC Leuven and HTC Eindhoven. Complementarities might occur between firms in the ELAT-region and these platforms. Firms outside the region could also benefit from these complementarities. In the ELAT-region, semiconductor firms are primarily related to the designs and sales core processes of the industry, the production core process is hardly present. This is amongst other things due to the displacement of production locations in the Southeast of Asia.

The technology pattern of the semiconductor industry seems to be *deepening* of character, but it could be that the technology development in the MtM trajectory is of more *widening* nature.

Chapter 5 Results of case analysis

5.1 Case analysis Océ

Semiconductor: Fabless
Turnover: €3,1 billion
Employees: 24.000
R&D budget: 8% of turnover (€248 million)
R&D employees: 1800
HQ: Venlo

Company description
Océ delivers digital printing systems, software and services to produce, reproduce, distribute and the management of documents, in colour and black-white, in small- and wide format. Océ is a global leading supplier of these systems and is commercially active in over 90 countries. The financial results of 2007 were a turnover of € 3,1 billion and a profit of € 78,9 million[12]. Océ has invested in the development of micro electro mechanical systems chip technology (MEMS) for the past 10 years. This technology holds the promise to perform a factor 10 better on quality and price in comparison to the traditional inkjet technology. The MEMS technology is a typical More than Moore technology in which functional systems (printhead) interact with the environment, is integrated on a chip. Océ develops this MEMS technology in cooperation with semiconductor partners, but there is no wish to produce the chip itself. The business model of Océ can therefore be typified as fabless.

Balance between exploitation and exploration
Océ spends roughly 8% of the turnover on R&D. Océ has globally 1800 R&D employees, half of them are placed at the R&D site in Venlo. In the past Venlo was the only R&D site, but as a result of acquisitions, a number of R&D sites located in Belgium, Germany, France, Romania, Japan, Singapore, Canada and the United States were integrated[13].

The R&D activities are mainly aimed at exploitation, these activities are characterized by their focus on enhancing and refining existing technologies for existing markets. An example of a resulting innovation is the transition from black-white inkjet printing towards colour printing. This colour technology was new and required the integration of new

[12] http://www.oce.com/nl/About/Profile/Business+organisation.htm
[13] http://www3.oce.com/jobs/bestanden/R_D.html

technology into existing technology, but still closely related to existing technologies and markets. An important aspect of these innovations is that they conform to the overall technology target and technology roadmap. Therefore, less attention is given to exploration when the result of such an innovation process is unknown or not useful. In the situation that there is an expectation of the result and this is useful, for example the MEMS technology, then an explorative process is organized. The MEMS technology is explorative because of the search to combine two distinct technologies coming from different industries.

The R&D site in Venlo is the only location where more explorative activities are organized. Within Venlo, 10 % of the R&D (90) employees are allocated to explorative research programs. Thus, the exploration covers 5% of the total R&D activities, 95% is aimed at exploitation. Exploration and exploitation are continuously organized. There is also a small R&D team of about 20 employees who are concerned with innovation activities after product development.

Organization of exploration

The explorative R&D employees are divided over three research groups, each group covers a specific technology. In these groups teams organized of 10 employees are responsible for a specific area of technology development. In addition, R&D employees have to scan the technology developments in the existing market of Océ, but also of adjacent markets. A result of this "open" attitude is the ability to identify possibilities for technology which could become useful for Océ in the long term.

"Employees (of the research groups) can come up with potential projects, which subsequently are collected, and once a year the program commission declares which projects will be pursued and which not. On the one hand it should not be directly related to the day-to-day business, on the other hand it has to contribute to Océ in the long term."

Formulating these explorative plans is simultaneously organized alongside on going projects. In the case of the MEMS technology development, a dedicated project team is busy developing the MEMS technology full time.

The final result of these explorative activities is a project definition which is a description of the potential success and the possible applications of the technology. If the project definition is judged as having potential, the technology is further developed and commercialized.

Organisation of exploitation

Exploitative projects are always organized in project teams, the employees are always appointed to a certain project. When the project is finalized (about a year after market introduction) they will be appointed to another project.

The exploitation of the result of the explorative MEMS technologies is currently organized. The lack of exploitative knowledge related to the MEMS technology remains the main problem Océ faces when making the transition from exploration into exploitation. There is no experience present of the production of MEMS technology in the organization. The project team therefore responsible for the exploitative development of the MEMS technology has project members of the explorative MEMS activities to safeguard technology transfer. In addition, external partners with knowledge and experience of semiconductor technology have seconded employees to the Océ exploitative project team. To acquire the necessary production knowledge Océ searches for external knowledge partners. It tries to organize the exploitative team according to the 'one-room approach'. This approach stands for the physical co-location of the project members. The project members have a different background like R&D engineers, production, marketing and service employees. Since the external partners do not dedicate their employees solely to the Océ technology development, they are not co-located.

"In real terms this means that the R&D employees are placed in a room together. They are R&D engineers, but also service and production employees, purchasers and marketers. The multidisciplinary team is working together in the one-room-approach and we strongly believe in this approach."

Océ has developed a technology and market roadmap for the most important technologies and markets. In the roadmaps, an expectation about the long term of certain technologies and markets is given. The function of the innovation activities is to develop technologies in correspondence with the roadmaps. Thus, the innovation activities of Océ are strongly related to an expectation of the market and how technologies should be applied in these markets.

Transition of exploration to exploitation

The transition of exploration to exploitation is based on the formulation of the project definition. In this project definition details are given concerning the technology and application for a specific market. The execution of the exploitative activities to further develop the technology is realized through organizing a project team with representatives of the explorative project team. To this team are also assigned employees of the R&D, production, marketing, service departments and possibly external partners. Océ thus recognizes that exploration and exploitation require different capabilities and mindsets.

"What the difference is between research (exploration) and product development (exploitation) is ...that they (research) do not think of the production process characteristics, if it is possible to make thousands of products with the technology. That is not what they worry about, for them it doesn't matter if the technology works on lab scale or on production scale. They from product development are only concerned with the producibility of the technology. Then, other aspects and partners are relevant."

Since Océ acknowledges the difference in mindset, exploration and exploitation are organized into separate teams.

ELAT-region exploitation and exploration

Océ has primarily contacts with partners in the ELAT-region for explorative projects. Especially partners who can deliver specific knowledge, like the firms C2V Enschede, a specialist in MEMS technology with relations to the nano-technology research institute MESA+ Enschede. But also with Philips Applied Technologies Eindhoven and their relation with the research facilities at MiPlaza. The ELAT-region does not offer sufficient support for exploitation of the MEMS development. There is a lack of exploitative capability of the current partners, and Océ has not found any suitable partners until now. In addition, Océ is used to organize innovation activities in the internal organization and has therefore not built a large and diversified network. Moreover, the partners who participate in exploitative projects are more and more located outside the region, in Asia for example.

"In the recent past, 80% of the sourced technology came from supplier in the region, the last 10 years this number has declined to 20%"

Developments

Océ expects that innovation projects in the future will be organized more and more in cooperation with external partners, for exploitation as well as exploration. The ELAT-region can facilitate in meeting firms from adjacent industries, like the semiconductor and other nano-technology industries. But until now, Océ has found difficulties in gaining access to the business networks of these technologies.

"In the ELAT-region there are mainly technologies present which are of interest to adjacent industries, such as nanotechnologies, smart systems Eniac, Artemis. We have not found the connection to these networks, or we have not tried hard enough."

Nevertheless, Océ has co-located a R&D site on the High Tech Campus (HTC) Eindhoven. This site is called the Inkjet Application Centre (IAC). The IAC develops technology together with different partners at the HTC, like for example the research institute Holst Centre.

At the moment the contribution of the ELAT-region to the exploitative activities is very limited. Moreover there are no other firms like Océ present in the region. The industry is very much globally spread, with concentrations in Asia and the United States.

"The main problem is that there is nobody in Europe who develops technology similar to Océ..."

The ELAT-region thus functions primarily as a possible source of exploration through the presence of adjacent technologies. In addition, geographical proximity is of importance because partners closer by have prevalence over partners further away.

"Cooperating with partner within 100-150 km is much easier than cooperating at greater distances.....Twente is already the limit. But because of their technology expertise it is doable. ....but our preferred network is within an hour travelling from Venlo."

Although Océ prefers partners close by, this is not always possible. Therefore Océ expects that cooperation with other partners outside the region will happen more often.

Innovation strategy

Océ organizes exploitation and exploration into separate business units in which 95% of the R&D employees are allocated on exploitative projects, and 5% of the R&D employees on explorative projects. These activities are organized simultaneously and continuously. When the innovation flows from exploration into exploitation, this results in a different team arrangement. Thus Océ uses the *Internal Corporate Venture* strategy to organize exploitation and exploration.

5.2 Case analysis NXP

Semiconductor: Integrated Device Manufacturer
Turnover: €4,6 billion
Employees: 31.000
R&D budget: 20% of turnover (€900 million)
R&D employees: 6000
HQ: Eindhoven[14]

Company description

NXP started in 2006 as a sold part of Royal Philips. NXP is one of the world's largest semiconductor companies. With total sales of approximately EUR 4.6 billion in 2007, it ranks among the world's top ten semiconductor providers and among the top three suppliers of application-specific semiconductors. With over 50 years of operating history, they are also one of the longest established companies in the industry. The business targets the home electronics, mobile communications, personal entertainment, and automotive and identification application markets (NXP FY2007 pg 9).

