Technische Universität Dresden
Fakultät Wirtschaftswissenschaften
Professur Innovationsmanagement und Technologiebewertung
Prof. Dr. H. Sabisch

THE CREATION OF A HIGH-TECHNOLOGY CLUSTER AS A REGIONAL DEVELOPMENT STRATEGY AND THE APPROACH OF THE IMEC INSTITUTE IN FLANDERS (BELGIUM)

Diplomarbeit

eingereicht von:

Ingo Boltz
Wirtschaftsingenieurwesen
Matrikel-Nr. 2189235

Betreuer:

Dipl.-Kfm. Dirk Meißner Ba (Hons)

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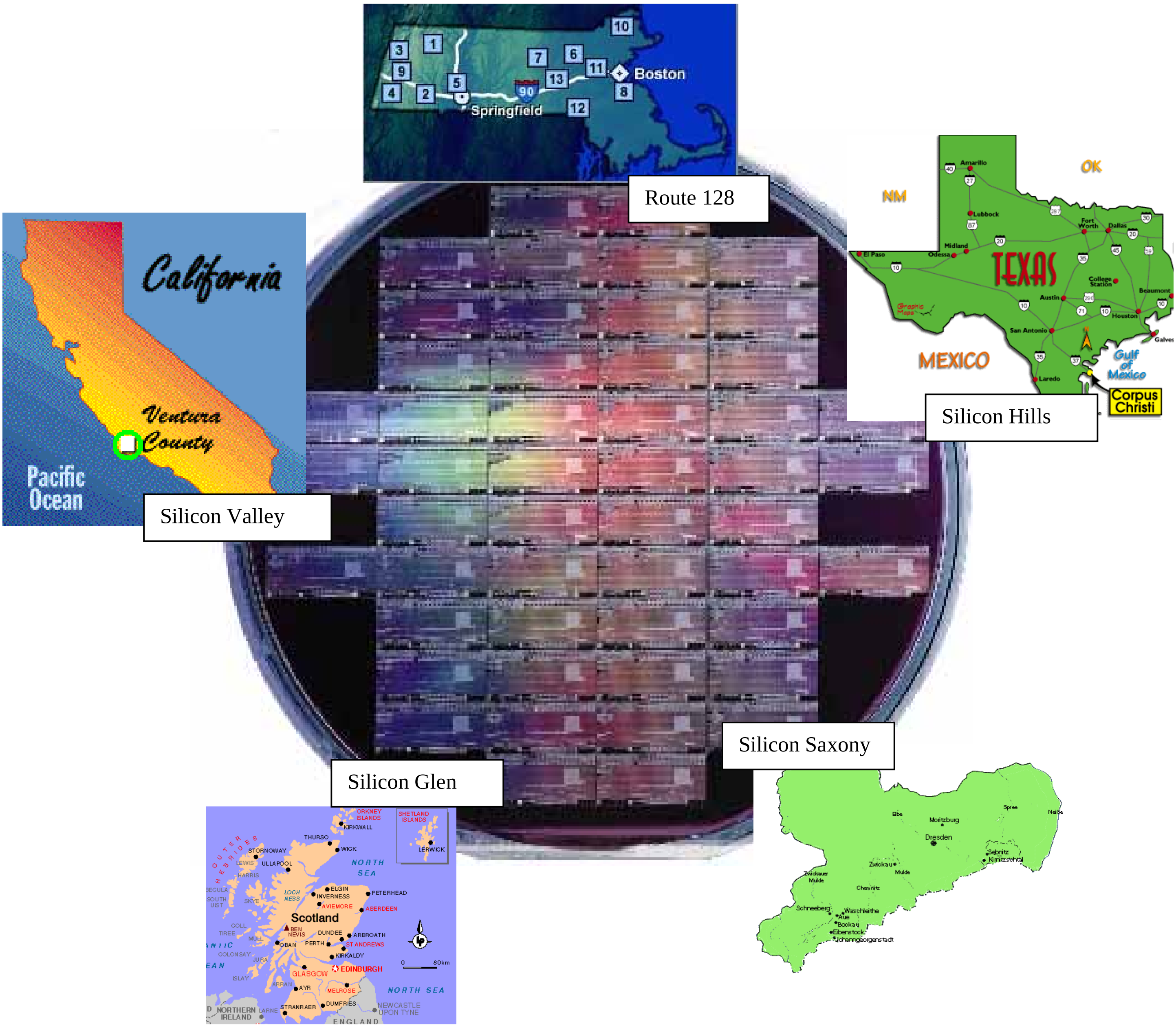

Route 128
Boston
Springfield
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MEXICO
Gulf of Mexico
Corpus Christi
Silicon Valley
California
Ventura County
Pacific Ocean
Silicon Glen
Scotland
EDINBURGH
GLASGOW
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1. Introduction

During the last 20 years, high-technology has been a source of significant wealth and prosperity for anyone able to master it. The rise of Information Technology (IT) has diminished the significance of formerly influential industrial regions; typical examples are regions related to steel and heavy industry. It has also transformed regions which recognized its potential early into thriving centers of affluence and high social prestige - the Silicon Valley IT cluster in California is the most distinguished example. The global demand for IT is expected to grow by 11% in 1997/98 - much faster than most other industrial sectors.[1] It does not come as a surprise that regions all over the globe strive to accumulate high-technology industry.

This thesis will examine issues that are relevant to anyone wishing to build a high-technology cluster for the purpose of regional development.

In the first of two main parts, analysis of theoretical models, as well as existing high-technology clusters, will be employed to answer four significant questions:

- **Why** should regional developers target the *industrial cluster as organizational form* of their region's industry?
- **Why** is a focus on clusters comprised of *high-technology* companies a sensible strategy?
- **Where** can such a cluster be built; what is *required of a region* to permit and promote high-technology cluster growth?
- **How** - using which *tools* - can such a high-technology cluster be built?

By answering these questions, section one will establish a theoretical framework.

In the second section, this framework will be applied to analyze a particular European attempt of such industry building. The "Interuniversity Microelectronics Center" (IMEC), located in city of Leuven, Flanders (Belgium). Section two will examine whether the region of Flanders/Belgium has the characteristics required for successful high-technology cluster growth. The industrial landscape that has grown around IMEC as a result of its activities will be explored. Subsequently, the appropriateness and efficiency of the tools that IMEC has been employing to fulfill its mission will be judged.

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[1] Source: EITO 1997; http://www.fvit-eurobit.de/pages/eito/

This combination of theory and case study aims to provide a comprehensive discussion of the phenomenon of the high-technology industrial cluster in the context of regional development.

2. Why target industrial clusters: the link between pressure, innovation and competitive advantage

2.1. Clusters and innovation

Before the specific case of high-technology clusters is examined, a more general question should be answered: Why should developers target industrial *clusters* as the preferred form of industrial organization?

Antonelli defines a cluster as:

> "...an organized set of partially separable productive units, characterized by high levels of diversity, complementarity and interrelatedness both with respect to existing technologies and eventual ones" (Antonelli 1995, p. 132)

Why should such a concentration of related industrial actors be preferred to other forms of industrial organization, like a broad and diverse landscape of different, unrelated enterprises?

The concept of the industrial cluster is relatively new. It has gained a high degree of popularity in parallel with the rise of the new technology industries who have come to dominate our age, most prominently the IT industry.

These industries seem to be structurally distinct from most older, established industries. Knowledge creation and knowledge transfer is the foundation of their value creation process. This attribute has sparked renewed interest in innovation research, which has ultimately led to a *new understanding of the innovative process and its driving forces.*

This section will outline the change from the traditional, centralist view of innovative activity and value creation to the new model based on the theory of industrial clusters, or network theory.[2] Prior to examining the models, however, the term innovation should be clarified.

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[2] The definitions of "clusters" and "networks" in the literature display strong similarities. Sometimes, they are used interchangeably, sometimes a "network" is defined as the intangibles that connect units which form the "cluster". In this work, both terms will be used interchangeably.

Clarifying the term "innovation"

There are four types of innovation: product innovation, process innovation, organizational innovation, and social innovation (Pleschak/Sabisch 1996, pp. 14-23). Organizational innovation mainly concerns the improvement of the internal structure of firms; social innovation covers better exploitation of human resources in a firm (ibid., pp. 22-23). They will not be in the centerpoint of the discussion in this paper. The two main types of innovation covered here are *product* innovation and *process* innovation.

Product innovation displays several levels. The most highly developed form is *new product creation*. With the creation of a new product, a new product life cycle begins.[3] Lower order product innovations, such as product differentiation and variation, usually occur in later stages of a life cycle that was initiated by a newly created product (ibid., p. 17).

Process innovation usually accompanies product differentiation and variation in the later stages of the product life cycle; it is aimed at perfecting the processes used to produce the product, which are often provisory and non-optimized in the early stages. It targets improvements in productivity and quality, as well as reduction of costs. (ibid., pp. 20-21)

From their different positions in the product lifecycle follows their different application for regional development, and the way they are related to high-technology.

High-level product innovation, especially when it employs new technologies, has the potential to create new products, market segments or even wholly new markets. A recent example is the Internet, which, upon its introduction to the general public, created a whole new related industry, from electronic commerce to electronic publishing.

These industries often enjoy high growth rates. From a regional development point-of-view, they represent the future employment and wealth generating potential of a region. Their current, absolute employment potential is, however, much lower than the one of more mature industries, which have passed their growth period and are in a more mature stage of their life cycle (see chapter 3.3.1).

This is why process innovation is the second important innovation of concern to this paper. Process innovation, although it often goes hand-in-hand with automation and a decrease in employment, has the potential to maintain some of the wealth creation and employment potential of maturing industries, because it helps to extend product life cycles and maintain

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[3] A full product life cycle starts with the generation of an idea for a new product and ends with the elimination of the product from the market. The three main stages are the growth period, followed by the maturation/market saturation period, and concluded by the decline period (Pleschak/Sabisch 1996, p. 17).

competitiveness (Hall 1985, p.2). High-technology can be fundamental to upgrading maturing industries via improved processes (see chapter 5.6).

Consequently, both product and process innovation are essential to regional development in their respective context. For the sake of readability, the general term "innovation" will be subsequently used in this work. The reader is asked to keep the contextual definitions in mind.

2.2. Changing views of innovation sources - from the traditional model to cluster theory

Ever since Joseph Schumpeter formulated his fundamental theory of "creative destruction" (Schumpeter 1950), innovation has been widely acknowledged as the driving force, and source of strength, of capitalism. The *source* of innovation, however, has been subject to debate.

Until well into the 1970s, the prevailing view was rather simplistic. Schumpeter himself, supported by John Kenneth Galbraith, had proclaimed that the ***sector-domineering, large company*** was the most powerful generator of innovation. (Schumpeter 1950, p. 106) and (Galbraith 1956, p. 86). This notion was largely based on economies of scale in research and development (R&D). It was argued that only large firms would have sufficient resources to perform ever more expensive research, while small firms would inevitably fall behind due to their limited resources (Scherer 1991, p. 25).

Most of the "top-down" approaches in regional development chasing large enterprises (see chapter 5.4), as well as the argument for protectionism and "national champions" (see chapter 2.3.3), were built on this line of thought.

During the late 80s and early 90s, this simplistic view came increasingly under attack. Acs/Audretsch suggested that the large number of management layers in the administration of large companies slows down the decision making and resource allocation process that precedes innovations. In smaller companies, only a few people are involved in that decision process, and action can be taken faster. While large companies do produce more innovation in absolute terms, the relative R&D productivity actually *decreases* with size. (Acs/Audretsch 1991, p. 57).

In another study, evidence was found as to the positive correlation between bureaucracy and the rate of "brain-drain" in a company — that the most innovative employees tend to leave a company if bureaucratic restraints become too strong. These people often transfer to small companies, or form their own ventures, taking with them their innovative capacity and transferring it to small and medium enterprises (SME) (Link/Bozeman 1991, pp. 179-180).

Porter (1994) found that, even if a company has used innovation to grow large and acquire a dominant technological position in an industry, it faces substantial obstacles to retaining its leading position. In order to stay ahead, it must be able to adapt quickly to changes in technology or the market. But a large size often raises considerable internal barriers to such adjustment. A successful management team may become complacent, rest on its achievements of the past and resist change. Also, growing firm size may bring increased union presence with it, which in turn may stifle process innovation or prevent outsourcing in order to preserve jobs. This can ultimately lead to a loss of innovative potential and competitiveness. Company assets can also slow down innovation. With the increasing specialization necessary today to succeed in most market segments, the assets of companies become more specialized, as well. But that also means that the assets of each company are tailored to its *past* strategy and technology. New, small competitors - without such ballast - face lower cost of innovation and will be much more willing to follow, or define, the latest trends by acquiring cutting edge technology or adopting new organizational structures. Thus established, large players in an industry are often replaced, or their industries made obsolete, by new, more nimble entrants (Porter 1994, pp. 168-169).