As a former part of the Royal Philips company NXP had the total value chain within the internal organization at its disposal. It was a typical Integrated Device Manufacturer, from design, production, sales till machinery. In the course of time Philips has spun out almost all related activities, amongst other the chip division in the form of NXP as well. Consequently the strategy of NXP has changed, from the IDM business model towards the fablite/fabless model, which has resulted into the divesting of different production sites and cooperation with dedicated foundries e.g. TSMC Taiwan. The NXP headquarter is located in Eindhoven. NXP has 26 R&D sites located all around the world and one of the largest is located in Eindhoven. The R&D investments are around 20% of the annual turnover.

Balance between exploitation and exploration

NXP distinguishes R&D activities into technology development and product development, in which the R refers to technology and D to product development. The D activities can be seen as exploitative activities and the R activities as more explorative of nature.

"The distinction we do make in R&D is the distinction between R and D, that is the D stands for development ... and everything that is required to bring a product to the market at any given time.

[14] http://www.nxp.com/profile/

This can be further distinguished into pre-development and product development. Research refers to selecting and studying technologies which pre-development has to work on."

About 10% of the R&D budget is allocated to exploration and 10 % to pre-development. The remaining 80% is allocated to product development. Basically it is the task of the *Research* employees to come up with ideas that fit in the existing technology roadmaps of NXP. If the idea is convincing enough, a small group of research employees is formed for further development. The transition towards real product development is organized through transferring the idea into a relevant business unit. A project team consisting of the research employees and product development employees realizes the transfer and product development.
Research employees are located in R&D centres situated all over the world, a large group is located in Eindhoven.

Organization of exploration
10% of the R%D budget is allocated to research activities. These activities are of an explorative nature. NXP has always linked technology development to technology roadmaps for the next 5 to 10 year. Hence, explorative activities are always related to concrete product and market expectations of NXP.

"The process of road mapping starts from the current market and how this will develop over the next 5 to 10 years. With this knowledge it can be determined what kind of technology is necessary. Research determines the road map and the goals. ... Research tries to identify what types of products are required over 5 to 10 years, and as such determines which technology is necessary to make these products."

Hence, technology development is strongly related to market expectations and concrete performance expectations for the forthcoming years. The research department does not allocate resources to technology development which has no concrete goal or use.

Strictly spoken, we are not doing any exploration, explicitly that is something we are not doing.. If you want to search without a concrete goal, you shouldn't be here. That is something universities can do in their research areas. A very popular field is nano-technology, nano tubes. I really do not have a clue what we could do with it. As long as we do not know, we won't do it."

There are a number of research sites of NXP situated all over the world, in which the Eindhoven location is responsible for the majority of exploration. Management of the R&D location is primarily concerned with facilitating in resources for research.

"If it is a good idea, then the research employee should be able to explain the idea. If he succeeds he is given time and other resources for further development. Most of the time these activities are individual projects, sometimes he is supported by two or three other researchers. To support the research activities a good infrastructure, computer system, materials and other resources are delivered."

Organization of exploitation

Exploitation of existing and known technology is organized in project teams which are located within business units. There is a difference in the way these teams are organized depending on the type of product that is developed. NXP distinguishes two types of products, namely components and systems.

"A component is a product of generic use, often in multiple types of applications."

A component is characterized by its specific functionality and specific (niche) market. It is important to be first to market, which is often the result of a technological innovation. To succeed in the components market, technological innovations are very important.

"Component development is normally organized internally with internal resources and knowledge covering the total supply chain. Firms have their own hardware and software technologies. But also internal researchers and manufacturing sites, or manufacturing sites working solely for you."

Component development is organized in small project teams of around 10 employees.

Systems are much more complex of nature and they are constructed out of a specific set of generic products. Most of these generic technologies are purchased from external partners, e.g. the operating software of a chip from Microsoft, or the controller software from ARM, or a design component from a design house like Catena. Consequently the project teams responsible for developing these systems do not have all the research, knowledge and manufacturing sites internally. The project teams are much larger than component development with approximately around 100 employees. The innovative element of these products is in the cleverness of the architecture of these systems.

The project teams responsible for product development of systems as well as components consist of employees from the responsible business units primarily, but seldom are they located at the same site. It can occur that the marketers and software engineers are located in the United States, that the generic controller suppliers are based in the United Kingdom, and that the production employees are located in Nijmegen. Despite the geographical distance, they are members of the same project team. Physical co-location only occurs when the project member are working together on the same site.

NXP acknowledges that this is not ideal and acknowledges the advantages of physical co-location.

"Successful firms which produce very complex products often co-locate their teams in the same area. For example Intel has all their developers co-located in Santa Clara...."

The main reason for NXP to not follow the example of Intel is quite practical of nature.

"There are practical reasons, because which country do we have to choose to co-locate the developers? And how about the partners of the employees?... Those things are developed in an organic way, and you cannot do really much about it, so it stays as it is. We do try to group activities close to each other, so that a group of employees closely co-located is responsible for only a part of technology development. Good communication therefore of the specifications of the different part is of the utmost importance."

Transition of exploration to exploitation

Although components and systems differ in type of technology development, that is the technology oriented approach of components opposed to the architecture oriented approach of the systems, the transition from exploration to exploitation is organized in a similar way. The transition of exploration to exploitation is organized through co-locating the research employees for a short period of time into the exploitative project team at the business unit.

"The transfer of research to the product development group is organized in multiple ways. The most successful method is organized when the researchers are physically part of the development team for a short period of time, 3 to 6 months."

NXP acknowledges also the difference in mindset of the different employees of the product development team. For example the mindset of a marketer or sales employee in comparison to that of a researcher. But NXP also points out that both ways of thinking are helpful to the success of the product development.

Researchers come up with all sorts of things, but it can be that they have 99 very good ideas, but that the 100th, the only one which is produceable, has not been one of those. This does not happen because the researchers don't want to, but because they did not have the time to. … Marketers don't have the time and patience to listen to the researchers. Because a marketer is supposed to be looking to the future, but in reality they only look at the sales figure in the next 3 months… That is another point of view in the project team, but the project team needs both to be successful.

ELAT-region exploitation exploration

For NXP, the ELAT region is limited to the High Tech Campus and its contacts with institutes like IMEC Leuven, Universities of Eindhoven, Delft and Twente, along with a certain amount of suppliers.

Primarily the High Tech Campus offers the opportunity for unintended knowledge spillovers from adjacent technologies, which occurs through the (un)intended meetings between research employees of the different firms in the shared public facilities.

"You can only benefit from the High Tech Campus when you are physically located on the campus. That is here, physically here. If you are located on the other side of Eindhoven the benefit is lost, because people do no bump into each other!"

A result of the High Tech Campus is the (un)intended meetings of the researchers of the different firms. A more concrete result like shared product development does not really happen, the High Tech Campus only functions as a kind of idea pool.

In addition, NXP has a history of internal organization of innovations, therefore there has been little cooperation with technology or knowledge suppliers. This in contrast to the machinery supplier ASML which has a small internal R&D group and therefore a large amount of suppliers located close by.

Cooperation with IMEC and other research institutes does happen to a limited degree. NXP purchases 'technology parts' from IMEC, which in a later phase will be developed further internally. This purchasing is realized through the physical co-location of research employees at the technology development programs of IMEC, which are highly explorative. After a period of developing, the research employee has absorbed the knowledge and is physically relocated in the research group of NXP to facilitate knowledge transfer. The advantage of this kind of technology purchasing is the speed and the lower costs of technology development in comparison to technology development internally. Moreover, it is of importance to stay informed on the continuous process enhancement (More Moore trajectory), since it remains an important technology driver for the forthcoming years.

"The drive to develop a new technology generation is always related to decreasing the total cost of ownership. That is a much bigger force than functionality. The costs of a transistor are decreased by every technology generation. The functionality is not helped by this, it is really difficult to secure the quality and specifications of the components. But it will go one like this for at least the next 5 years."

In the case of exploration, it is important that employees with difference in technology background can meet each other. The High Tech Campus can facilitate in this. For co-located exploration (like IMEC) and exploitation geographical proximity is of importance. If the travelling time exceeds 2 hours from Eindhoven, local proximity has lost it value.

"We make use of nearby located research institutes e.g. Delft and technology suppliers because they are within these 2 hours of travelling. Why do we collaborate with IMEC, University of Twente, because it is less than two hours travelling. If it is more than two hours, it has lost its value and it would not make any difference if your partners were in China or in France."

Hence, geographical proximity makes unintended meetings possible. In addition, geographical proximity is advantageous for collaboration with external partners.

Developments

The expectation is that explorative technology development will be increasingly organized into shared research institutes to keep R&D affordable , like IMEC Leuven. Exploitative technology development will increasingly be organized around application cluster, for example the cluster of firms like NXP, STMicroelectronics and Ericsson around mobile phone chip technology.

Innovation strategy

NXP organizes exploitation and exploration simultaneously. With 90% of the R&D expenses the emphasis of the activities lies heavily on exploitation. Despite the difficulties in identifying the team structures caused by the globally dispersed activities, researchers work in separate facilities to organize explorative activities, and exploitative activities are organized with project teams within the relevant business units. The strategy followed by NXP to balance exploitation and exploration can be typified as Internal Corporate

Venturing, because of the transition of the research team into the exploitative business unit.