Through all of these findings, small and medium sized enterprises (SMEs) have established themselves as significant sources of innovation. In fact, there appears to be a tradeoff between small and large companies in regard to innovation. Large companies, such as Intel, Hewlett Packard or IBM in the IT sector, *are* able to muster more R&D resources than SMEs, and some "big-ticket" research projects can only be done by them. Therefore, they retain an important role as drivers and promoters of innovation. But many small firms can approach an innovation problem from many different angles, which increases the likelihood of finding the best solution. The tradeoff is then between research *intensity* (large firms) and research *diversity* (SMEs) (Cohen/Klepper 1991, p. 197).

In addition, it was found that other institutions, such as universities and research institutes, influence innovative activity in several industries considerably (see chapter 5.5.2).

The acknowledgement of this diversity amongst innovation producers has led economists to abandon the old monolithic model of the source of innovation. A wider, and more complex, model of innovative activity was necessary, taking into account the diversity of innovation sources, and their interactions with each other. Thus, the notion of the ***industrial cluster***, or network, was born.

2.3. The case for clusters - why and how they foster innovation

Cluster theory states that a whole range of "players" contributes to the innovative potential of a region, from established, large companies to small, highly innovative start-ups and institutions such as universities and independent research institutes. While the large company does retain a large influence as a player, small companies provide vital impulses to the cluster. Non-industry institutions like universities can contribute a long term perspective in the form of basic research, which companies will often be unwilling to undertake themselves due to shorter financial planning cycles and more stringent requirements for return on capital. Research institutes, which focus more on applied research, can then form the linkage between universities and industry.

Why are clusters a superior form of organization?

Firstly and most obviously, the *combination of resources* in the cluster has been shown to be of great importance for the efficiency of knowledge creation, and the speed of its diffusion. The cluster reduces transaction costs between its members due to the frequent exchange of information. It thus increases the innovation potential of its members (Granberg 1993) cited in (Carlsson/Jacobsson 1995, p.50).

Besides reduced transaction cost, a number of positive external effects occur:

> "A large body of empirical evidence shows how within industrial districts an evolving mix of cooperation, non-price coordination and competition appears to reinforce the mutual exchange of benefits generated by externalities. Countries endowed with a variety of industrial districts and firms located in industrial districts and thus able to take advantage from the network of upstream, downstream and horizontal externalities are likely to achieve higher levels of productivity and competitiveness." (Antonelli 1992, p. 28)

As can be seen, the reasons for the innovative potential and success of clusters are more complex than the simple exchange of information. A comprehensive model is necessary to capture the origins of these externalities.

The Porter "diamond"

Porter identifies a system of determinants influencing the innovative and competitive strength of an industrial cluster, which he calls the "diamond" (Porter 1994, pp. 69-129).[4] Porter's work has been a milestone in cluster research. It summarized and clarified much of

[4] All arguments in relation to the "diamond" are, if not stated otherwise, derived from this source.

the fragmented research done before. Therefore, the argument for clusters brought forward here is based largely on his work. It will occasionally be expanded upon by other authors' work.

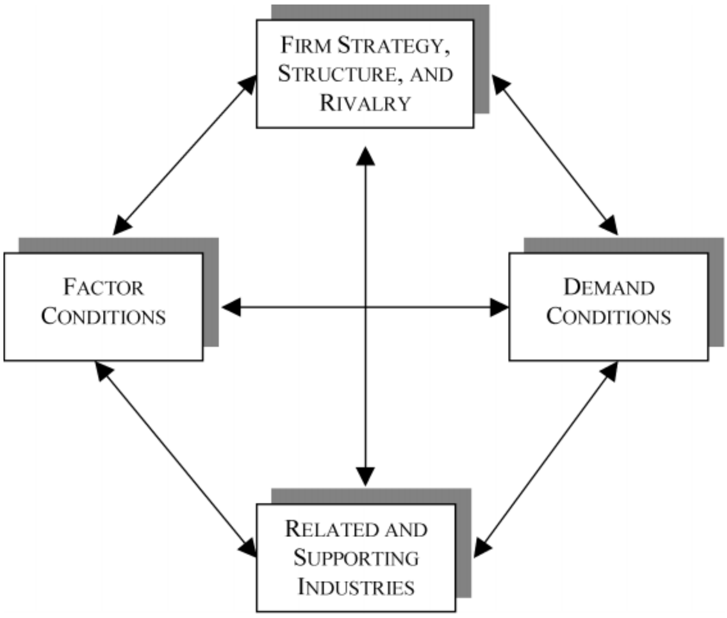

Figure 1: The "diamond" model of cluster competitiveness (Source: Porter 1994, p. 72)

According to Porter, *Factor conditions, demand conditions, related and supporting industries, and domestic rivalry* are the central pillars of cluster-competitiveness[5] (see figure 1). The latter two determinants describe mainly why the cluster form of organization is beneficial to innovation. The former two determine how the innovative strength of a cluster depends on the environment it grows in. These determinants form a complex system; they interact strongly with each other. Deficiencies in one of them can cause deficiencies in others, leading to a downward spiral. Similarly, advantages in one can upgrade other determinants, creating a virtuous cycle. A regional developer must therefore pay close attention to all of the "diamond" determinants.

2.3.1. Factor conditions

Factor conditions are the traditional centerpiece of regional development. The presence of adequate *Human Resources, Physical Resources* (such as energy, minerals, etc.), *Knowledge Resources* (residing in universities, research institutes, associations, and others),

[5] The factors *firm strategy and structure* will not be further explored here. They vary strongly between different firms even within the same cluster, and are difficult to influence using regional development tools. To examine them, and apply them later to IMEC, would require extensive micro-economic analysis on the level of the individual firm. Such analysis is beyond the scope of this work, which will be largely concerned with macro-economic analysis on an aggregate level.

Capital Resources (e.g., venture capital and efficient stock markets*),* and *Infrastructure*, is of course extremely important to cluster formation and operation. There will be a closer examination of many of these factors in chapter 4.

At this point, a distinction between two primary groups of factor conditions, low level and high level ones, will be made. According to Porter, there are general, or *basic* factors (such as raw materials, climate, low wages, or size of the labor pool) and more specialized, or *advanced* factors (such as highly trained workforce, or an efficient capital markets). As a source of sustainable competitive advantage, higher level, advanced factors are more suitable than basic ones. This is because low level advantages are can be copied more easily by competitors than high level ones. For instance, a company relying on low wages would initially be able to compete successfully on a global level. But such competitive advantages can be lost rather easily. Low wages will rise with rising productivity and prosperity. Competing companies in countries with lower wage levels will then become a threat (Porter 1994, pp. 77- 80).

Many industries in Eastern Germany before 1990 derived some competitive advantage from low cost of labor, while productivity was generally low. After the reunification, wages were quickly raised to Western German standards in response to pressure of labor unions. Eastern German productivity was not able to increase with the same speed. Higher level advantages like a highly skilled workforce and capital infrastructure were largely absent due to lack of competitive pressure in the socialist economy. Consequently, the rise in the cost of labor eroded the competitive position of most Eastern German companies. As a result, whole industry sectors went out of business. Only a few small companies with higher level advantages, such as a unique artistic quality as found in regional traditional handicrafts workshops, remained competitive. These advantages were much harder to imitate by foreign competitors outside the cluster, and hence were sustainable.

Another reason why basic factor advantages are a weak base for regional competitiveness is that their *mobility is higher* than the one of advanced factors. Inexpensive raw materials, for instance, can be sourced from outside by a region which lacks them. Similarly, low-skilled labor can be imported from poorer neighboring countries. Contrarily, advanced factors, like a high quality school system or a venture capital industry, are largely immobile and tend to benefit only their host regions. (Porter 1994, p. 76)

It must also be noted that the presence of many basic factor advantages may not even advantageous for creating and, more importantly, sustaining a clusters competitive advantage. A *selective disadvantage* in some of the basic factors can actually increase the strength of the cluster (Porter 1994, pp. 81-86). The abundance of cheap crude oil in the USA has discouraged energy conservation in the region (illustrated for example by its car producers, whose products underperform in regard to fuel efficiency). A lack of such inexpensive energy might have sped up the development and adoption of energy saving methods in the cluster. Since the rising cost of energy due to depleting global resources of fossil fuel will eventually effect all economies of the world, this early adoption would give a cluster an edge over more "spoiled" competitors. Another example would be short supply of blue-collar labor, which may spur investment in factory automation. Examples of this effect in several European countries, amongst them Belgium, have been shown (Franko 1976, pp. 42-45).

2.3.2. Home demand

As it will be shown in the IMEC case study, the importance of home demand is very often not adequately acknowledged. The home market for a company's products can either propel it to excellence, or dim it to mediocrity.

There seems to be a perception that, in the age of globalization, the international market can serve as a replacement for the home market. This argument, however, is not credible. It ignores that a company has to go through a period of early growth, in which it is still small and unlikely to be in close touch with the world market. In this period, the home market forms a company's vital characteristics.

Home demand of a region is characterized mainly by its *quantit*y, i.e. the size of the home market for the products of a cluster, and its *quality*, which is determined by the character and organization of the buyers (Porter 1994, p. 86).

A large home market in absolute terms is an advantage, as it allows an industry to reap early economies of scale. A markets *relative* size compared to other segments of the home market is also relevant. Segments that are perceived to be relatively important often receive special attention, and resources are focused on them.

More important, however, for the creation of sustainable advantage, is the *quality* of home demand, defined by Porter through:

- Sophisticated and Demanding Buyers
- Anticipatory Buyer Needs
- Rate of Growth of Home Demand

The importance that local buyers attribute to a certain product group is often directly mirrored in the strength of the respective local industry. As common example may serve the Japanese obsession with high quality audio equipment, and the resulting dominance of Sony, Matsushita, and numerous other Japanese consumer electronics companies. Another case can be made of the German dedication to cars and driving as a leisure and sports activity, and the resulting weight of Mercedes Benz, BMW, or Porsche. In addition, this line of argument can be extended beyond special product groups. Space is a good that's in short supply in Japanese households. Not surprisingly, Japanese companies are leaders when it comes to small, compact, and portable consumer goods. Of course, the same principle is valid for negative influences. American abundance of space has been reflected in the lack of compactness of many of its products.

Sophisticated buyers also demand, and are early adopters of, new technology. The early success of Sony's MiniDisc system in Japan (already in 1995, there were more MiniDiscs sold in Japan than blank magnetic tapes[6]) anticipated the boom that the system is enjoying now, three years later, in less sophisticated markets like Europe or the USA. In such a way, local buyers pressure their relevant clusters to innovate and define trends, creating an immeasurable comparative advantage (Porter 1994, pp. 86-98).

Home demand is a determinant that can be positively influenced by the (national or regional) government. If the government acts as a *competent* buyer of the goods whose production it wishes to encourage, it can be a strong support to industrial demand. (Pleschak/Sabisch 1996, p. 305).

IMEC's sectoral home markets in Belgium provide important clues in regards to the success of its mission, as will be shown in chapter 7.4.

2.3.3. Domestic rivalry

Porter does not identify cooperation and resource sharing between players as the biggest advantage to agglomeration. *Domestic rivalry* between local cluster members is the major force that drives clusters to innovate and build competitive advantage (see also Scott 1991, p. 145).

Evidence of this proposition is not difficult to find, yet it hasn't spread widely amongst decision makers. It has been argued that rivalry between domestic firms is wasteful because it creates duplication, for instance in R&D, and prevents each single company from growing large enough to develop significant economies of scale, which it could use to compete successfully with foreign competitors in the global markets.

Empirical evidence, however, has not been able to prove that point. Countries which have adopted a strategy of nurturing "national champions" in selected industries in order to avoid "duplication" and "harmful" competition have rarely been successful. Examples in-

[6] Source: http://www.sony.com

clude the French bank Credit Lyonnaise, which has not been competitive despite heavy government subsidies and protection, and the Deutsche Telecom in Germany. For further evidence on the failure of national champions in international competition see (Adams/Brock 1988).

Deutsche Telecom used to underperform compared to companies in the US, and still has an unfavorable reputation for its poor customer service. In preparation of the liberalization of the German telecommunications market, however, its services have improved remarkably. This has undoubtedly been caused by the entrance of new, agile competitors and the resulting increase in domestic rivalry in the newly created cluster. The US telecommunications industry, the world's most innovative and competitive, has been demonstrating that effect for years with its strong domestic competition between the rivals AT&T, Sprint, MCI, and many smaller players, such as the rising WorldCom. Other examples of domestic rivalry leading to global dominance are the German automobile industry (BMW, Mercedes, Volkswagen) or chemicals industry (BASF, Hoechst, Bayer, and others).