The objectives of the explorative activities are always related to a concrete industry, technology and market expectation for the forthcoming 5 to 10 years.

5.3 Case analysis Catena Group

Semiconductor: Fabless/ IPR
Turnover: €26 million
Employees: 140
HQ: Delft

Catena Radio Design
Employees: 60
Location: Son

Firm description

Catena is an international group of innovative companies, experts in design of Integrated Circuits and in software for design, layout and verification of Integrated Circuits. Catena has since its establishment in 1986 developed as a centre of excellence in Radio Frequency Communication, Analog, Mixed Signal and Digital Signal Processing. Catena group is located in high tech areas in the Netherlands, Germany and Sweden with headquarters in Delft, the Netherlands[15].

The location in Delft began as the spinout of the anolog micro electronics department of the University of Delft. The location in Son also started as a spinout, but from the research department of Philips at Eindhoven. The location in Son focuses on the application of digital radio microelectronics. The location in Sweden focus on wireless electronics, the locations in Germany and England focuses on software development. Catena has concentrated the different fields of expertise in the different sites. The product of Catena is a design of a chip, or a part of a chip. Catena sells the design to the different major semiconductor manufacturers and to system integrators like NXP, Intel, Ericsson, Nokia etc.

Balance between exploitation and exploration

Within Catena Radio Design, technology development is almost always directly related to a concrete application. Explorative activities, in which the result and expectation are uncertain is not done. But this does not mean that all innovation activities are exploitative of nature. Catena Radio Design operates in a market in which chip technology is changing continuously. It is of the utmost importance to integrate continuously an innovative

[15] http://www.catena.nl/intro.htm

component in the designs. This innovative component can be more or less explorative of nature.

"X2 (a product technology) is a thing, we know what we can do with it, but we do not exactly know how, so we have to expand our knowledge. Hence, our innovative activities are almost always related to a specific application, a product. But to be able to realize that, expanding our knowledge can be necessary."

When it is certain that this knowledge is needed in the near future, the more explorative technology is developed. Sometimes these explorative activities are pursued by one or two employees, but when a broader view is required a meeting with the relevant researchers/ engineers is organized.

"For a company like Catena it is essential that all designs have an innovative component. I think it can be said that there is no product in which no innovation is integrated. Of course the proportion of exploration to exploitation differs between products. ...."

Organization of exploration

Explorative activities are always related to a concrete existing or upcoming application. Employees have the freedom to scan for developments in industry, market or science by, for example, attending conferences. In addition, technology meetings are organized for development of a technology so that employees can become better acquainted with the technology and how it can be applied in the Catena products.

"Today we had a meeting about a certain technology because we had the feeling we somehow lacked in understanding this technology. Since we do this with a number of employees, we pick a day and do this ones in the two weeks until we know enough."

"Predicting how a technology will work in a specific situation is sometimes difficult, in this particular situation we didn't know enough. As we know that this specific situation will arise in the near future, we have to learn to be able to anticipate."

These meetings are organized when more explorative development is required. The frequency is about once every three weeks..

Organizing exploitation

Since all products more or less have an innovative component, it can be said that in all products a result of exploitation is integrated.
Catena has concentrated their expertise in different locations, and therefore extensive communication between the sites is required for product development.

"It is quite normal that a product for a customer, that could be Ericsson, or NXP, Nokia, Intel... that we require knowledge from Son, but also from Delft and Sweden. The system architect or the system owner is responsible for the fit between the different technologies from the different sites."

To organize this in a structured way, Catena uses a project administration. The project teams consist of a maximum of 10 employees.

The project members always work on a number of projects at the same time. These can be exploitative or more explorative. Since the employees are involved in multiple projects, structural physical co-location of the team members is not possible, not even on the same site.

Transition of exploration to exploitation
In some cases the products of Catena Radio Design integrate more results of explorative activities. The transition of the developed explorative knowledge is realized through appointing the employee involved in the explorative development into the project team.

"It is best to appoint the employee who has developed the explorative part to the exploitative development team of the product. Ideas and knowledge can not easily be transferred from employee A to employee B. The employee himself has to take part in the product development."

Since the employees often work together with project members on other locations, much travelling between the sites is necessary. But since the employees are always appointed to a number of projects, it will be co-location for a short period.

" I think that being physically together is very important in an explorative technology development, I can hardly imagine how explorative technology can be explained on the phone..."

ELAT-Region
The ELAT-region is of little importance to Catena Radio Design. One of the biggest influences is the presence of NXP as a major purchaser of Catena products. There are relations with the University of Eindhoven, but this is primarily aimed at selecting potential

employees from students and PhD's. A similar relation is tried to realize with the Stan Akkermans Institute. This is a program aimed at linking academic research to firms, it is the result of a collaboration between the three Technical Universities of the Netherlands and firms.

There are no contacts with IMEC or the University of Leuven, which is mainly caused by Catena not being acquainted with their researchers, and the small overlap in activities between Catena and IMEC. Catena has also a very limited relation with the High Tech Campus, there is too little overlap in activities to be able to benefit from the unintended knowledge spillovers on such a geographical location.

"They (Catena) had no wish for locating the office on the High Tech Campus..."
"One of the reasons was the higher rent ... I think that there is little value in being present there, or lunching in the public areas."

That Catena cannot benefit from the region in technology development is mainly due to the specialist position in the value chain of the industry and developed expertise internally. Catena's focus is on the global market, and not specifically on the ELAT-region, since the clientele of Catena is globally distributed

Developments

Catena Radio Design has built an expertise in a specific technology field of chip applications. Catena expects to be able to hold this specialist position in the fort coming years, and become complementary in technology to the NXP's and Intel's of the world.
"If firms have enough money they can keep their research programs alive, but in the situation that resources decline and R&D programs become too expensive firms have to choose what to do. Firms can stop investing in R&D and exploit what they have, or they have other actors do their R&D. "
...
"The situation at the moment is that firms like NXP do not have enough resources to invest in all the R&D programs, therefore they have to share the R&D activities with other partners like Intel, Nokia etc. The shared R&D activities are now performed by specialists, like us."

Innovation strategy of Catena Radio Design

Catena Radio Design has a very much application oriented view on innovation. The more explorative activities are organized to be able to anticipate on the future. These innovations are mainly organized internally. The employees can decide for themselves to allocate time to more explorative technology development and visiting conferences, or to exploitative product development. The strategy followed by Catena Radio Design can therefore be typified as *contextual ambidexterity*. But how the transition of exploration to exploitation is organized has similarities with the *Internal Corporate Venture* strategy.

5.4 Case analysis Cavendish-Kinetics

Semiconductor: Fabless/ Intellectual Property Rights
Turnover: -
Employees: 22
R&D budget: Venture Capitalist investment rounds (1st /2nd $6 / $15 million)
R&D employees: 18
HQ: San Jose, USA

Firm description

The firm Cavendish-Kinetics originated as a spin out from Cambridge University. Cavendish-Kinetics focuses on the development of MEMS process modules, the design and modelling of MEMS devices and subsequently providing these two combined (process module and design module) as an IP (Intellectual Property) package for customers to use in numerous different application areas.[16] Cavendish-Kinetics develops intellectual property rights for specific memory applications which can be integrated in chips. There are three locations, but technology development is organized in two locations. The location in Den Bosch focuses on MEMS technology, and process development is developed in San Jose, USA.

Balance of exploitation and exploration

Cavendish-Kinetics has had two investment rounds to obtain enough resources for an explorative development of a technology. The majority of the activities at Cavendish-Kinetics are focussed on developing this technology.

"CK develops their first product and everything is aimed at the future performance of this technology. This product is based on a completely new technological development in which the technology is the centre of attention."

In Cavendish-Kinetics are two technology disciplines. These two disciplines have as their main target to transfer the original explorative technology into a concrete product. 7 Employees are developing the MEMS technology at the location in Den Bosch. In San Jose 11 employees are developing the process technology. The transition of the technology into exploitative product development is becoming increasingly important. So Cavendish-

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[16] http://www.cavendish-kinetics.com/index.php?option=com_content&task=view&id=89&Itemid=158&Itemid=149

Kinetics is collaborating with potential purchasers of the product to adjust the production process and the technology to produce the chips.

ELAT-region

Cavendish-Kinetics is deliberately located in the region to utilize the highly qualified personnel working here.

"Back then Cavendish-Kinetics chose Den Bosch as location with the intention to utilize the highly qualified workforce of NXP/Philips at Nijmegen and Eindhoven. In reality, Cavendish-Kinetics sourced their personnel from foreign countries and lost them subsequently to Philips/ NXP."

Cavendish-Kinetics has not had any significant contacts with other actors in the region. This is primarily due to the explorative nature of the technology developed at Cavendish-Kinetics which makes it stand out from other technologies.

Cavendish-Kinetics tried to collaborate with IMEC Leuven to develop the process technology, but because troubles arose concerning intellectual property rights, Cavendish-Kinetics didn't pursue this option. Because there is no similar actor in the region like IMEC Leuven on process technology, Cavendish-Kinetics co-located themselves at San Jose, Silicon Valley, which can facilitate in process technology development. In the case of the MEMS technology development, there was no reason for co-locating these Cavendish-Kinetics activities. Therefore it is still located in Den Bosch. Since Cavendish-Kinetics acknowledges the importance of complementary actors in a certain region it has therefore relocated its headquarters to San Jose.