Such a competitive environment can compensate for the disadvantages of a home market that is small in absolute terms. The products and services resulting from a competitive market prove to be superior in export markets, as well. As the firms export to the larger global market, the lack of economies of scale in the home market is compensated. Vigorous domestic competition also nullifies basic factors as a source of advantage for the individual firm, since all domestic competitors can exploit them. In that way, it provides the pressure necessary to force companies to upgrade to advanced factors as a source of advantage. This will strengthen their international competitiveness compared to foreign competitors who lack that pressure at home and may continue to rely on basic factor advantages alone. If Japanese companies had relied only on low wages in the last 20 years to hold their position in the world markets, they would have been replaced by now by lower cost Korean or Indonesian competitors. Instead, the intense domestic competition that is present in virtually all of Japan's successful industries has pushed them to innovate and allowed them to maintain their competitive position despite rising wages. (Porter 1994, pp. 117-119)

As Darwin might have phrased it, only a tough environment breeds strong species, and these strong species will dominate in environments that are less harsh.

2.3.4. Related and supporting industries

The presence of sophisticated related and supporting industries (e.g. in the form of internationally competitive suppliers) creates the externalities that Antonelli mentions:

1. by providing the cluster companies with components (and other inputs) of high quality and most recent technology level, or preferred access to scarce inputs.

2. by allowing continuous coordination between supplies and manufacturers, and a resulting stream of innovation and upgrading of equipment.

(Carlsson/Jacobsson 1995, p. 54; Pleschak/Sabisch 1996, p. 312).

Not only do these supplier and related industries constitute a reason for the competitive strength of a cluster; they also have been frequently cited as a reason for early agglomeration of advanced industry in certain regions. Oakey (1985) lists the quality of *local* input suppliers as one of the major reasons for high-technology companies to locate in Silicon Valley. With equipment becoming increasingly sophisticated, often a lot of technical capacity lies in the supplier firm, therefore the proximity of such a vendor facilitates interaction on new inputs to rapidly changing product designs in the SMEs studied (ibid., p. 98). One of the reasons for the problems of the "Silicon Glen" electronics cluster in Scotland (see chapter 5.4.3) was and is the local scarcity of equipment suppliers and subcontract firms. A mere 11% of Scottish firms purchase more than half of their material inputs (by value) from local firms. In the dominating Silicon Valley cluster, 68% do so (ibid., p. 99).

2.3.5. Conclusion: Clusters are preferable

It can be concluded that the strength of industrial clusters results from the pressure that forces cluster members to innovate in order to maintain their competitive position. At the same time, the benefits of proximity to companies and industries similar to their own are strong for cluster members. They allow a flow of information and horizontal externalities that put cluster members ahead of isolated competitors. ***This is why, on the total, the industrial cluster is preferable as a form of industrial organization in a region.***

Other authors' work on clusters

There have been other authors who have approached the issue of industrial agglomeration - before and after Porter. For example, Antonelli (1995) classified networks by their organizational structure, dividing them into "pluralistic", "federative", "centralized", and "technological" networks:

(1) pluralistic networks: based upon reciprocal agreements, as in industrial districts in Italy. With marshallian districts the necessary complementarity and cooperation among firms is achieved ex-ante in the market place by means of a variety of contractual agreements among firms that enforce the arms-length mode of inter-

> action. Proximity in the regional space, moreover, makes easier the necessary co-ordination among the complementary activities of different firms. hence agglomeration economies arise and small specialized firms located into marshallian districts enjoy - with respect to ‘lonely’ often larger competitors - the competitive advantage of aggregate downward sloped supply curves and of significant demand externalities for bundles of products that have high levels of complementarity in usage and in production;
>
> (2) federative networks: based upon regulating boards as the financial federations built around banks and financial companies in France and Germany;
>
> (3) centralized networks: based upon a large company specializing in research and development, procurement, core manufacturing, linked by means of long-term contracts and on-line communication, to a variety of smaller companies specializing in components manufacturing and retailing, as in the Italian experience and in the Japanese Keiretsu system;
>
> (4) technological networks or ‘clubs’: when complementarity between firms is especially strong in generating and implementing new technologies based upon alliances and cross-patenting as it is more and more the case in many high-tech industries. (Antonelli 1995, 132-133)

While this can be used to *classify* clusters, it is not very helpful when examining the reasons for success of clusters. The author found that no other work could match the "diamond" model in scope and practical applicability to regional development. Since the intention here is to *apply* the theory provided to the case study in section two, the most comprehensive and applicable model has been used.

3. Why focus on high-tech clusters: high-tech's potential between myth and reality

In chapter one it has been shown that the cluster is the preferable form for local industrial organization. But which industry should be targeted for the establishment of such a cluster? The answer made by most regional developers in the last two decades has been: high-technology.

A statement made in 1986 is still very true today:

> In the mid 1980s, high-technology has become the economic Holy Grail. In the countries of the advanced industrial world, it is hailed as the antidote to the decline of the smokestack industries of the nineteenth and early twentieth centuries. (Markusen et al 1986, p. 1)

This chapter will examine whether the unison enthusiasm for high-tech is justified.

3.1. The problem of defining of "high-tech"

Although the term is widely used, it is rather unclear what exactly "high-tech" really is. It is common knowledge that high-technology industry is characterized by its high reliance on innovation to achieve competitive advantage. But measuring innovation in an industry is very difficult. The following proxies are often used:

- the average percentage of R&D spending in the expense pattern of an industry
- the percentage of employees in the industry who have a degree of higher education, i.e. scientists and other "knowledge workers"
- the amount of patents produced by the industry

Yet all these approaches have their limitations. R&D spending as a proxy of innovation does not reflect how much innovative *output actually resulted* from the money spent. The percentage of knowledge workers measure excludes external research services, which may be a key factor in producing innovative output. Patents are also a weak indicator, since many innovations are never patented, and not all patented inventions result in an innovation (Acs/Audretsch 1991b, pp. 3-4).

Because measuring innovation is so complicated, there simply is no common definition of which industries belong to "high-technology", and which do not.

Different lists of industries classified as high-tech, which are usually grouped by US Standard Industry Classification (SIC) codes, abound in literature. Some observers see high-tech as a rather broad field of industries[7]. Others define it much more narrowly, excluding for example fields like biotechnology.[8] Therefore, it is difficult to obtain meaningful and comparable statistics on the regional impact of high-tech industry on factors like employment. This constitutes a major problem for analysis in the field.

But even the "correct" static list of qualifying industries would not be sufficient, because "high-tech" isn't static:

> "High-technology" is a dynamic and relative concept that describes the early phases of industrial development. Industries...pass through high-technology phases - characterized by rapid technological change, a relatively high degree of R&D expenditures, and a dependence on highly skilled workers. While the textile industry is often referred to as mature or traditional today, it represented a high-technology industry a hundred years ago. Similarly, industries considered high-technology today, such as computers, biotechnology, information processing, and robotics...may not be the high-technology industries of tomorrow." (Flynn 1986, p. 298)

During the last Kondratieff wave[9], regions embarked on "smokestack hunting" to attract heavy industry which was then the motor of progress, just as they now embark on "high-tech hunting" (Vaughan/Pollard 1986, p. 268).

It must be recognized that high-tech is a transient label.

3.2. Why today's knowledge industries may still be special: Reasons for targeting high-tech industries

There is evidence that the current high-tech clusters may be less prone to decline than the steal and textile industries. Today's high-tech clusters are much more strongly committed to research and development. They benefit from the output of a highly skilled R&D and production workforce which can *create,* and *adapt to* totally new technical innovations and production concepts (Oakey 1985, p.110). As Oakey lays out:

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[7] Definition of the Texas comptroller of public accounts, for a complete list, see http://www.window.texas.gov/comptrol/forces/volume2/focii20.txt

[8] Definition of American Engineering Association (AEA), for a complete list see http://www.aeanet.org

9 Kondratieff introduced the theory of long waves in innovation in the 1920's. A "Kondratieff wave" refers to one of these waves, which are thought to occur about every 6 years, and bring with them revolutionary changes in the world economy. The recent Kondratieff has been defined by Information Technology, the previous one by heavy industry and automated production methods. Please refer to (Kondratieff 1984) for more detailed information.

> "This intense research and development input, both at the level of the individual high-technology firm, and at an aggregate level of the local economy when they are agglomerated, promotes rapid technological change through the acquisition of new leading edge technology, either through indigenous development in the agglomeration, or through the attraction into the area of externally discovered ideas. The high quality of the development and production workers in high-technology agglomerations is an attractive force to any external entrepreneur seeking a location to develop a high-technology product." (ibid.)

For these reasons established high-tech clusters are able to *define*, or at least swiftly adapt to, new champion industries. In the ideal case, high-tech clusters make themselves continuously obsolete through constant renewal, and are so "dynamically stable".

That renewal process manifests itself in a characteristic attribute of high-tech clusters, which makes them attractive: they are potent creators of spin-offs, and therefore particularly capable of indigenous growth. More than any other type of economic activity, R&D incorporates the potential for individuals to set up shop independently in a venture with high growth potential (Malecki 1997, pp. 23-24). The electronics and computer industries have provided numerous examples of entrepreneurs literally becoming millionaires with their own firms, and they continue to do so. The two founders of internet-firm Yahoo! had become multi-millionaires just five years after starting their company. Examples such as these are what make high-tech industries so attractive to regional and local economic developers.

An important underlying reason for this are the short product life cycles found in high-tech industries. Products frequently don't reach the stage of mass production and are superceded by new ones - before a standard can evolve and lock out innovators who don't conform. Because they are highly innovative, these products do command high prices and allow significant profit margins. These margins offer the incentive and the short cycles open the "windows of opportunity" for researchers to become entrepreneurs, to use spin-offs to commercialize research which they did while being employed by another company. Production volumes in such a turbulent market are initially small enough to be handled by these spin-offs. If successful, they can grow with their market. Reinforcing the effect, the spin-offs will then again attract and nurture small, specialized support firms, who cater to their needs and form linkages with them. These support industries, too, work on the short product cycles, and constantly rejuvenate themselves to embrace new trends. Their presence subsequently encourages other researchers to attempt the step into entrepreneurship. Long product life cycles, in contrast, would favor process innovation, with large-scale, automated production methods as the result. One industry standard would likely establish itself over time. Margins would be slim due to intense price competition and favor big operations, which capitalize on economies of scale. Such a market provides little incentive to employees to become independent with a spin-off (Oakey 1984, pp. 51-52).

To summarize: It is the *self-renewal capabilities* and *the predisposition to constantly form new ventures* from research results that make high-technology clusters so promising for regional development. These attributes are the main justification for any project attempting to build such clusters.

3.3. Misguided Perceptions on labor market influence of high-tech

Despite the attributes that elevate high-technology clusters in comparison with less R&D intensive industries, a number of qualifications are necessary. High-tech is not the "cure-all" that it is often portrayed as. Especially as employment generator, it has important limitations.

3.3.1. Perception one: "High-tech creates perpetual employment growth."

The main reason for the popularity of the current high-tech industries has been percentage growth rates, and the high status and pay associated with working in them.

According to the American Engineering Association (AEA), in 1996 the total US high-tech industry grew by 240,000 jobs, or 5.5%.[10] It was the largest manufacturing sector in the US industry. High-tech industry represented 6.2% of the US Gross Domestic Product (GDP) - No. 2 trailing only the private health care industry, and was the leading US export sector by value. The average high-tech wages were almost US$50,000 in 1996, 73% higher than the US national average in the private sector.[11]

Looking at these numbers, the notion of technology as the "Holy Grail" of development seems wholly justified.

Looking at the period from 1990 to 1994, however, a different picture emerges. Total US high-tech employment declined during that period, from close to 4 million jobs to 3.7 mil-

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10 The principal clusters did ever better proportionally. A whole 60% of all new high-tech jobs came out of the leading technology states - another indicator for the clustering typically observed in the industry. For instance, California's (No.1) high-tech sector grew by 55,00jobs, or 8%, and the younger Texan one (No.2) added 27,700, or 85%. Massachusetts (No. 5) added 7,371, or 9%. Source: http://www.aeanet.org (AEA)

11 Source: http://www.aeanet.org (AEA)

lion. Even in the proverbially innovative Californian high-tech sector, employment shrank from 715,000 to 640,000 in that period.[12] This serves to show that high-tech industry has always been experiencing ups and downs, just like any industry, and that the myth of everlasting growth often evoked in the media is wishful thinking. The current period of regained rapid growth will not last indefinitely, and the presence of a high-tech sector in a region is no *guarantee* for continuous prosperity.