Innovation strategy

Cavendish-Kinetics has one potential product, which comprises different technology disciplines and which is based on explorative development. The R&D employees are all dedicated to this technology. Cavendish-Kinetics is pursuing the *specialisation strategy in exploration*. In the forthcoming years, technology development of Cavendish-Kinetics will shift from exploration into exploitation of the developed technology.

5.5 Case analysis ItoM

Semiconductor: Fabless/ Intellectual Property Rights
Turnover: €8 million (2005)
Employees: 25
R&D employees: 18
HQ: Eindhoven

Company description

ItoM refers to 'Semiconductor Ideas to the Market', and that is exactly what ItoM produces. The focus at ItoM is on producing chips design and selling the corresponding intellectual property rights. ItoM was started 10 years ago as a design house to produce innovative ideas but not to produce the chips themselves. ItoM sells the designs to clients likes the OEM's Sanyo, Philips and NXP. ItoM has 25 employees who are located in two offices, one in Eindhoven and one in Veldhoven. ItoM is a specialist in transmitter and receiver functionality integration on chips, and has a global clientele.

Balance between exploitation and exploration

ItoM aims to continuously create innovative designs. Their reason for existence is the ability to produce innovative designs and IPRs. Therefore most of the employees are allocated to produce innovative ideas, which are primarily exploitative of nature and in some occasions more explorative of nature. At the start of ItoM there was a strong belief in certain chip functionality, which at that time was strongly explorative.

"Listen, we were visionary, because a long time ago, say 10 years we had a meeting with the Philips management and we predicted that there would come a machine (chip) that could do multiple tasks. It could receive information from phones and the internet ... And it could perform multiple tasks, it could be used as a phone, or to watch videos, or to make photographs, or to use for video gaming, or to use at as a method of payment. That machine could perform multiple tasks, and that means that it has to cope with different technological demands. When we proposed this at Philips 10 years ago they reacted like, 'the chip has also to be able to brew a cup of coffee and to polish your shoes...' They didn't believe in it, nevertheless we pursued this technology, and now we are specialists in this field of technology."

Since the start of ItoM, the innovation activities have been dedicated to develop the explorative technology. In the meantime ItoM has built an expertise in this technology field, and the focus is shifted towards more exploitation of the technology. In addition, explorative activities are organized to stay informed on the latest developments by attending conferences and by cooperation with universities.

Organization of exploitation and exploration

ItoM organizes the product development always according a concrete market demand. Technology is developed because the ItoM management has identified a market need or demand to, which ItoM can deliver. ItoM has developed their explorative technology which is the result of the integration and refinement of existing technologies into a new architecture. In the meantime ItoM has shifted the focus from explorative development to exploitative development of this technology application. Within the development of such a technology, different employees with differing specialisms are involved. Securing the synchronization between the different specialisms is very important, so ItoM has located the employees in the same building. In addition, ongoing developments are discussed weekly in a meeting.

"If all the parts of the process are working, but one is not, then you have problem. You have to organize a structure in which the employees involved are put together. In addition, we have three management meetings, of which the most important is the technical meeting there we discuss the success and problems in every development project. All employees involved are present, and everybody has to speak out. It's all about helping and getting help."

To not become too much dependent on already developed technology and knowledge, ItoM stimulates their employees to come up with new ideas. ItoM gives extra attention to the recruiting of new employees.

"Since we have the talent required for delivering a unique product, we have the exceptional talents, the nerds! ...They have a specific knowledge and capability, I always look into the study history of a job-applicant and look for 9s and 10s, if they have low marks they are not selected! ... And that is part of the success. Why is this a luxury environment, why are the employees better paid than at Philips? Why do the employees get a car after three years working, and a good car! Because we want to keep the good ones in our company, we have a small company and we have to keep our employees otherwise we lose too much, we lose our knowledge."

A result of the employment strategy is that ItoM secures the knowledge and talent which makes exploitation possible, as well as the talent for more explorative activities. The management functions in such a way that the employees are given the facilities to develop their ideas, but the management is also setting clear targets for technology development.

ELAT-region exploitation exploration

ItoM is located in Eindhoven and Veldhoven because the founders live in the area. Besides, it is located close to Eindhoven University and a number of firms of the electronics industry. ItoM benefits primarily by recruiting highly qualified personnel at the universities and firms. So ItoM can secure the inflow of skilled personnel and state-of-the-art knowledge. In addition, ItoM had PhDs students researching at Eindhoven University and Twente University, which made knowledge transfer possible, and created the opportunity to utilize the research facilities at these universities.

"When we have to test a technology or product which is too difficult for us, we go to the university, because they have the appropriate facilities we cannot afford. Such machines cost around 100.000 Euros, the most expensive machine we have is 40.000, and so we can utilize the knowledge and facilities of the university."

ItoM has also several employees with a history at Philips and NXP, who know the routines, interests and responsible people at Philips. Except for the availability of machines at the university, skilled personnel and the presence of a large client, the ELAT-region doesn't contribute to the exploration/ exploitation activities of the firm. There are no connections to IMEC Leuven, Holst Centre or shared development programs with other firms in the region.

Innovation strategy

ItoM has built an expertise in a more explorative technology which has subsequently been further developed, and thus the focus has shifted from exploration toward exploitation. ItoM organizes innovation in one group of employees and doesn't have a separate R&D department. Hence, ItoM pursues a *specialist strategy in exploration transitioning into exploitation*. The way in which the exploration and exploitation are organized can be typified as *the contextual ambidexterity strategy*.

5.6 Case analysis SiTel Semiconductors BV

Semiconductor: Fabless
Turnover: €130 million (2006)
Employees: 160 (2005)
R&D employees: 100
HQ: Den Bosch/ Satellite design centra in Hengelo and Greece / Sales offices in Hong Kong, Japan, and the U.S.A.
Manufacturing foundries in Asia en U.S.A, employees in Singapore supervise the production process.

SiTel is the former Dutch business unit of National Semiconductor Corporation, which is involved in the design and sale of high-quality chips for cordless phones and other devices. In June 2005, SiTel was created after a successful management buy-out. SiTel designs chips for cordless phones and other cordless applications. SiTel organizes the manufacture of ICs at specialized semiconductor factories around the world and is a fast-growing company. SiTel uses standard CMOS technologies to develop complete modules and system-on-a-chip solutions, with supporting software, for phones that operate at 1.9 GHz (Europe), 2.4 GHz (USA, Japan and China), and 5.8 GHz (also for the USA). The products are designed to address the explosive growth of new applications for cordless voice and data communication like VoIP telephones, as well as home entertainment products like set-top boxes, gaming (X-box) and headsets.

Balance between exploitation and exploration

SiTel develops all technology in accordance with a concrete application. Explorative activities which are not directly linked to a product or application are not organized. But this does not mean that all activities are exploitative, SiTel is situated in a market in which chip technology is constantly changing and integrating innovations in products is very important. Most of the time the innovations are new components integrated in an existing design of chips. The relative distance in newness of the component determines if it is more explorative. Thus innovations in a chip design have an explorative and exploitative part, in which a new component or technology linked to the existing chip can be seen as explorative, and the further development of the existing knowledge as exploitative. SiTel doesn't have a separate R&D department. The majority of employees are involved in new product development.

Organizing exploration

Sitel has no employees specifically tasked to pursue exploration. It is the responsibility of all the engineers to be informed about the latest technological developments.

"The majority of the employees have a degree in science. Attending congresses, following courses and reading scientific literature is an essential part of the job."

In addition, SiTel has links with external partners to keep access to technology development programs.

Long term research (> 1-2 year) is not organized in SiTel. In general we depend on research done at the universities, research institutes and firms (IMEC, Philips Applied Technology, TSMC etc.)"

These contacts are maintained through, for example, seconding employees at a university for a day in a week.

When the application of a certain new technology is required, extra attention is given to the feasibility and suitability of the technology for the specific application. This part of the product development process is more explorative of nature. SiTel uses a product development model in which the different phases of the process are determined, the first and second phase are concerned with technology development, and later phases are concerned with implementation of the technology and production. Thus the transition from explorative to exploitative activities is organized in the same product development process. The product development process is performed by a project team, in which employees with different technology backgrounds are active.

"All chips are developed in a project team in which all relevant disciplines are involved. (Software application engineers, radio experts, analog and digital engineers, system and architecture engineers and product developers.) The objective of the team is to develop a new IC (chip) and to put it into production."

Most of the time the employees are appointed to one project until the project is finalized.

Organization of exploitation

SiTel sees exploitation as activities which enhance a current existing product or technology SiTel is already familiar with. The process is organized in a similar way as more explorative projects. The exploitative activities also have a project team in which the different phases of the product development are pursued, but the activities are now primarily focused on implementation of the technology and on the production.

ELAT-Region exploitation - exploration

SiTel has contacts with partners which pursue explorative activities in the region. There are no contacts with partners in the region which pursue exploitative activities.

"SiTel utilizes and cooperates with, for example, Philips Applied Technology, IMEC, TARGET, ANSEM, … those are all firms in the region of Eindhoven and Leuven. It is useful to be located close by because of the 'face to face 'meetings, but it is not necessary. In general we use the technology research of these firms to integrate in our ICs."