It must also be noted that the "core" high-tech industries represent only a small portion of *absolute* employment. The total of high-tech employment in the US in 1996 was only about 4.3 million, or 6.1%. In California, noted for its dominant position in high-technology industries, only 5% of the total workforce were employed in these industries.[13] Even over the long term, it has been estimated that employment in high-tech firms is unlikely to exceed 10% of the US workforce. Even in the areas of highest concentration, such as Massachusetts and California, it is unlikely to exceed 15% (Malecki 1997, p. 23). The business services sector employs the same number of people alone, the medical services even twice as much as the high-tech sector. It is the services sector at large (of which only a few segments are dependent specifically on high-tech) that is expected to provide for the lion's share of future employment (Weiss 1985, p. 83). The number of new jobs created by a high-tech industry will not be sufficient to employ all workers displaced by the contraction of older industries (Pleschak/Sabisch 1996, p. 314).

For these reasons, perception one is not plausible.

3.3.2. Perception two: "Jobs created by high-tech industries will be a remedy for displaced workers from declining industries."

This assumption is even less realistic than the preceding one. This is because the new jobs created by high-tech industries are often highly specialized in nature, which makes them unsuitable to the skills of displaced workers of "low-tech" industries (Vaughan/Pollard 1986, p. 269). In many cases, the workers will be too old to be retrained. Therefore, recruitment often occurs over-regionally. It is targeted at highly mobile professionals from all over the world, not necessarily the local labor surplus (Jowitt 1991, pp. 127).

If displaced workers find work in the new industries, it is seldom in the high profile jobs; a high level of employment polarization is frequently found in high-tech indus-

12 Source: http://www.aeanet.org (AEA)

13 Source: http://www.aeanet.org (AEA)

tries (Weiss 1985, p.84). In the semiconductor industry, for example, this manifests itself in a two-tier structure: Highly paid, highly skilled white-collar workers and rather low-paid, low skilled production workers comprise the workforce. Employment opportunities in the "middle ground", such as higher skilled, well-paid blue-collar jobs found in steel or coal production, are small. It is people who've held these jobs, however, who are most heavily hit by industrial decline of the old industry.[14] Often, such workers will choose not to re-enter the workforce because they deem the wages paid in the lower profile jobs to be insufficient (Schoenberger 1985, p. 17).

Perception two is therefore implausible, as well.

3.3.3. The need to integrate

Because of all these facts, the attraction of a high-tech industry alone will never be a "quick fix" solution for economically declining regions. Existing - and often "old" - industry continues to carry the most significant responsibility for employment. It is therefore necessary to carefully consider all remnants of industries left in place by industrial decline before establishing a high-tech based strategy for industrial revival (see figure 2). Simply attempting to put high-tech production facilities into the countryside without a proper fit to existing industrial and educational bases is neither feasible nor beneficial. They are not likely to develop and upgrade further, and will hardly become innovative hotbeds and lead to self-sustaining growth in a region. High-tech industry must *complement, not replace*, existing industrial activities.

[14] Of course, the trend towards this two-tier structure is universal, fuelled by rationalization and automation and found increasingly in any industry. Hence even workers that are able to secure employment in the 'old' sectors will eventually face this issue.

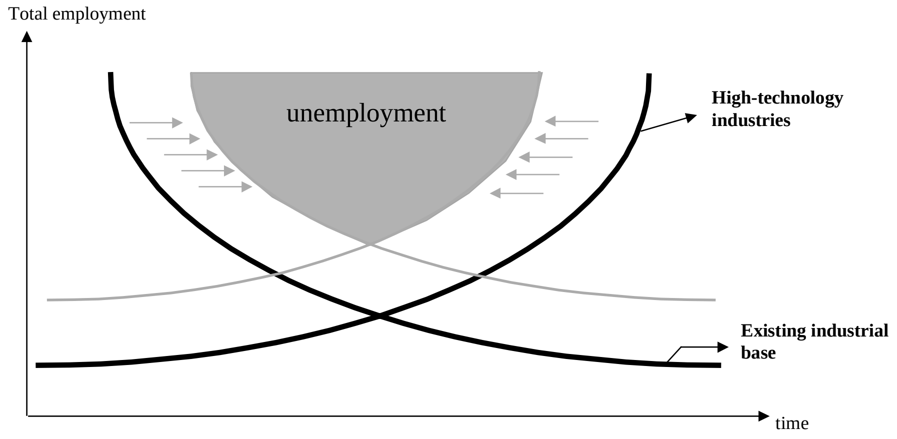

Figure 2: Dual approach to employment creation: the contribution of old and new industries (Source: IMEC internal presentation)

To name an example: it may be more useful for a region with a declining metalwork tool industry to attempt the creation of an industry making semiconductor equipment, instead of trying to lure semiconductor manufacturers themselves. The former will draw more heavily on the skills and capabilities of the workforce available, i.e. metal working and machining, and hence complement the existing occupational structure much better. It will also offer a more seamless upgrade path for the skills of that workforce.

As Porter points out:

> "Being preoccupied with 'new' industries..obscures the fact that clusters always represent a mix of traditional and new industries. Even 'mature' industries involve new technology." (Porter 1994, p. 656)

The aspect of promoting the *upgrading of existing industries* will be covered in more detail in chapter 5.6 below.

The recognition of the limitations that high-tech industries have as regional development solution has led to the introduction of policies addressing both new industry creation and old industry revival in IMEC. They will be covered in detail in chapter 7.5.3.

4. Where high-tech clusters can emerge: requirements that must be met by the target region

After establishing both the plausibility and the limits of high-technology in regional development, it is time to turn to some important location factors. High-tech cannot evolve and grow everywhere. There are certain prerequisites that must be met before a high-technology cluster can establish itself in a region.

Vaughan and Pollard mark out the principal elements needed:

> "A self-sustaining high-tech industry must be able to transform ideas into economically viable market processes or products. To succeed in nurturing this industry, a region must possess the scientific personnel and the facilities to generate promising ideas, mechanisms for transmitting this information to individuals who are in the position to act on it, skilled technical personnel capable of taking ideas to the marketplace from the production line, and the money to invest in this costly and risky activity." (Vaughan/Pollard 1986, p. 272)

This description is still rather general. A more detailed "checklist" would be helpful for evaluating the suitability of a region for high-tech cluster growth. Jowitt distills - from the experience of existing high-technology clusters in the US - the following concrete eight determinants important to location of high-technology industry:

1) Association or proximity to high quality institutions of higher education.

2) Association with military research and development.

3) The existence in the area of advanced manufacturing and research facilities.

4) The availability of venture capital.

5) Good communications/transportation network.

6) A pleasant environment with good cultural, recreational and retailing facilities.

7) The availability of specific kinds of labor:
a) well educated and skilled
b) a pool of cheap labor.

8) The creation of a pro-business environment." (Jowitt 1991, p. 116)

These factors have also been confirmed empirically. In a recent study, graduates from Boston’s Massachusetts Institute of Technology (MIT) who had founded companies were asked to define factors for determining their company's location. (BankBoston 1997, p. 12) The answers largely support Jowitt's findings[15] (see figure 3).

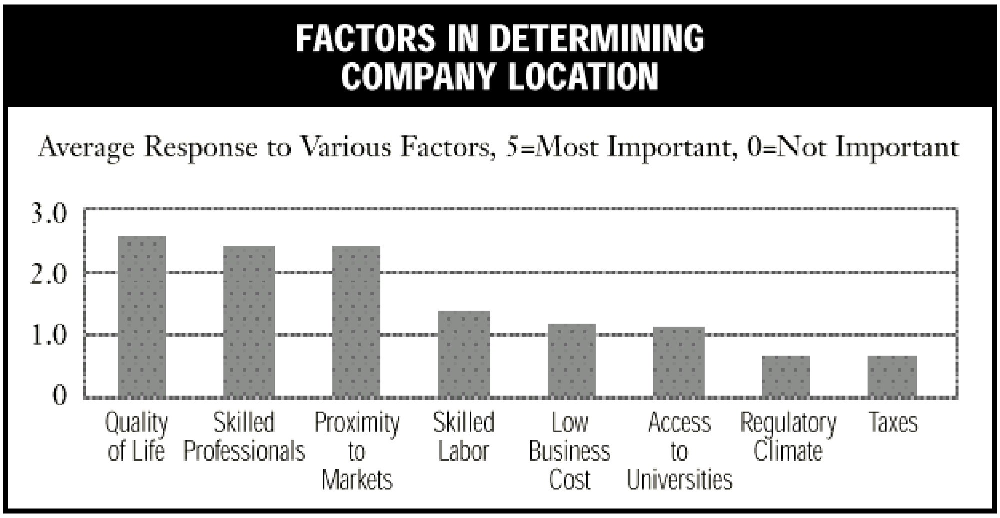

Figure 3: Factors determining start-up company location according to polled MIT graduates (Source: BankBoston 1997, p. 12)

Most of the factors conditions defined by Jowitt were met by the benchmark clusters in their early stage, and continue to be driving forces in their operation today. It will be attempted to validate the list of factors using evidence from these clusters and supplementary theoretical material.

4.1. High quality institutions of higher education

MIT and Stanford University have been crucial to the creation of their respective clusters - Silicon Valley and Route 128 (Jaffe 1989, p. 957). In the 1960s alone, more than 175 new firms were founded by full time employees of MIT's research labs. The most famous example is Donald Olson from MIT's Lincoln Laboratory, whose development of the minicomputer and founding of Digital Equipment Corporation (DEC) laid the foundation for New England's high-tech transformation (Malecki 1986, p. 53). In total, 1065 companies have been set up in Massachusetts by MIT graduates (BankBoston 1997, p. 6). Between 1987 and 1992, 40 start-ups were spun off directly from MIT (Carr 1992b, p.9). In Silicon Valley, a similar wealth of companies was spun off from Stanford University, creating

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[15] In a derivation from Jowitt's point one, the graduates rated university access as being not so important for company location. Still - a majority of them emphasized the entrepreneurial spirit prevalent at MIT, which had encouraged them to found their companies in the first place. Hence, the existence of MIT was essential for the cluster formation.

more than 250,000 jobs between 1960 and 1996. Examples include Silicon Graphics, Cisco Systems, which were founded by Stanford faculty members (Hamilton/Himelstein 1997, p. 63).

It is not only the major universities who are relevant. There are 120 public and private institutions of higher education in Massachusetts; in Boston alone, there are more then 15,000 graduate faculty members. This highly skilled labor pool has been of enormous benefit to the state, and has been frequently cited by companies as the main reason to locate in Massachusetts. Besides drawing outside investment and being the frequent source of spin-offs and start-ups in the state, these graduates contribute to the "intellectual image" of the state and the city of Boston (Schmandt 1991, pp. 160-161). Such an image is an important high-tech location sub-factor, because it contributes to a "pleasant environment" for highly skilled professionals.

The role of universities in regard to cluster growth will be further explored in chapter 5.5.2.

4.2. Military research and development

Military R&D and production is distinctively high-tech in nature (Markusen et al 1986, p. 46). It doesn't surprise that there is a very high correspondence between industrial sectors directed towards military production and the growth of high-technology regions (Malecki 1994, p. 87).

The two US benchmark regions are no exception to this; both benefited heavily from defense spending of the US government, especially in the early days of their expansion (Schmandt 1991, p. 160). Microprocessors are a case in point. Up until as late as 1976, the US federal government, through the Ministry of Defense and the space agency NASA, purchased more than half of total US output of microprocessors, pulling both early clusters with it (Vaughan/Pollard 1986, p. 270).

While Silicon Valley diversified into a wide area of related non-military fields, Route 128 has remained more heavily focused on production related to military. Military industry is the most concentrated industrial cluster in Massachusetts (MTC 1997, p. 9). Of the US$370 million worth of on-campus sponsored research done at MIT today, US$271 million come from federal agencies; which sponsor a majority of military projects. MIT's Lincoln Labs, which it runs for the US Air Force, add another US$338 million in military funds (BankBoston 1997, p. 12).

Without military funding, the benchmark clusters would not have evolved as quickly as they did; maybe they would not have developed at all.