The importance of the presence of these actors in the ELAT-region is in the delivered technology to be integrated in the chips and not in the fact that they are in the neighbourhood. But SiTel admits that ´face to face' meetings can be helpful. The part of sourced technologies coming from the ELAT-region is about 10% of the total sourced technology. Hence, SiTel is not continuously cooperating with a certain partner in the ELAT-region, this depends on the required technology needed for the application.

SiTel doesn't expect any major changes in ways of working for the forthcoming years.

Innovation strategy of SiTel

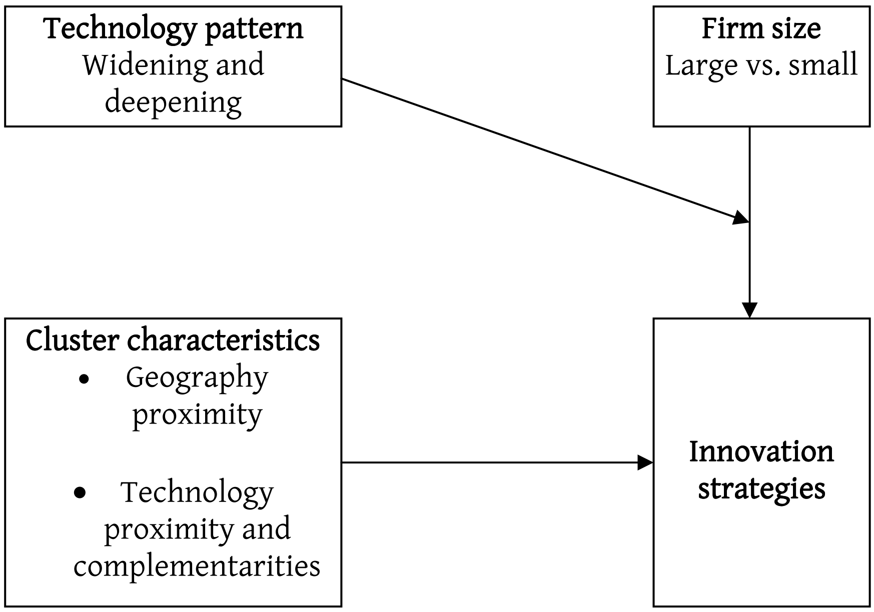
SiTel innovation activities are application driven. The more explorative activities are organized to analyze the feasibility and suitability of new technologies. Further integration and development of the innovation is exploitative and the innovation activities are organized internally. Employees are responsible for keeping up to date about technology developments and are appointed to exploitative as well as explorative projects. The strategy of SiTel for organizing exploitation and exploration can be typified as *contextual ambidexterity* with a strong focus in *specialization on exploitation.*

Chapter 6 Analysis

6.1 Introduction

This study has tried to identify relations between technology and cluster characteristics, and firm strategies. First of all the data on the technology characteristics, the cluster characteristics and the firm strategies will be analysed. Then the analysis will be linked to the theoretical debate on balancing exploitation and exploration. This will result in a number of suggestions for further research. The discussed relations are outlined in figure 12.

Figure 10 Presentation of relations between findings



6.2 Technology

The technology pattern of an industry can be typified as *deepening* or *widening*. This typification is the result of how the industry is characterized by four aspects, viz. technological opportunity, appropriability, cumulativeness and knowledge base.

Technological opportunities reflect the likelihood of innovating for any given amount of money invested in research. The technological opportunities of the semiconductor industry are 'low'. Firms of the semiconductor industry have to invest many resources to 'produce' innovations. Especially in the MM trajectory, large investments are required in machinery, knowledge and research facilities. The MtM trajectory also requires large investments, in particular in knowledge development, although facilities and machinery require fewer investments since they can be used in an extended lifecycle.

Appropriability of innovations summarizes the possibilities of protecting innovations from imitation and of reaping profits from innovative activities. The appropriability of the industry is 'high'. Innovations can be protected through patents, as is seen by the analyzed firms. The rate of technology development is also high, which stimulates firms to innovate continuously.

Cumulativeness of knowledge is related to the necessity for having an innovation history to be able to produce innovations. The cumulativeness of knowledge in the industry is 'high'. Firms develop knowledge continuously along a shared technology path. It also requires large investments to 'build' the required knowledge in order to produce innovations as a result. The Océ cooperation with firms of the semiconductor industry emphasizes the importance of a history in technology development.

Knowledge conditions are related to the character of knowledge underlying the ground of innovations. The knowledge base which initiates innovations in the MM trajectory is primarily generic, for example, the production process innovations developed in IMEC Leuven and controller software for chips. In the MtM trajectory, the knowledgebase is more application specific, but a large part of the technology is based on a generic knowledge base.

The previous paragraphs described the industry on four aspects. It can be concluded that the technology pattern of the semiconductor industry can be typified as Schumpeter Mark II or *deepening*.

6.3 *Innovation strategies*

The innovation strategies pursued by the six firms are visualized in table 4. The + refers to the strategy which is primarily pursued, the (+) refers to other less noticeable strategies pursued.

Table 3 Pursued innovation strategies

		Innovation Strategies					
		Contextual	*ICV*	*Structural*	*Separated*	*Temporary*	*Specialize*
1	Oce	-	+	-	-	-	-
2	NXP	-	+	-	-	-	-
3	Catena	+	-	-	-	-	(+)
4	ItoM	+	-	-	-	-	(+)
5	CK	(+)	-	-	-	-	+
6	SiTel	+	-	-	-	-	-

Basically, the firms choose two types of strategy to balance exploitation and exploration. The larger firms, NXP and Océ, choose the Internal Corporate Venture strategy. Smaller and medium sized firms choose the Contextual Ambidexterity strategy to balance exploitation and exploration. Catena and ItoM are also positioning themselves as specialist in the industry, as such they specialize in their technology area. Therefore the Specialist (in exploitation) strategy is noticeable at these firms. Cavendish-Kinetics has pursued the

Specialization strategy in exploration the last 10 years, but is shifting its focus towards exploitation. The exploitation activities are executed by the same personnel, so the Contextual Ambidexterity strategy can be seen.

An obvious observation is the difference in firm size and chosen strategy. The size of the firms has a relation to their organizational structure and the availability of resources. Large firms consist of various business units aimed at specific markets, e.g. NXP and Océ. The medium sized firm, SiTel, is aimed at one specific market. Smaller firms are focussed on development of one technology, e.g. Cavendish-Kinetics, ItoM.. At the large firms, the researchers concerned with explorative activities are not directly linked to one of the business units, they are grouped together in a R&D department which delivers to the business units when appropriate. The integration of the result of exploration and its developer in the business unit is realized when the innovations can be implemented in one of the business units. Exploitation of the technology is realized within this business unit. Since large firms can structure and allocate resources to innovation activities (Lubatkin et al., 2006) and since these firms are organized in functional areas, it is logical that firms like NXP and Océ allocate research employees to exploitative and other employees to explorative activities. Smaller and medium sized firms, however, lack the possibilities to allocate employees solely to one area or the other and are much more focussed on one technology or market. So they can have their employees' research both. Although this line of reasoning explains the difference in contextual versus structural, it does not explain why large firms choose the ICV strategy instead of Structural Ambidexterity, Structural Separation or Temporary Separation.

The technology pattern of the industry is characterized as *deepening.* This type of technology pattern can determine why large firms prefer the ICV to the other strategies. In *deepening* industries firms are cumulating and developing technology along a known and foreseen technology path. The innovations resulting of exploitation as well as exploration should be aligned with this technology path. Integrating the innovations into the technology path is important to stay on this technology track. In the semiconductor industry these activities are seen. Technology development is performed when it is aligned with the technology roadmap of the firms, for example, at NXP and Océ, but also at the smaller firms SiTel, Catena and ItoM. The majority of the R&D resources are allocated to exploitative activities which further develop the accumulated knowledge. The more explorative activities are aimed at specific applications or products which are aligned with the technology roadmap. Innovations resulting of explorative activities are realized since firms expect that these technologies deliver the required performance in the foreseeable future, e.g. the NXP, the Océ, the SiTel and the Catena explorative activities. Integration of these innovations in existing knowledge and technology is of importance to these firms.

The ability to integrate the innovations in existing technologies determines the pursued strategy.

The Structural Ambidexterity and the Separation strategies separate explicitly explorative activities from the existing routines and activities. These strategies do not facilitate in integrating the result of exploration in existing technology. Therefore the strategies are not appropriate when integration is important. In the analysis of the Océ case the Inkjet Application Centre (IAC) is briefly mentioned and was not really a focal point of attention. The IAC, however, is an example of the separation strategy of exploration from the existing technology for document management of the Océ firm. The IAC technology is used in new markets not related to the document management markets and is consequently separated.

That firms do not choose the Structural Ambidexterity or Separation strategy to balance exploitation and exploration is described and can be understood from the perspective of firms which need to be able to integrate technology in existing technology. But this does not explain why large firms do not choose the Temporary Separation strategy. The technology pattern of the industry characterized as *deepening* creates insights in why this strategy has not been seen at the firms. The Temporary Separation strategy is suggested to be the right strategy in a dynamic and changing environment when interaction between firm activities and technologies is important and pervasive, for example, interactions between exploitative and explorative activities (Siggelkow et al., 2003). Although the Temporary Separation strategy stimulates interaction and integration, it is not the appropriate strategy in a *deepening* industry since technology development is continuous and along a technology path. The semiconductor industry can not be typified as truly unstable and dynamic at this moment. From this perspective, it further underlines why firms do not choose the Structural and Separation strategies which are also appropriate in dynamic and unstable environments.

6.4 Cluster ELAT-region

Cluster effects, and their connection with exploitation and exploration can be identified through analyzing the geographical proximity of different actors to each other, the technological proximity, and by looking at how firms can become complementary to each other in the ELAT-region or industry.

The geographical proximity of firms in the ELAT-region is small around the two main points of technology development, viz. Eindhoven and Leuven. A number of firms are situated on the High Tech Campus near the Philips research facilities and research institutes. In addition, a large number of firms are located near the research institute IMEC Leuven and Leuven University. At these two locations, various spin-offs are born out of the research activities of the institutes and located firms. The analyzed firms are not heavily involved with partners in the ELAT-region. NXP is co-developing technology at IMEC Leuven. Catena is a supplier of chip designs to NXP. SiTel sources technology from IMEC Leuven and cooperates with various firms to a different extent in the ELAT-region.

The technological proximity varies between the firms in the ELAT-region. Around Eindhoven, firms are primarily present from different, sometimes adjacent industries. The research facilities are aimed at MtM technology development at the High Tech Campus. Besides NXP, a small number of firms directly related to the three core processes are present. The majority is indirectly related, for example, firms of the mechatronics industry supplying to machinery and equipment manufactures like ASML and FEI. Around Leuven, firms are related to the MM as well as the MtM trajectory. At IMEC Leuven, prominent firms from all over the world are co-developing semiconductor MM and MtM technology, although the focus of these prominent firms in co-development is primarily at the MM trajectory.

Complementarities in the ELAT-region are seen between the research activities at IMEC Leuven and prominent semiconductor firms from all over the world, including NXP. Around Eindhoven, the MiPlaza research facility and the presence of firms related to the semiconductor industry create the possibility to organize complementarities in the MtM trajectory, as can be seen in the Océ case. Other complementarities in the ELAT-region exist between specialist firms, like Catena and ItoM, and design integrators, like NXP and SiTel. The complementarities between these specialist firms and integrators are not only realized in the ELAT-region, but they are globally realized. The majority of the clients of these specialist firms (Catena, ItoM) are situated outside the ELAT-region.

The complementarities between specialist firms, like Catena, ItoM and Cavendish-Kinetics, and integrators like NXP and SiTel, are realized through technology exchange of technologies closely related to each other. The distance in the technology of these firms is small. In principal, NXP is capable of developing and designing the 'designs' of Catena and ItoM. But NXP, and other prominent integrators like INTEL, IBM etc., choose to buy these designs from the specialist firms. The specialist firms are complementary to the integrators, in the ELAT-region and all over the world.

The complementarities between the explorative activities at IMEC Leuven and the sourcing firms are quite similar, although the technology development at IMEC is much more explorative. The complementarities between IMEC and the sourcing firms cannot directly be typified as complementarities between a truly explorative actor and truly exploitative actor. The exploitative actors, viz. prominent IDM/ Fabless and foundries firms like NXP, INTEL, TSMC etc., co-develop the technology at IMEC and subsequently transition the developed technology into their firms. The technology is co-developed in order to integrate

the technology in their own organizations and to stay informed at the latest technology developments in the industry.
What does the perceived complementarities between specialist firms and integrators tell us. It describes the presence of complementarities in a social system between exploration and exploitation, which was the first and evident condition to realize complementarities in a social system. But the complementarities are not realized between a distinctive explorative actor and a distinctive exploitative actor. Also it describes the absence of two conditions, viz. differences in domains and the absence of co-specialization.
Differences in domains were prerequisite for creating complementarities, but as described in the technology proximity analysis, complementary actors require closely related technology to integrate each others technology. Complementarities are realized in the same domain, e.g. between NXP and Catena and between NXP/ other prominent firms and IMEC Leuven. According to Gupta et al. (2006), the complementary actors should be active in different domains. In their argument, they distinguish fabless firms and foundries, in which fabless are active in a dynamic domain, and foundries in a stable domain. They assume that foundries are manufacturing sites with little change and great ability to produce the continuously changing chip designs from fabless firms. Thus, foundries are exploiting the semiconductor production technology, and fabless are exploring new technologies which could be produced subsequently at these foundries. As such, foundries and fabless firms operate as a chain in which the foundries follow the fabless firms. At the explorative technology development in IMEC Leuven, fabless, IDMs as well as foundries participate. In addition, the most state-of-the-art production equipment is tested and developed.[17] It cannot be maintained therefore that foundries are responsible for exploitation and fabless are responsible for exploration, since they are both heavily involved in explorative precompetitive technology development and are co-developing in the same domain.
Since the exploitative and explorative activities are almost always aimed at integrating new technology into existing technology, complementarities between firms delivering and integrating the technology should be on the same technology ‘level’, otherwise integration of technology can become difficult. Firms have to co-specialize in being at the required technology ‘level’. Although this does not directly require investments in machinery or facilities, it could require investments in the technology and the knowledge base of the firms. Therefore co-specialization may be required.
The second and third conditions to realize complementarities in a ‘social’ system have not been noted. Following the line of reasoning of Gupta et al. (2006), this observation implies that no specialisation strategies could be pursued by the firms in the social system. This can

[17] http://edageek.com/2006/08/29/imec-extreme-ultraviolet-euv-adt/

be maintained since none of the analyzed firms specifically focuses on truly exploration or exploitation, but they are all more or less exploring and exploiting the same technology, for example, the co-development of IDMs, fabless and foundries at IMEC. But on the other hand, it could also be stated that complementarities occur between firms pursuing the specialisation strategies and the integrators, e.g. Catena, ItoM and Cavendish-Kinetics, and SiTel, NXP. So, no complementarities occur between truly explorative and exploitative actors, which is in accordance to the expectation of Gupta et al. (2006), but complementarities in technology exchange between actors in the same domain do occur. These complementarities are important to the firms, since they have access to co-development of state-of-the-art technology at IMEC Leuven, and to maintain the output from technology specialists.

The ELAT-region does not function as a 'social system' that facilitates in specialisation strategies of firms from the semiconductor industry. But the ELAT-region is stimulating firms from adjacent industries to develop technologies with integrated semiconductor technology, for example, the Océ print head and Inkjet Application Centre. Although this study has only identified one situation in which firms of adjacent industries integrate semiconductor technology, it could refer to more instances of complementarities between semiconductor actors and firms from adjacent industries in the ELAT-region. The rationale is that various actors from the semiconductor industry are situated in the ELAT-region, so firms from adjacent industries situated in the ELAT-region could search in their direct environment for support to develop and integrate semiconductor technology. In addition, the research facilities at the HTC are aimed at explorative technology development in the MtM trajectory. The ELAT-region has the 'ingredients' to support MtM technology development with firms from adjacent industries.

Chapter 7 Conclusion and Discussion

7.1 Conclusion

In this study the following research questions are dealt with*: Which innovation strategies do firms follow in order to balance exploitation and exploration present in a nano-electronics cluster? In which way are the innovation strategies influenced by cluster and technology characteristics?*

The innovations strategies are identified in six firms in the ELAT-region. Large firms pursue the Internal Corporate Venture strategy, small and medium sized firms pursue the Contextual Ambidexterity strategy. The six firms primarily organise exploitative activities, explorative activities are closely related to their existing technology and are aligned to the technology expectations of the nearby future.

The technology pattern of the semiconductor industry is typified as *deepening*. Firms have to have an innovation history as accumulation of knowledge is of importance in the semiconductor industry. The technology path of the semiconductor industry is distinctive and developing along a predictable path. The technology path of the industry also knows distinctive technology trajectories, for example, the MM and the MtM trajectories.

The influence of the *deepening* pattern on the innovation strategies can be seen in the choices of the firms to pursue a strategy which facilitates in the integration of the explorative activities and their result in the existing technologies and products. The ICV and the Contextual Ambidexterity strategy are the appropriate strategies. The firm size and organizational structure influence the choice for ICV or Contextual Ambidexterity. Larger firms have the possibility to allocate employees solely to exploration and to exploitation (ICV), smaller firms lack the resources and pursue the Contextual Ambidexterity strategy.

Cluster characteristics of the ELAT-region do not influence the firm strategies of the local semiconductor firms. Complementarities are found in the region, for example, between NXP and Catena, but these complementarities are not between truly explorative and exploitative actors, but they are realized between closely related actors and in the industry as a 'social system'. In the ELAT-region, various actors of the semiconductor technology are situated, although the innovation strategies of the firms in the semiconductor industry are not influenced. The region it could influence innovation strategies of firms of adjacent industries situated in the ELAT-region. An example of possible complementarities can be seen at the Océ Inkjet Application Centre which cooperates with various actors on the HTC Eindhoven.

7.2 Recommendations

Though this study is not designed to propose recommendations to organize a balance between exploitation and exploration in a nano-electronics cluster, the analysis of firm strategy and cluster characteristics did create insights in the possibilities of the ELAT-region and the local firms

The fact that the firms of the semiconductor industry perceive the ELAT-region as not contributing or relevant to their innovation activities refers to two things. Firstly, the ELAT-region does not consist of firms with a technology that is closely related to their technology, or it does not converge to their specific technology. Secondly, the firms lack the capability to see the use of technology development in firms not directly related to their technology, and therefore they ignore the potential convergence.