A more recent technology cluster that has benefited from early defense spending is Austin, Texas. In the early eighties, large amounts of military spending from the cold war build-up poured into that area, mostly due to the states political clout with the US federal government. From 1983 to 1986, the amount attracted rose from US$8.2 billion to US$ 10.9 billion. In 1991, the area ranked second in defense contract expenditures, behind California, and ahead of Massachusetts. The high-technology industry developing on the base of that spending formed the basis of its current sprawling IT sector, which makes it an important cluster with steadily rising weight in the US, and catching up with Silicon Valley and Route 128 (Sharp 1994, p. 9).

It has been generally argued that with declining military budgets this factor's importance will decline. With recent cutbacks in defense spending, the Massachusetts defense cluster has contracted by 8.9% annually between 1990 and 1996 (MTC 1997, p. 9). This raises doubts on the future benefits of military spending for high-technology development. But the trend to "electronic warfare" and intelligent weapons will shift a large percentage of defense funds towards the most highly advanced technologies, and may at least partly counterbalance the absolute decline of available funds. The author hence believes that access to military funds will remain important as a factor.

4.3. Advanced manufacturing and research facilities

This criterion is not fully met by one of the benchmarking clusters. The area in which Silicon Valley developed certainly lacked "advanced manufacturing" in the beginning -- it was a region centered heavily on agriculture (Saxenian 1985, p. 20). Route 128, in contrast, had advanced manufacturing capabilities as a result of its textile industry (Schmandt 1991, p. 160).

The fact that Silicon Valley evolved as successfully as it did suggests that some factors, if they are very well developed, can compensate for weaknesses in others.

Research facilities were present at both benchmark clusters. Most of them were associated to the leading universities mentioned above, and are innately discussed in the university-related sections. Of course, there are also research facilities that are not related to universities. Examples are military research labs like MIT's Lincoln laboratory and Los Alamos National Laboratories in California, and industry research consortia like MCC[16] and SEMATECH[17]. Their influence is covered by the analysis of the influence of military

[16] the Microelectronics and Computer Technology Corporation

[17] Semiconductor Manufacturing Technology Consortium

spending in the previous chapter, and by the exploration of the role of research institutes as tools of regional development in chapter 5.5.1.1.2.

4.4. Venture capital

Venture capital is a special, high-risk form of investment. It provides mostly new, unproven start-up companies with often very large amounts of capital in a very short time, and with little bureaucracy attached. The venture capitalist acquires an equity stake in these firms, and profits from gains in the value of these stock holdings after the company is brought to the stock market through an Initial Public Offering (IPO) (Oakey 1984, pp. 139-142). Alternatively to an IPO, the venture capitalist can privately sell the equity stake to another company, in a so-called trade sale.

The investment of a venture capitalist may be lost entirely if the new business fails and the equity stake become worthless. The young companies that require venture capital rarely have a track record on which a risk evaluation could be made. Banks and other traditional lenders tend to be risk averse, and consider providing such early capital as too risky. Therefore, they will usually ***not lend to start-ups*** (Pleschak/Sabisch 1996, p. 343; Oakey 1984, p. 129). Consequently, venture capital fills an important niche as a capital source for such start-ups.[18]

Even if bank loan capital was available to start-ups, the stringent debt service and repayment schedule required by banks is a hazard to a young firm's unsteady cash flows and carries risk of insolvency in the vulnerable, early stages of development. The long-term nature of venture capital is more suited to new firms in the growing phase. In later phases of firm development, banks will be more willing to lend, providing capital used for further expansion of a business that has already proven initial viability. But without the early capital provided by venture capitalists, many start-ups would never reach the expansion stage (Pleschak/Sabisch 1996, pp. 341-342; Oakey 1984, pp. 137-139).

It has been attempted to provide seed capital to SMEs through various government programs, such as the US' Small Business Investment Company (SBIC). But obtaining capital from such sources has frequently been associated with extensive red tape. The bureaucracy, and the long period between application and decision, discourages many small firms from

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[18] In the literature on venture capital, a dual classification of venture capital *by the point in time of investment* can be found. Very early capital, which is often used to develop the business plan and prepare the company start-up, is called **seed capital**. Capital provided once the company has been founded is then called **venture capital** (Pleschak/Sabisch 1996, p. 340). The role of venture capitalists in both instances is very similar in nature (MacMillan et al 1989, p. 31). The author has chosen to use the term "venture capital" to include both pre- and post-foundation capital.

applying. Seed capital from venture capitalists is provided much faster, often based on a half-hour conversation and a handshake. Therefore, such programs can maybe complement, but not replace, venture capital firms as a source of seed capital (Oakey 1984, p.137).

But venture capitalists provide not only money; their role goes far beyond that:

> "[They] sit at the center of multifaceted networks - which they actively help develop - comprised of financial institutions, large corporations, universities and entrepreneurs, and in doing so, forge important linkages between large and small institutions." (Florida/Kennedy 1988, p. 121)

They are financial intermediaries who manage funds provided by pension funds, corporations, insurance companies, philantrophic foundations, foreign sources, and families and individuals (ibid.). This network function goes far beyond the simple capital supply a bank has to offer. It is also a very 'local' phenomenon. Global financial markets can be tapped universally, but the "deal-making" found in venture capital is based on face-to-face contacts. "..[S]ince most venture capitalists are 'local men', they are more likely to plough back their profits into new businesses in the same local agglomeration. Since their main expertise lies in knowing what is being developed locally there is every likelihood that they will restrict their investments, and hence the level of risk, to known local industries." (Oakey 1985, p. 108). Venture capitalists can *gather* money over-regionally or even globally, but they *dispense* it locally within their respective networks (Florida/Kennedy 1988, p. 122). This is why venture capital is showing such strong tendencies to agglomerate, as seen in Silicon Valley and the Boston area.

Many venture capital funds specialize in certain technological areas, and make syndicated investments together with others venture capitalists in order to obtain information on market sectors and recognize trends. They may even take charge of a new technology related to their field of expertise, organizing a company structure around it and so nurture the technology during the critical first months of existence. The tendency in high-technology venture capital investment goes increasingly towards such specialization. Investors, who prefer venture capitalists that are specialized in their firm's field, also pull this trend. They can provide more and better-tailored information on competitors, customers, follow-up investors, and relevant trends in their industry (Bygrave 1987, pp. 152-153; Carr/Hill 1995, pp. 23-24).

Moreover, venture capitalists can have substantial control over management decisions in the companies they invest in, usually on long term strategy via a seat on the board of directors, but often also in day-to-day operations. They can act as mentors to young entrepreneurs. This way they can apply their substantial experience with the specific management issues facing new start-ups or spin-offs (which often results also from their own experience as entrepreneurs and their personal successes and failures) and increase the chances of survival of their firms. They can help with the finding and selection of key personnel, solicitation of essential suppliers and customers, and organization of their venture's financial affairs (MacMillian et al 1989, p. 28).

Venture capital is basically an extension of older, non-institutional sources of funds, such as personal savings, family and friends, and business angels[19]. These are also very *local* in character. Before the emergence of venture capital, individuals were the primary source of business financing (Florida/Kennedy 1988, p. 124). These sources continue to be very significant today and provide the first seed capital before venture capitalists set up shop in a region (BankBoston 1997, p. 20). Venture capital *magnified* the amount of funding available manifold, matching the increasing capital needs of high-tech start-ups which could not be met easily anymore by these "old" sources, and institutionalized the process of capital provision to include new entrants to the venture capital network.

These clustering tendencies and agglomeration benefits of venture capital explain why technology loan programs, such as the SBIC have not been able to significantly draw companies out of established clusters into regions targeted for development. These programs are essentially loan programs; although they also offer advice, neither their level of involvement and assistance nor the scope of their connections can match those of a venture capitalist (Thompson 1989, pp. 166-160).

Governments have acknowledged the unique characteristics of venture capital financing by creating *true venture capital funds* with state money as starting capital, or state capital matching private venture capital to leverage its effect. They are often managed by professional, experienced venture capitalists. This approach is superior to the agency approach. Such funds can equip regions outside of the established clusters with venture capital, and they also provide a seed effect. This is because the presence of a successfully operating venture capital fund demonstrates the existence and viability of deals in that area to the venture capital industry, and attracts it into to the region (Vaughan/Pollard 1986, p. 278).

By holding controlling stakes in their companies, such government initiated funds can also put a cap on premature, asset stripping acquisitions of local start-ups by larger firms from outside the region, a process in which key technology might be relocated out of the region. Such protection makes it easier to achieve critical mass for a young cluster.

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[19] Business angels are wealthy private investors who invest outside of institutionalized structures such as venture capital firms or banks. They are usually associated with high risk, high tech investments. Often, starters of SMEs who accumulated wealth in the process of growing their business, stay close to their roots and invest their new wealth in "their" home sector, creating an additional source of funds for new start-ups (Malecki 1997, p. 176).

Empirical evidence in the benchmark clusters confirms the relevance of venture capital to high-tech cluster development. Both benchmark areas have a long history of successful venture capital investment.

The Boston area led the field after World War II. A specialized division of First National Bank of Boston provided venture capitals for MIT spin-offs as early as 1943. Boston is also home to American Research and Development since its setup in 1946, a venture capital firm which funds specifically high-tech companies. It provided the crucial investment to start DEC (Jowitt 1991, p. 119).

In 1996, venture capital investment in Massachusetts reached US$831.5 million (MTC 1997, p. 28).

Even stronger is the Californian venture capital industry. About half of the US' 600 venture capital firms are located in Silicon Valley (Himelstein et al 1997, p. 72). In 1996, Silicon Valley's venture capital industry provided start-ups in the Californian Bay Area with US$1.8 billion; in 1997 the amount increased to US$2.8 billion, out of a US total venture capital investment of US$10.8 billion (MTC 1997, p. 28; Aley 1997, p. 5).[20]

Cashing out - Efficient stockmarkets as prerequisites of venture capital success

Venture capital can unfold its full potential only in the presence of efficient stockmarkets, because most venture capitalists *realize their profits through IPOs*. Therefore, the level of efficiency and flexibility of the stock markets is an important factor. Stockmarkets that make the listing of small, high-risk firms difficult are not suitable for such IPOs, and will provide an obstacle to successful venture capital development.

The US' NASDAQ stock market, with its easy access for small-firm IPOs, has been providing the necessary flexibility. In 1996, 260 high-tech companies went public in the USA, raising a total of US$12 billion in the process (Cortese/Himelstein 1997, p. 77); 52 of these IPOs were taking place in Massachusetts' Route 128 related industries; 73 in Silicon Valley (MTC 1997, p. 18).

[20] With venture capital, cause and effect may be blurred - as with many of the factors - as the venture capital industry develops and matures in parallel with investment opportunities and hence is the product as well as the initiator of high tech agglomeration.

Venture capital in Europe

In Europe, after decades of neglect and stagnation, venture capital is finally coming off the ground. In 1997, Europe's venture capital firms raised US$22 billion, more than double the figure for 1996. Venture funding rose more than 650% in Germany, and 2000% in Sweden. This money is also increasingly flowing into start-up companies, instead of the more mature firms and management-buy-outs it went to hitherto; in 1997, such early stage investment rose by 60% in Europe. These European venture capitalists may not yet have developed networks comparable to the ones of their counterparts in the US, but in time they may well match them (Economist 1998)[21].

The opportunities for European venture capitalists to cash out via stock markets are increasing in parallel. Germany, Britain, France, Belgium, the Netherlands, and Ireland all have instituted small-company markets, which are linked by the Euro.NM network to create critical mass; EASDAQ, Euro.NM's rival modeled on NASDAQ, has also been set up. Both are still small, with 95 and 27 listings respectively, compared to NASDAQ's 1,500, but the trend is clearly positive (ibid.).

Last but not least, the European Commission (EC) has called for an "action plan" to remove barriers to venture capital, most notably to make tax treatment of capital gains through stock options more favorable. Put into effect, this will greatly boost opportunities for small company founders to earn a fortune, and, in combination with the fresh money pouring in, possibly lead to a revival of small company creation in Europe (ibid.).

All these observations strengthen the notion that, apart from business angels and the acquisition funds of larger companies, ***venture capital recouped via IPOs is the financial backbone of small high-tech company agglomeration***. Without it, high-tech clusters will not emerge. The presence of venture capital in IMEC's environment will therefore carefully be checked for.

4.5. Communication and transport

High-tech industries need sufficient infrastructure, both to communicate with their international partners and to transport their products to global markets. Consequently, a well developed communication infrastructure, as well as an efficient transportation network - especially access to an international airport (Malecki 1986, pp. 61-62) - are vital to high-tech agglomeration (MTC 1997, p. 31).

Communication and transportation is usually provided by metropolitan areas, which are invariably found near the successful clusters, such as Boston, San Francisco/Bay area, or Austin, Texas. For example, the area around Route 128 has a higher ISDN telephone line density that the US average, and the second highest number of internet connections per capita in the US, with California holding the leading position (MTC 1997, pp. 29-30).

Transport capability for Route 128 is provided by the extensive Boston metropolitan area: Boston's Logan International Airport is amongst the top 30 in terms of passenger and cargo traffic (MTC 1997, p. 39). The Bay Area/San Francisco facilities support Silicon Valley comparably. In Austin, Texas, the importance of improved airport access has been recognized by meeting demands of the business community for a new large international airport; it will be finished in late 1998, early 1999 (Engelking 1996, p. 4).

4.6. Pleasant environment

A pleasant living environment is essential to high-tech agglomeration. The highly skilled workers who drive a high-tech cluster are in high demand, and they tend to be very mobile (see chapter 4.7). Amongst the most important factors influencing their choice of workplace are urban amenities as found in attractive larger cities. A rich cultural life, supported by theaters, operas, concert halls and libraries, or ethnic diversity represented in things like a wide variety of restaurants, are of prime importance to these workers. The local weather has also plays a significant role in defining a "pleasant environment" (Markusen et al 1986, p.134-135; Pleschak/Sabisch 1996, p. 314). Trying to locate a high-tech industry in areas where pleasant features are missing will be an uphill battle, because it will be next to impossible to convince such professionals to locate there.

The benchmark clusters' metropolitan areas, Greater Boston and the San Francisco Bay Area, provide a rich cultural and diverse environment as described[22]; rankings listing desirable places to live in in the USA frequently display them in top positions.

4.7. Available labor

The availability of highly skilled labor[23] is considered the location factor number one for high-tech companies (Rees/Stafford 1986, p. 42). The professionals required by the

[21] article retrieved from **online archive** [no pagination].

[22] Author's personal experience.

[23] It must be pointed out that strength pool in a developed cluster is *employed* at any given moment in time. To hire, firms have to outbid each other for the specialists, which causes the upward wage pressure observed in, e.g., Silicon Valley (Oakey 1984, pp. 111, 119).

benchmark clusters have constantly been produced by the regions' strong universities, which is why the sub-factor "highly skilled labor" is, in fact, highly dependent on factor one, "proximity to high quality institutions of higher education". Massachusetts, for instance, has the highest level of education in the USA. One third of its residents had at least a bachelor's degree (MTC 1997, p. 21).

Besides drawing outward investment, a high level of education of the local labor force also increases the likelihood of new company formation and start-ups. High standards in education in the primary and secondary school level create an adaptable and flexible workforce. It has been shown that this education level (proportion of high-school graduates) is amongst the most significant factors influencing small business start-up rates (Bartik 1989, p. 1017). The level of primary and secondary schools in Massachusetts is amongst the highest, and drop-out rates are amongst the lowest in the US. Drop-out rates were also low in California (Silicon Valley) and Texas (Austin's "Silicon Hills") (MTC 1997, p. 26).

Since small high-tech companies do not primarily focus on process innovation and hence run "improvised" equipment, they need highly competent people both in research *and production* (in contrast, larger companies employ a mix of high-tech researchers and engineers and lower-skilled equipment operators). For small high-tech firms, the availability of such talent is a major location and growth factor (Oakey 1984, pp. 108-109).

Successful clusters continuously attract the brightest engineers and scientists from all over the world, which can partly compensate existing local shortages. They can dip into a huge global pool of talent that lessens their dependence on local graduates. According to some estimates, up to one third of the highly qualified workforce in the Silicon Valley are foreign-born (Engardio/Burrows 1997, p. 75).[24] In Massachusetts, 28% of all immigrants entering the state have a bachelor's degree or higher (MTC 1997, p.21). The importance of this extra-national supply of labor can be seen from the pressure that the high-tech lobby has been exercising on the US government in regard to immigration policies during the recent years. The caps currently in place on the number of foreign specialists allowed to immigrate into the US are perceived as too low. The high-tech industry has been demanding an increase in the number of work permits issued.

Nevertheless, a continuous shortage of highly skilled labor exists - throughout the whole high-tech sector, and especially in Silicon Valley. It has been claimed that labor shortages are a bearable by-product of overheating in high-technology agglomerations, that they are

[24] This also contributes extra venture capital capacity, as foreign funds follow their countryman and also invest, focusing on their respective ethnic groups (Engardio/Burrows, p. 75).

"the price of success". The fact that firms in Silicon Valley don't migrate out in large numbers proves that the benefits of agglomeration compensate sufficiently for labor shortages. The higher wages for highly skilled personnel accompanying the shortages also help alleviate the problem of inflated cost-of-living, such as high housing cost, in these clusters (Oakey 1985, p.108). Still, the major factor that has prompted companies to start establishing high value-added design and R&D activities in new areas outside the powerful benchmark networks, as the US Integrated Circuit (IC) design company Cadence did in Silicon Glen (see Annex 8.1), has been a shortage of highly skilled labor. Europe's available labor pool has been a major draw for inward high-tech investment (Lineback 1997, p.3). The pressure to expand internationally - into new locations outside the established clusters - to follow the supply of skilled labor is rising steadily.

The other portion mentioned above, cheap labor, has been supplied in the past by displaced textile workers in Massachusetts and immigrants in California. Today, low-skilled immigrants, as well as an increasing number of female workers, provide for that factor in both clusters. Flexibility of labor laws and low minimum wages have allowed the cost of lower skilled workers to remain low (Schmandt 1991, p. 160).

4.8. Pro-Business environment

A pro-business environment consists of many factors.

Labor market flexibility, which allows companies to adapt quickly to changes in the volatile high-tech markets, is present in both clusters, because of the flexibility of the relevant US laws. In 1997, 88% of all Massachusetts companies polled in a study called the business climate "good" or "outstanding" (MTC 1997, p. 11).

The *entrepreneurial climate*, which includes the whole system of values in a society, such as attitudes toward science, toward economic and social change, towards private enterprise, and towards risk affects small business creation strongly. It relies almost entirely on a well connected network of investors, especially informal investors, previous entrepreneurs - all of them important role models - and an aura of non-routine, innovative activity (Malecki 1997, pp. 162-165, 178).

Most notable may be the attitude to *risk taking*, which is most highly developed in the Valley. Entrepreneurs who experienced failure are more likely to get funded by venture capitalists, based on the assumption that they have learnt from their mistakes and are hence more likely to succeed the second time. Failure is not a black mark on anybody's career in the Valley. To the contrary: it is a "badge of merit" (Port 1997, p. 71). This attitude to risk is one of the most potent factors to high-technology agglomeration, because it lets businesses thrive in the face of the inherently risky nature of high-tech. In regions with more risk-aversion, this attribute of high-tech constitutes an inhibiting factor.

Contrary to popular knowledge, "pro-business environment" does *not* necessarily mean low taxes. The tax base must be sufficiently high to support the provision of a pleasant environment for the highly mobile specialists driving the high-tech sector (Malecki 1986, p. 62). The MIT/BankBoston study (BankBoston 1997) supports that point: The surveyed graduates assigned the lowest importance to taxes in regard to determination of company location. While they admit that high personal income taxes *out of line* with other states could form obstacles to company expansion, they emphasize that "if taxes are lowered at the expense of quality education, cultural facilities, open space, and good transportation, this .. lowers the quality of life and would make it harder to recruit skilled people." (BankBoston 1997, p. 12). Hence the relatively high tax rates found in Massachusetts and California are in fact a prerequisite for success, not unexplainable aberrations.

4.9. Applying the list of factors

The list of factors above will prove very useful when checking whether IMEC's environment is suitable to high-tech cluster formation. Failure to meet some of the requirements can both serve to explain past success or failure, and provide suggestions for future policy.

It must be emphasized again that a strong development of some factors can substitute for a weakness in others. Silicon Valley was lacking "advanced manufacturing" in the beginning, Massachusetts' rather cold and wet climate leads to a less "pleasant environment". It can be concluded that the list doesn't have to be matched point by point to allow success.

5. How to build a high-tech cluster: methods, tools, and limitations

Once it has been established that a region is suitable for high-technology cluster growth, the attention of a regional developer can turn towards the next logical step: building the cluster. There are a number of tools that can be used to do that, some of which will be explored in this chapter. Prior to that, however, the degree of effectiveness of these tools will be critically examined.

5.1. The Limits of regional development instruments and the "technology trap"

One important fact must be stated prior to any analysis in this chapter: Many development strategies are limited in effectiveness. They are not universally applicable, and are not able to transform *any* area into an innovative region. They work as a *reinforcement* of existing conditions as illustrated in the previous chapter.

But a regional developer's influence on these conditions is limited. Many of them are out of the immediate control of regional governments. Some, such as the existence of good transport infrastructure, e.g. through international airports, or the availability of military funds, are determined on a national rather than a local scale. This may be due to political reasons, or to cost so large that they cannot be born by a region itself. Without beneficial national policies, and often large-scale national investments, local efforts are doomed to fail (Hilpert 1991, pp. 21-22).

Many factors also require a very long development time, such as establishing renowned universities and research facilities, or building a pleasant living environment as found in sophisticated urban areas. These factors hence depend very much on decisions made far in the past, and cannot be created quickly (Hilpert 1991, p. 23). Things like "attractive climate" cannot be influenced at all.

This means that *there is only a limited number of regions* endowed with the vital initial conditions. Remote regions, which don't provide such an environment, will not be able to grow a high-tech industry that is self-sustaining and grows endogenously in the short or medium term.

Consequently, governments should avoid the "technology trap". They should resist attempts to spend large amounts of money in order to place technology industry in such remote regions in order to achieve equality of living standards. The money will produce very little effect and will be lacked in other regions, where some conditions may be already present and seeds already existing. There, it can be used with much more effect to strengthen and expand a promising basis. Once a self-sustaining cluster emerges, trickle-down effects and the outsourcing of manufacturing operations to the peripheral regions could more efficiently alleviate the problems of the remoter regions (Hilpert 1991, pp.25-28).

The only active option for handicapped regions may be to bet on the future success of new technologies *early on*, when they are still in a very *infant state*. The technologies targeted should have a potential for a synergetic relationship with the existing local industrial system. This system, which includes the universities and the areas they train graduates for, can then be tailored and reinforced to form a suitable cradle for the growth of the new industry. (Carlsson/Jacobsson 1995, pp. 55-56) This reinforcement has to be carried out with the limited funds generated by a declining tax base provided by little economic activity in the region. Such a gamble is risky, since it is hard to predict which of these technologies will be economically relevant in the future, and the lead-time for the supporting measures, such as specialized training courses in academia, is very long. "Betting on the wrong horse" will be expensive and can severely limit subsequent development efforts, but this strategy may be the only option for these disadvantaged regions (Hilpert 1991b, 293-294).

5.2. Can the established clusters be copied at all?

If, given the right regional circumstances, it is possible to create high-tech cluster seed, the question remains: Which type of high-tech cluster can a regional developer create? It is obvious that a cluster displaying self-sustaining, endogenous growth is most desirable. Only such a cluster will be viable in the long term. But can such a cluster be created using regional development measures?

It is only natural that the regional developers turn to Silicon Valley or Route 128 - the typical examples for self-sustaining growth clusters - in search for a blueprint for their own regions.

As Schoenberger rightly remarked:

> "The US experience is of particular interest in part because of the early and continued dominance by the US in many of these [high-tech] sectors and because this development is of sufficient duration that we are now in a position to begin an evaluation of the outcome in terms of regional development." (Schoenberger 1985, p. 3)

But it is still unclear whether they can be copied at all. They were never "created", were not results of regional planning. They have evolved, to a large degree, spontaneously, driven by market forces (Malecki 1986, pp. 52, 56).

Once the cluster seed had been in place, agglomeration economics reinforced and strengthened the cluster. The *genesis* of that seed is, however, much less understood. Often, "spontaneous" birth, possibly out of the home towns of innovators with revolutionary inventions, is cited. (Markusen et al 1986, p.42) Whether that genesis can be artificially replicated is not clear till today as none of the newer clusters, which are the result of regional planning, has managed to come close to the benchmark clusters in influence and relevance.

Still, regional governments unfortunate enough not to experience spontaneous cluster birth in their area do not contently sit at the sidelines. They see that information age industry creates wealth elsewhere. About 7,000 electronics and software companies reside in Silicon Valley today, with a combined market valuation of US$450 billion in 1997; the wages paid to their employees rose 5.1% in 1996 - five times the national average of the US in that year (Reinhardt et al 1997, pp. 50, 52). The latecomers hope for a "piece of that pie". They want to create the seed from which self-sustaining clusters can grow, and their tools are regional planning initiatives.