The first option could be very true, since the ELAT-region is not a region particularly known for firms from the semiconductor industry, especially not in comparison to regions like Silicon Valley in USA, Cambridge in England, Ottawa in Canada or Tel Aviv in Israel (Macher et al., 2007). But the second option could also be true. Since the industry has a history of continuous exploitation along a technology path, firms can become blind to change or expecting no change in technology development. This last argument refers to a line of reasoning closely related to the success trap of exploitation (Gupta et al., 2006). The first assumption, viz. that there are too few firms of the semiconductor industry in the ELAT-region, ought to imply that these firms should not specifically aim at organising innovations along the predictable technology path of the semiconductor industry with nearby actors. This is achieved through complementarities in the industry. The second argument relates to the focus of the firms in the ELAT-region. (Semiconductor) Firms could benefit from the ELAT-region since many firms of adjacent industries can be found in the vicinity, e.g. Philips multinational in various electronics applications, Fluxxion in filtration technology, Dalsa Digital imaging, FEI Electron Optics and Océ. Integrating semiconductor technology into new applications outside the current scope of the industry can be strengthened, but firms need to have the right mindset to understand the potential of converging technology of adjacent industries. Firms could be more successful in identifying the use of unintended knowledge spillovers of adjacent industries, especially in a nano-electronics cluster.

7.3 Discussion

In the analysis of the results several theoretical concepts have been dealt with. The analysis and their alignment with the theory are discussed in this section. Firstly, this section discusses the contingency factors of the technology pattern on the balance between exploitation and exploration. Then it continues with a discussion of the concepts of exploitation and exploration and how these concepts can be interpreted as related to the innovation process in the firm, and to complementarities in the social system. Finally the proposed added value of regional clusters is discussed.

The review paper of Raisch and Birkinshaw (2008) on organizational Ambidexterity outlined the current state of research at antecedents, moderators and performance outcomes on organizational ambidexterity. In their paper the influence of external environments is related to organizational ambidexterity. The organizational ambidexterity concept refers to the ability of firms to pursue conflicting tasks, for example, investment in current versus future projects, differentiation versus low-cost production or exploitation versus exploration (Gibson et al., 2004). Other antecedents, e.g. structure, context and leadership, are also seen as antecedents of organizational ambidexterity. Although Raisch and Birkinshaw (2008) argue that these antecedents and moderators could interact and thus influence organizational ambidexterity, they present them in their framework individually. This study has analysed how the external environmental is influencing firm strategy and firm structure to organize a balance between exploitation and exploration. It supports the claim that environment and structure are antecedents of organizational ambidexterity, and that the antecedents interact. The results of this study implicate that further research at the interaction between the different antecedents is useful and could consequently enrich the discussion on ambidexterity and exploitation/ exploration.

Other studies have discussed characteristics of the environment, such as the competitive intensity (Auh & Menguc, 2005) and the environmental dynamism (Jansen et al., 2006), and their influence on the balance between exploitation and exploration. In the study of Jansen et al. (2006) is argued that exploration lead to an increase of the financial performance of firms when there is an increase in environmental dynamism. They state that a higher environmental dynamism requires a different balance in exploitation and exploration. This study has analyzed the influence of the deepening technology pattern on the balance between exploitation and exploration. Though the environmental dynamism has not been an explicit subject of research, it is expected to be stable in a deepening industry in comparison to a widening industry. This study supports the claim that environmental dynamisms is of influence on the balance and that firms choose to focus on exploitative activities in stable environments.

As is already mentioned in the previous paragraph, it is of significance to understand which aspects of the four variables of the technology pattern are of the greatest influence on the balance between exploitation and exploration. Though this study has not explicitly focused on the four variables individually and their individual relation to the balance, the four variables do seem to differ in their influence. The variables technological opportunities, appropriability of innovations and cumulativeness of knowledge do seem to have an influence on the balance between exploration and exploitation. The fourth, the knowledge base is less noted. The variable technological opportunities are 'low', which can be seen in the capital high investments in facilities and knowledge required to organize innovations. These investments tie the organization of innovations to these facilities (Robinson et al., 2007). This 'ties' firms to these facilities and stimulates participating firms to exploit these technologies. The variable cumulativeness of knowledge is directly related to these investments. Other examples are complementarities with specialist firms, which cause integrating firms to focus on exploitation of the specific technology expertise of these specialists. The variable appropriability of innovations is high, this enables firms to secure their innovations through patents and IPRs, which is much visible, especially at the smaller fabless firms, e.g. ItoM, Catena and Cavendish-Kinetics. Basically these three conditions seem to be the major forces to focus on exploitation. The fourth variable, the type of knowledge base is less noted and has not been well recognized in this study. These thoughts are aligned with the analysis of Breschi et al (2000) who found similar results and proposed that the cumulativeness and appropriability conditions increase the stability of the innovators in the industry. In addition, this study indicates the role of technological opportunities as an important driver. Further research is required to fully understand the relation between the variables of the technological pattern and the balance between exploitation and exploration.

Another discussion is the debate on the interpretation and use of the concepts of exploitation and exploration. In this study the concepts are used to identify the exploitative and explorative activities at the firm and to identify the distinctive exploitative and explorative actors in the value chain to analyse complementarities between these actors. This conceptualisation is aligned with the suggestions in the review study on exploitation and exploration of Li et al. (2008) At the firm level though, the typification of exploitation and exploration has caused some problems. This study started with March's initial premise that organizational "adaption requires both exploitation and exploration to achieve persistent success" (March, 1991, pg. 205). But since the innovation activities at the studied firms were primarily exploitative, truly explorative activities without a known target or application were not performed. It seems to be the case that in certain industries the balancing act requires a much larger focus on exploitation and much less on exploration. Gupta et al. (2006) already argued that not all situations require exploitation and exploration simultaneously, but "that cycling though periods of exploration and exploitation is a more viable approach than simultaneous pursuit of the two" (Gupta et al., 2006, pg. 694). This study supports this claim since the studied firms seems to be primarily focussed on exploitation and hardly on exploration. It would be very interesting to see if the exploitation/exploration of the industry occurs in cycles, or that certain industries like the semiconductor industry require a different balance in exploitation/ exploration with less attention to exploration.

Although it may be unclear if the industry cycles through a period of exploitation, firms try to incorporate new or less known technologies into their existing technologies. Linking the goals of exploitation and exploration to the result of the process is expected to occur, especially in an "exploitative" period as because the technology then is much more stable and predictable. This study used the mapping tool for innovations of Henderson and Clark (1990) to typify the specific knowledge areas of an innovation. It is argued that exploitation should lead to incremental and modular innovation, and exploration could lead to architectural and radical innovations. Although this seems straightforward, it was difficult to use it as a proper analysis of the innovations, especially since innovations integrate modular innovations, which subsequently led to architectural innovation, and the other way around (Henderson et al., 1990). It is difficult to typify the relation between exploitation and exploration activities and the innovation as result at one specific moment in time. It could be that at one moment the innovation process is exploitative with a modular innovation as result, but this could subsequently be followed by an architectural innovation, which would refer to a result of more explorative activities. Further research should try to clarify how exploitative and explorative activities are organized during an innovation process and possibly link these to the time dimension of the process. So a better understanding of the goal of exploitation / exploration, and the result of the process can be made.

Typifying the complementary distinctive explorative and exploitative actors in the semiconductor industry has given some interesting insights. The conditions of Gupta et al. (2006) to realize complementarities between genuinely exploitative and explorative actors have not been noted (Gupta et al., 2006), so firms did not pursue a specialisation strategy in genuinely exploration or exploitation. In their article, Gupta et al. (2006) propose the semiconductor industry as an example of an industry which consists of such truly explorative and exploitative actors. This study cannot support their claim and disagrees with them. In the semiconductor industry the linkages are strong between the different actors along the value chain, especially since the various chain actors are co-developing technology. It would be difficult to maintain that in such an industry complementarities occur between truly explorative and truly exploitative actors, which implies that the result of a truly explorative process, for example, a radical innovation, has no consequences for the other actors in the value chain. There has to be some co-specialization in each other's technology to be able to integrate the output of the explorative actor in the exploitative actor. The conditions of Gupta et al. (2006) are therefore not appropriate in an industry with strong linkages along the value chain. One would not expect firms in such an industry to opt for truly specialized explorative or exploitative strategies.

Innovation clusters and the presence of technology platforms to facilitate in exploitation and exploration were expected to influence the innovation strategies of the firms, especially since in the ELAT-region technology platforms can be found, e.g. IMEC Leuven and Miplaza. The ELAT-region should stimulate linkages and coordination amongst different fields and industries which enables innovations (Robinson et al., 2007). This study has specifically chosen to analyse firms of the semiconductor industry in a nano-electronics region since these firms are involved in exploration and exploitation of nano-electronics. But as is stated, few effects can be seen. The technology platforms in the ELAT-region and the technological agglomeration of different sciences and industries around these platforms do not really function as a locus or source of innovations to the studied firms. As Robinson et al.(2007) already pointed out, it could be that the ELAT-region is just emerging as a geographical region characterized by technological agglomeration and that it will be a locus of innovation in the near future. At this moment, the technological agglomeration of different sciences and industries around the technology platforms is not influencing firms of the semiconductor industry in the geographical region.