5.3. Choosing the right approach, and the problem of a short history

Different administrations have taken different approaches to emulate the spontaneously evolved originals. However, to estimate the level of success of the copies, and thus the "winning method of creation", is difficult because of the short time that has generally elapsed between their birth and the present.

High-tech cluster growth needs time. The naturally evolved clusters took many years to develop. Silicon Valley's birth date lies far back in the 1920s, when Frederick Terman, a professor at Stanford University, first encouraged his students to start up small electronics companies[25]. Despite optimal supporting conditions[26], it was not until 30 to 40 years later

[25] Two of them, David Packard and William Hewlett, started in 193in a garage in Palo Alto the company was to become the first and most famous success story of Silicon Valley - Hewlett-Packard (Hamilton/Himelstein 1997, p. 62).

[26] If one examines Silicon Valley in regard to Porters model, the driving forces can all be identified. Home demand for electronic components was early and of high quality in the US during and after World War II, spurred by the then still dominating American consumer electronics companies, such as Zenith, and continued military spending. Both military and consumer electronic industries required sophisticated input factors, the former buoyed by large government procurement, the latter to serve a huge domestic market that

that the Valley really started to blossom, and a significant amount of jobs began to be created (Hall 1985, p. 11).

The same time requirements are likely to apply for the replication efforts. A report of the OECD on regional development estimated the period required for high-technology development measures to become successful to be 15 to 30 years (OECD 1987, p. 15).

Only a few of the present, created contenders have such a long history. The North Carolina Research Triangle in the US and Silicon Glen in Scotland trace their earliest beginnings back to the 1960s, Belgium's IMEC only to the early 80s. Since they have had less time to evolve, a comparison with the benchmark cluster is difficult.

Despite this obstacle, it is very important to analyze current programs, in order to find the most promising approaches, or "best-practices". Regional governments everywhere struggle to establish their regions as players in high-tech markets such as semiconductors, biotechnology, or new materials. Even assuming explosive growth, these markets will only bear a limited number of participants, which leads to the conclusion that, inevitably, a large number of such developments must fail (Vaughan/Pollard 1986, p. 268-269).

In fact, it has been estimated that, on average, as many as half of all seed projects for cluster creation do fail (OECD 1987, p. 16). In this competitive environment, the chosen method of cluster building, or the right mix of methods, becomes the pivotal element.

From the various programs, two approaches can be distilled: A top-down approach based on the attraction of external companies, and a bottom-up approach, targeting endogenous growth from within the region (Pleschak/Sabisch 1996, p. 313).

The top-down approach is represented mainly by Foreign Direct Investment (FDI). It is sometimes termed the "fast track" method because of its immediate economic impact, but has important drawbacks, some of which will be outlined in chapter 5.4 below. The other approach, the bottom-up method, is comprised of a set of activities to encourage new indigenous small firm formation and growth - i.e. to create a home-grown industrial cluster. It is a time consuming method, as small firms take time to grow and have significant economic impact (Oakey/Pearson 1995, p.7). It will be analyzed in chapter 5.5.

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had been left unscathed by the war and whose consumers where the most prosperous of the world at this time. Factor conditions were favorable, too, with strong US government spending on education for soldiers returning from the war providing for ample supply of the advanced factor education, infrastructure being on a high standard resulting from the war effort, and a traditionally easy access to risk capital through efficient capital markets (Saxenian 1985, pp. 22-24). With most of the "diamond's" parts in place and reinforcing each other, the emergence of world dominating electronics clusters was conceivable.

As it will become apparent during the following analysis, the two approaches - although often seen as discriminatory - should be used *complementary*. Neither alone will provide the desired results. Additionally, they should be supplemented by efforts to upgrade and integrate existing industrial bases, as will be shown.

5.4. Foreign Direct Investment - the top-down approach

The top-down approach has, by any means, a longer history to look back on. Policy makers and developers, inspired by the Schumpeterian views of a large company as innovation motor, have been dedicated to the attraction of FDI for a long time.

5.4.1. Advantages of FDI - instant employment creation

Companies who make such investments tend to be large, established firms, with large capital resources. They consequently have a greater initial capacity to *generate employment* than small local enterprises (Schoenberger 1985, p. 8). The rewards for the attraction of a large manufacturing facility of a foreign multinational company to a region are immediate and sizable. A modern semiconductor factory ("fab"), for example, can easily employ 1000 people or more.

A recent facility that the American Semiconductor Company AMD has erected in 1997/98 in Dresden, Germany, will have about 1400 employees; another fab in that city built by Siemens will eventually employ 1850 people. Additional employment is claimed to come in FDI’s wake, generated through suppliers setting up business units close to the new fab, or jobs created in the local industry through the additional purchasing power of the new employees.[27]

Whether these new jobs will benefit predominantly local workers depends, however, on the skills available locally; over-regional recruitment will likely occur to at least some extent. (see chapter 4.7).

As another benefit, it has been pointed out that the greater financial resources of FDI-type investors mean that they are more likely to withstand cyclical downturns than local SMEs (Schoenberger 1985, p. 8).

5.4.2. Cost of FDI - The value question

On the other hand, FDI is closely linked with incentives; today, few large-scale capital investments, such as semiconductor fabs, are made without them. Tax breaks, cheap land, guaranteed loans and increasingly cash grants are part of a standard "package" to attract FDI. This means that, before generating any return, FDI *costs money*.

[27] For the Siemens fab, another 185jobs were forecast to be created through suppliers, though not all of them will be local jobs. Including jobs "created through increased demand due to high income" of all new local employees, 430local jobs are expected to appear (DIW 1997, p. 3).

For semiconductor fabs, governments have been compelled to offer assistance packages covering from 30% (Scotland) to 35% (for the location of two recent Siemens and AMD fabs in Dresden, Germany). In some regions even 40% of a firm's total fab cost have been offered (Lineback 1997, p.1). Fabs today typically cost between US$1.5 billion and US$2 billion, which means that a minimum of US$500 million is necessary to attract one.

Whether such an expense can be justified largely depends on whether such a fab will act as seed for cluster growth, generating additional employment in the long run. If it does not - and it will be shown that it is not likely to do so - the value-for-money of such a "fab-purchase" is questionable. Since fabs employ between 1000 and 2000 people, spending between US$500 million and US$800 million on such assistance amounts to a subsidy per job of US$500,000 or more. In the absence of the seed effect such expense is hard to justify.

It has been suggested that the cost of such subsidies can be recovered through the tax revenues eventually provided by the subsidized venture. But a recent study (DIW 1997) concerning the attraction of the above mentioned Siemens fab to Dresden estimated that the total amount of the subsidy, DM 937 million, will be met by only DM 700 million in tax revenue over the 10 years following start of operations, and hence produce a deficit.[28]

This also assumes a continuous operation of the fab during the time frame, and is based on an extrapolation of recent dynamic growth in the world demand for semiconductors. However, both cannot be taken for granted.

For example, the recent - and by many observers unexpected - plunge of memory chip prices due to over-capacity has put many Asian memory producers, who were thought invincible before the crisis, to the brink of bankruptcy. There are suggestions that over-capacity in the logic (processor) market due to the current shift to more productive 0.25 micron process technology[29] may cause the same slump in that market.

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[28] The study includes contributions to social security funds in the total revenue and subsequently claims that the net effect of the investment is a positive return, not a subsidy. Whether that methodology is justified appears questionable. Not only are the estimates based on levels of these contributions, which have been publicly identified as a source of German lack of competitiveness and hence may be reduced soon, leading to a reduction of the total amount contributed. More importantly, such contributions have an insurance function and are not funds that could be used freely outside of their frame of purpose. To include them in the return on investment seems a rather political method designated to camouflage the true cost of the subsidy.

[29] "0.25 micron" refers to the smallest feature size on a chip. Continuously improving process technology is able to reduce the size of devices present on a chip, leading to higher device density and thus less space required for a given chip. As process throughput is measured in wafers per hour, more chips on a wafer means higher output/capacity.

Even barring market slumps, the volatility of branch plant location in Scotland (see chapter 5.4.3) shows that a 10-year operation period must not be taken for grated. Fabs have prematurely closed down in the past and will continue to do so in the future. The subsidy, in contrast, must be invested mostly up front, and presents a fixed expenditure that won't be recovered in case of failure of the venture.

Even allowing for a partial recovery of funds over a long period, the huge initial amount of money needed for the investment is a significant barrier for many regions.

5.4.3. FDI - seed for sustainable cluster growth?

The fact that a company has invested in facilities at one location does not necessarily mean that later investments will be located there, too. Large companies have a broad range of geographical options for subsequent rounds of employment. Profits made in the region can easily be invested outside it. This fact that puts a large degree of uncertainty on the future prospects for local employment growth generated by the FDI investor itself (Schoenberger 1985, pp. 8-9).

Besides continuing investment by the same company, it is often expected that, once a large player has located production facilities in an area, they will *work as seed* for a cluster of supporting industry and R&D activity, which will then somehow develop around them. They are assumed to form the core of a developing network of innovators, which will boost the innovative capacity of the region and be the base of endogenous growth.[30]

A recent study (MERIT 1997) analyzed the contributions of foreign firms to the innovative capacity of their host regions in Europe. It found that these potential contributions depend on the level of embeddedness of the firm in the region, defined as the quality and extent of reciprocal linkages between the firm and its region, providing a pathway for both the flow of information and know-how. In many cases, these linkages did not develop, most often because the plants attracted via FDI were "screwdriver - plants" with little in-house R&D and in-house management. Consequently, no meaningful information was exchanged between them and the local industry.

The study reaches a number of conclusions:

- Although FDI can have benefits on employment, policies to encourage FDI cannot be justified on the basis of benefits to a regional innovation infrastructure.

[30] This view goes back to the so-called "growth-pole" theory. For more information, see (Moseley 1974).

- FDI in core regions will occur without subsidies and FDI in peripheral regions will be limited to firms that contribute very little to the innovative capacity of the host region.

- Any policies to attract FDI, given their limitations, should be designed to attract firms that begin with an integrated R&D strategy.

- The potential for FDI to have a positive effect on regional innovative capabilities depends on an approximate match between the innovative capabilities of the foreign firm and its host region.

- The most important incentives for FDI are infrastructural factors such as good transport and educational facilities, all of which should be supported for a myriad of other reasons and are not unique to FDI policies.

- The low number of differences in the embeddedness of foreign and domestic firms in the same sector and of the same size suggests that there is no need for additional policies to encourage foreign firms to develop greater contacts with their host region. Firms are completely capable of building a network with local firms if these networks can complement their business strategy.

- Policy actions should be designed to preferentially support domestic firms over foreign firms, or at least remain neutral to ownership, since innovative capabilities of domestic firms are consistently greater than those of foreign firms. (MERIT 1997, pp. 118-129)

These findings contradict much of the conventional thinking on regional development and put doubt on many FDI based development programs.

The example of "Silicon Glen" in Scotland

An FDI based strategy was adopted in the 1980's by the Scottish Development Agency (SDA) and its initiative "Locate in Scotland" (LIS) in the UK, whose mission was the development of structurally weak areas of Scotland into high-technology areas.

Today, the region's electronics sector employs 46,000 people (7,300 of which work in semiconductor industry and account for about 11% of total European production)[31]. Another 20,000 work in supporting industries. Inflows of FDI have broken records over the last ten years, with 86 projects attracted in 1996/97 involving planned investment of £3.1 billion and the expected "creation or safeguarding" of nearly 14,300 jobs.[32]

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[31] Source: http://www.scotent.co.uk (Scottish Enterprise)

[32] Source: http://www.scotent.co.uk (Scottish Enterprise)

Does this show that an FDI based development strategy works, after all?

An early study of Scottish FDI investment (Hood/Young 1982) already showed in 1982 the problem that has plagued Silicon Glen's developers until the present day. It found that the lion's share of the FDI attracted to Scotland were blue-collar types of plants. A full 50% of them didn't perform any research, and of the research undertaken by the rest, only half was thought to have produced any significant product or process innovation. Local subcontracting is limited. Therefore, these plants have failed to spark an extensive genesis of new start-up firms in the region and hence to improve the innovative capacity of the region. Their mother companies show no interest in locating a significant extent of R&D, or upper level management, in them. Consequently, benefits to the local economy in the form of technological spin-offs and spillovers don't appear (ibid., pp. 17-19). This situation has remained largely unchanged until today. In a recent article, the *Economist* describes the situation as follows:

> "Despite its name, and the fact that it is churning out about one-third of the personal computers sold in Europe, Silicon Glen has never had much in common with California's prodigiously innovative Silicon Valley. Although some big computer firms, such as America's Hewlett Packard, and some small Scottish companies do some research and development, most Scots electronics workers assemble or produce things which are designed in America or Japan." (Economist 1997)[33]

The lack of an innovative backbone has consequently thwarted efforts of the LIS to create sustainable industrial growth. Despite all the success in attracting new investment, ***the net gain in jobs in the last 10 years has been no more than 1,600.*** The jobs attracted by LIS have "proved to be frustratingly mobile" in the absence of an innovative network of the Valley's caliber, making Silicon Glen more a "collection of mostly foreign electronics firms" than an innovative cluster (*ibid.*). Many facilities have closed down again or have fired employees in the sight of problems. A current example is Siemens, which announced on July 31st 1998 that it will close down a memory fab in the area; 1100 employees will lose their jobs. The fab had only started operations 15 months before the announcement. (Quan 1998).