7.4 Suggestions for further research

The model provides a starting point for future research as to how the technology pattern and cluster characteristics affect firm strategies to balance exploitation and exploration. This study advances conclusions about the effects of these technology and cluster characteristics. Moreover, the analysis on multiple levels was desired by various scholars and this study has provided a basis for better understanding the multilevel effects for further research. Further empirical work to understand the influence of technology patterns and cluster characteristics should be aimed at studying differences in technology patterns between industries and the influence on the innovation strategy of firms to balance exploitation and exploration. Examples of more widening industries could be the biotechnology industry. The biotechnology industry is characterized by a distinctive innovation pattern. Innovations are developed at small firms and funded by incumbents. The technology pattern of the biotechnology industry is expected to be different and possibly more widening.

In addition, it would be useful to study this in a biotechnology region. Examples of such regions are the Munich biotechnology region (Lechner & Dowling, 1999), or the Munster nano biotechnology region (Robinson, 2007). The Munich region is a specific biotechnology region with a large number of biotechnology firms. The Munster region is typified as a nano-technology region and has situated large incumbent firms, like BASF, and research facilities, e.g. CENTech and Munster University.

Since the variables of the technology pattern of an industry and the organizational structures used to facilitate innovation strategies are clear, a quantitative analysis of the influence of the technology pattern can be performed and would be worthwhile to enrich the discussion on antecedents of ambidexterity and exploitation/ exploration.

It would be very interesting to understand in more detail the relations between the learning processes of exploration, exploitation and innovations as a result. It is needed to more explicitly couple research and theory in *learning*, innovations as a *result* and firm *strategy*. Such a study would be concerned with an analysis of the development of an innovation over time. This would create further insights in the relation between an exploitative or explorative goal, and the process to the innovation as a result. There is much to be gained by integrating these perspectives to construct a more cohesive approach.

While the ideas of this study may be relevant for all firms of *deepening* industries, they might not be applicable to small start-ups in their initial phase – not yet challenged with balancing exploitative and explorative activities.

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Appendix I Interview Protocol

Interview protocol used for expert interviews of the six firms. The numbered questions and marked questions with a black point (•)are asked, the question marked with a clear point (o) are used as a checklist for the interviewer. The respondents received the interview protocol without the questions marked with a clear point (o).

Interview Protocol– Innovatiestrategieën van bedrijven in een nano elektronica cluster.
Universiteit Twente - september 2008

Inleiding

Dit onderzoek streeft ernaar te analyseren hoe strategieën van bedrijven worden afgestemd op zowel het verbeteren van hun huidige producten en de daarbij behorende technologie, en hoe bedrijven hun innovatiestrategie afstemmen op toekomstige producten en eventuele nieuwe technologieën. Om deze twee typen producten te kunnen ontwikkelen is kennis nodig. Het doorontwikkelen van bestaande kennis voor het verbeteren van producten en technologieën op de korte termijn wordt benoemd als exploitatie. Het ontwikkelen van nieuwe en nu nog onbekende kennis voor het versterken van producten en technologieën op de lange termijn wordt benoemd als exploratie. Exploitatie en exploratie zijn dus twee manieren van leren om te kunnen innoveren, maar de vraag is hoe de juiste balans kan worden gerealiseerd tussen kennisontwikkeling voor de korte en lange termijn. Men veronderstelt eveneens dat beide een verschillende manier van organiseren vraagt, of dit in de praktijk ook echt zo is wordt in deze studie onderzocht.
In dit onderzoek worden daarnaast twee extra factoren meegenomen, [1] de invloed van een cluster op de innovatieactiviteiten, denkt u hierbij aan bijvoorbeeld geografisch nabij gevestigde afnemers, [2] de invloed van het ontwikkelingspatroon van de technologie binnen een industrie. Kost het ene technologietraject binnen de industrie bijvoorbeeld veel meer R&D inspanning dan het andere? Of worden innovaties voornamelijk door onderzoeksinstituten gerealiseerd en de andere voornamelijk door kleine hightech start-ups?

De hoofdvraag is hoe de innovatiestrategie voor het bereiken van een balans tussen exploitatie en exploratie wordt georganiseerd waarbij wordt gekeken hoe de twee extra factoren worden herkend en erkend.

Naam:
Functieomschrijving:

Bedrijf

1. Interviewer geeft korte omschrijving van het bedrijf, waarbij onder andere ingegaan wordt op de kernactiviteiten, organisatiestructuur, producten markten en innovatieactiviteiten gerelateerd aan semiconductor technologie.

- Kunt u aangeven waar met name het zwaartepunt ligt in de innovatieactiviteiten, op de korte of op de lange termijn?
    - Percentage aan medewerkers
    - Percentage van R&D budget

- Kunt u aangeven hoe innovatie voor de korte en lange termijn opgenomen is in de strategie van uw organisatie? Zijn hier duidelijke doelen voor opgesteld? Kunt u hier een voorbeeld van geven?
    - Beleidsmatig

Exploitatie en exploratie

2. Wat is specifiek voor de wijze waarop de organisatie bestaande en bekende technologie in de organisatie doorontwikkelt? Denkt u hierbij aan termen als organisatiestructuur, locatie, samenwerking.
    - Doelstelling van exploitatie
    - Organisatiestructuur
    - Locatie
    - Moment
    - Samenwerking type partners (afnemers, of juist onderzoeksinstituten)

- Kunt u een concreet voorbeeld geven van een exploitatief innovatie proces ?

3. Wat is specifiek voor de wijze waarop de organisatie nieuwe en onbekende technologie zoekt en ontwikkelt. Denkt u hierbij aan termen als organisatiestructuur, locatie, samenwerking.
    - Doelstelling van exploratie
    - Organisatiestructuur
    - Locatie
    - Moment
    - Samenwerking type partners (kern processtappen afnemers, of juist onderzoeksinstituten)

- Kunt u een concreet voorbeeld geven van een exploratief proces?

4. Hoe verhouden de exploitatieve en explorative activiteiten zich tot elkaar. Ziet u dit als complementaire of juiste tegenstrijdige activiteiten? En hoe is dit concreet in de invulling van deze activiteiten te zien. Denkt u hierbij aan termen als organisatiestructuur, locatie, samenwerking.
    - Als tegenstrijdig, waarin uit dit zich? Ext en Exr worden geacht complementair te zijn? [in overeenstemming met vraag 1 en 2?]
    - Als niet tegenstrijdig, betekend dit dan ook dat exr en ext door dezelfde mensen wordt uitgevoerd, mindset, resultaat verwachtingen? [in overeenstemming met vraag 1 en 2?]
    - Transitie van Exr naar Ext? Organisatiestructuur, personeel, moment van transitie?

Cluster

Tot nu toe is er specifiek over exploitatie en exploratie gesproken, maar het is ook interessant hoe het ELAT-cluster deze activiteiten kan ondersteunen. Het is vooral van belang om te achterhalen wat nu precies de kenmerken van de ELAT-regio zijn die exploitatie en exploratie kunnen ondersteunen.

5. Kunt u, als het relevant is, beschrijven hoe de organisatie invulling geeft aan het aanwezig zijn in deze regio? Kunt u enkele voorbeelden geven?

- Wat is de waarde van deze activiteiten in de regio voor uw organisatie? Denkt u hierbij aan onderwerpen als, beschikbaarheid van technologiepartners, geografische nabijheid, mogelijkheid tot uitbesteding van activiteiten.
    - Technologie achtergrond verschil dan juist exr of specialisatie, ext dan juist samenwerken voor verdere ext.
    - Geografie proximiteit tot Holst/ IMEC/ Aachen?juist exr en ook ext?
    - Complementariteit technologiebedrijven?

- Zou u kunnen beschrijven met wat voor type actoren uw bedrijf voornamelijk relaties heeft in de regio, en hoe deze relaties getypeerd kunnen worden? Denkt u hierbij aan termen als klant-leverancier, concurrenten, gebundeld onderzoek.

- Wat zijn de voornaamste redenen dat exploitatieve activiteiten in samenwerking met actoren in de ELAT-regio worden gerealiseerd? Kunt u hier een voorbeeld van geven en omschrijven hoe deze ontwikkeling concreet wordt geoperationaliseerd, denkt u hierbij in termen als type partners, type technologie, organisatiestructuur etc.

- Wat zijn de voornaamste redenen dat exploratieve activiteiten in samenwerking met actoren in de ELAT-regio worden gerealiseerd? Kunt u hier een voorbeeld van geven en omschrijven hoe deze ontwikkeling concreet wordt geoperationaliseerd? Denkt u hierbij in termen als type partners, type technologie, organisatiestructuur etc.

Reflectie

- Hoe staan de activiteiten die u nu worden uitgevoerd in de ELAT-regio ten opzichte van R&D activiteiten buiten deze regio?

- In hoeverre hebben bedrijven die nabij gevestigd zijn een voorkeur in technologie ontwikkelingstrajecten?

- Stel dat u met deze R&D locatie niet in deze regio was gevestigd, had u dan alsnog met dezelfde partners samengewerkt? En is er een verschil tussen exploitative of exploratieve projecten?

Ontwikkelingen en verwachtingen

6. Wat zijn uw verwachtingen ten opzichte van de technologietrajecten voor de komende jaren? Verwacht u veranderingen in de balans tussen de exploitative en exploratieve processen? Kunt u een beeld schetsen hoe uw organisatie hiermee verwacht om te gaan?