It must be concluded that much of the spectacular volume of FDI goes towards *preserving* the level of industrial activity, not towards growth.

Significant numbers of local companies, which would form a less mobile industry support and hold home-grown future potential, have largely failed to emerge. When, despite these obstacles, start-ups and spin-offs did emerge, the insufficient innovation environment pre-

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[33] article retrieved from **online archive** [no pagination].

vented their development. They were acquired by foreign companies, and their technological assets relocated out of the region, into other areas where conditions for development were more favorable (Balfour 1989) cited in (Oakey/Pearson 1995, p. 6).

What have been the reasons for Scotland's problems?

The positive attributes of high-tech clusters described above - self-renewal and spin-off creation - stem from research and researchers. In the absence of both, they will obviously not occur.

The Scottish region itself, analyzed using Porter's framework, does not provide superior conditions for cluster growth in electronics. Its strong point, besides the incentive packages, has been chiefly *basic factor conditions*. The cost of building and operating a fab in Silicon Glen is highly competitive in international comparisons, due to inexpensive land and low factor costs of operation, such as low wages, and low corporate tax rates (see table).

	Japan	***USA/Cal.***	***EU/Scotland***	***Asia/Pacific Rim; China***
Energy	1	0.6	***0.5***	0.2
Water	1	0.3	1.3	0.03
Nitrogen	1	0.4	***0.3***	0.7
Land	1	0.1	***0.05***	0.25
Wages (Engineer)	1	1.2	***0.6***	0.1
Wages(Operator)	1	0.8	***0.5***	0.1
Engineering Resources	sufficient	short supply	***sufficient***	sufficient
Working Hours p.a.	1870	2080	***2030***	2000
Public Holidays	16	9	***8***	3
Tax Rate	50%	44%	***33%***	33%

Table 1: Factor conditions for fab-location in different regions (Source: IMEC)

The other determinants of the "diamond" are much weaker.

Home demand in Scotland itself is virtually non-existent, most of the production is exported abroad, to Japan, the US, and into Europe.[34] The guidance effect that a high-quality home market can provide is therefore absent.

Rivalry between branch manufacturing plants of the sort found in Silicon Glen could only be an extension of the rivalry of their mother companies in the US and Asia. Whether that is sufficient to evoke the benefits shown by Porter is highly questionable, especially since the "innovation race" does take place where R&D is located, not at manufacturing outposts. While the companies locating manufacturing in Scotland are certainly rivals, their rivalry does not benefit Scotland.

Supporting industries are present, due to the necessary support of the complex manufacturing facilities used in semiconductor production. However, they mostly represent service centers and sales offices, or supply raw materials for production.

Often, the foreign headquarters of the semiconductor companies act as a central purchasing agent for capital equipment in all of their fabs worldwide; equipment will thus be 'imported' and only serviced locally (Schoenberger 1985, pp. 9-10). The supplier office's staff will hence not be extensive and the contribution to the creation of local economy not very significant. Impulses for R&D, or spin-offs, cannot be expected. *Design facilities* of supplier companies / equipment manufacturers, which would benefit from exchange of research results with the IC producers, and thus produce the "downstream externalities" that Antonelli describes, have been rarely found in Scotland (Hood/Young 1982, p. 19). Hence the biggest benefit of the presence of supporting industries - coordination between them and the IC producers, resulting in the stream of innovation and upgrading of equipment - is not found.

It can summarized, that the Scottish "top-down" approach has not been encouraging indigenous growth because of:

1. Lack of R&D carried out in plants.
2. Weak determinants of the "diamond".

Financial Aspects - The value question in the case of Scotland

It is certainly true that the activities of Scottish Enterprise have transformed formerly economically depressed Scotland and greatly improved the standard of living of its people. Its FDI based strategy has, however, been very expensive. Scotland has benefited tremendously from the financial resources of the whole of the United Kingdom; some observers

[34] Source: http://www.scotent.co.uk (Scottish Enterprise)

have remarked that its industry has been "bought" with the tax money of the rest of the country. Scotland has consistently received a higher proportion of government expenditure then the UK average[35]

The total budget of Scottish Enterprise in 1996/97 has been £478 million, which does not represent a single peak of expenditure, but a permanent, yearly flow of money. Only a fraction of this, £31m, is covered from business receipts, or repayable loans (£5m). The bulk, £442m, came out of "Grand-in-aid", i.e. taxpayer subsidies.[36]

Considering the very limited job growth during the last ten years, *value-for-money has not been a high priority* in the Scottish case. The limited effect and low cost efficiency of Scotland's attempts to locate high-tech via FDI in a remote region without an appropriate industrial base confirms the findings of the MERIT study mentioned above.

Recent trends: Scotland targets higher level advantages

Scotland's basic factor advantages should have been seen, from the beginning, only as a platform, enabling the region to upgrade to higher level factor advantages, such as a high standard of education and a base of highly skilled industry experts. If the chance to upgrade factor advantages is not taken, the basic advantages may be easily replicated by competitors.

Two large recent European fabs, of Germany's Siemens and US' AMD, have already been located outside of Scotland: in Dresden, Germany. The region was initially not even shortlisted as a location option by AMD. Certainly: a good reputation of the microelectronics department of the local Dresden University of Technology, as well as the presence of ZMD, a small local maker of ASICs[37], did play a role in the location decision. Nevertheless, both Siemens and AMD named the *amount of financial assistance* as a commanding reason for their decision (DIW 1997, p. 1; Lineback 1997, p. 4). Dresden had been able to put together the most substantial aid package and subsequently succeeded in attracting the facilities.[38]

The LIS has started to recognize the weaknesses in its approach. It has recently put increasing focus on the creation of advanced factors with a number of specialized programs

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[35] for instance, 16% above average in 1992-9 (Webpage of the UK Treasury, http://www.hm-treasury.gov.uk)

[36] Source: http://www.scotent.co.uk (Scottish Enterprise)

[37] Application Specific Integrated Circuits. They are non-standard ICs specifically designed for a certain product of an industrial user and manufactured in smaller volumes than standard ICs.

[38] The developers in Dresden have, however, taken the Scottish experience into consideration by requiring both AMD and Siemens to locate R&D and design capacity in Dresden, as well. Siemens will employ 130 researchers in its center, AMD is expected to employ 200 designers (Yoshida 1997).

aimed at industry-university cooperation, legal improvements and innovations, SME services, and venture capital provision (Please refer to Annex 8.1 for details on these measures).

It can be concluded from the example of Silicon Glen that bottom-up measures are essential to establish a cluster that will display indigenous growth.

5.4.4. "Critical mass" and visibility through FDI

Despite its limitations and its unsuitability as cluster seed, FDI can be beneficial as a ***support to bottom-up cluster growth*** by providing critical mass and visibility to a region. If other industry players are already present, it proves the viability of the operation of a fab there, and "puts the region on the map" of the industry (some of Scotland's inward investment is certainly due to that "herd-effect"). But, more importantly, this visibility will help newly born start-ups to gain credibility. They will win customers more easily, and gain a foothold in the industry, if their "address" is meaningful to their industrial customers (Malecki 1997, pp. 230-232).

5.5. Indigenous growth through SME - the bottom-up approach

It has been shown that large (foreign) branch plants, though often providing a short term employment boost, offer only limited benefits to innovation and rarely create genuine, self-sustaining cluster growth. Even the ones with an integrated R&D strategy underperform homegrown companies in terms contribution to a regions innovative capacity.

The conclusion must be that an FDI based development strategy, standing alone, will not succeed. With the long-term development perspective in mind, increasing attention must be paid to the creation of a local network of innovative small and medium sized enterprises. It has been shown repeatedly that they are a prerequisite for self-sustaining growth, even if their short term impact on regional development (and absolute employment) tends to be small. These SMEs are more likely to be fully integrated in the region, including the R&D functions that are so beneficial to cluster growth as shown in chapter 3.2. They are also more likely to develop supplier relationships with local firms, and re-investment is likely to stay in the region. (Schoenberger 1985, p. 10)

In a recent, broad study examining Italian companies, it was found that small innovating firms displayed the highest employment growth rates, highest value added, and highest per-hour worked productivity growth. They show the highest export growth rate, and are increasing their share of total exports (although their total share of exports is still small). They also display higher (and less recession-sensitive) investment growth rates then larger or non-innovative rivals (Rome University 1996, pp. 4-5).

If developers succeed in encouraging the formation of these SME in a region, *they will form the seed for a high-tech cluster from which larger,* ***home based*** *innovative companies will grow*. These will then contribute more strongly to overall employment creation. It is important to see SME not as an end in themselves, not only as the innovative mesh of clusters. They have got the potential to grow into powerful, sector dominant corporations, as seen, for instance in the case of Apple Computer, which started out with a US$1300 investment (Vaughan/Pollard 1986, p. 279).

Once the seed for high-tech agglomeration has caught root and resulted in an initial, if small cluster of competence, there are several agglomeration effects that reinforce the lead of that cluster. Markusen *et al*, after studying benchmark cluster Silicon Valley, identified such factors specifically for high-tech industry:

- *Information needs*. In high-tech, changes in the new product and reorganization of its fabrication and marketing take place on an almost daily basis, so that word of mouth becomes a primary means of data gathering for key decision making.

- *Prestige*. Only firms with a "high-tech address" will be part of the club. Having an address in the Valley, e.g. in Palo Alto, significantly increased business opportunity for the respective firm.
- *Formation of a highly specialized labor force*. Its members develop an institutional knowledge about the area's firms and a stake in the options available to them regarding mobility among employers, and are hence difficult to entice to relocate. Since they form the innovative core and strength of the region, their fidelity reinforces agglomeration.
- *The growth of a specialized supporting sector*. Most new high-tech firms are run by an engineer or technician who often lacks the basic business skills so essential to survival. For this reason, a set of small, specialized business service firms often spring up around new high-tech centers, offering marketing, accounting, consulting and financial services to high-tech hopefuls. The presence of this sector both increases the likelihood of success of the cluster's new ventures, and draws outsiders from areas with a less favorable infrastructure (Markusen et al 1986, pp. 73-76).

Before these effects can work to strengthen the cluster, the seed has to be present. There are different approaches to creating that seed. However, if any of them is to succeed, the conditions necessary to early stage high-tech agglomeration as identified above must be met. Only then will a high-tech cluster core emerge at all.

5.5.1. Strategies and tools - how to create the seed for cluster growth

In order to create and nurture a high-tech cluster "from the bottom", two things are necessary:

1. Innovative activity must be stimulated in order to obtain marketable ideas, and
2. A constant exchange and flow of information regarding these ideas has to be achieved.

It has been argued that, with modern telecommunication and the arrival of the Internet, distance will cease to matter. Information will be accessible from anywhere, by anybody. It can hence be created anywhere, and transferred to any place. Why then are *local* transfer institutions still necessary?

> "It is a tired cliche that technology transfer is a 'person-to-person' activity, or a 'body contact sport'. Tired or not, the cliche is accurate. For any transfer to occur, some contact between people must occur first. ... Written descriptions, samples, or even working prototypes rarely convey all that is to be known about a new technology. The developer's knowledge and intuition about further potential must be transferred via personal contact between individuals on both sides...[N]on patented know-how, ideas, and suggestions often constitute information of considerable value, however difficult it is to measure and evaluate this sort of transfer." (Carr/Hill 1995, p. 4)

It will always be necessary to stimulate innovation and enable information flow on a local level. Communication technology advances don't change that. The attention must therefore turn to the different types of tools that can create and transfer technology locally.

Carr and Hill group the transfer tools in two categories:

(1) organizations which perform R&D internally, contract for R&D, or perform contracted or cooperative R&D, and transfer primarily the resulting technology:

- Independent R&D institutes
- Affiliated R&D institutes
- Consortia or other organizations which conduct R&D and technology transfer

(2) organizations which transfer or facilitate the transfer of technology created by others:

- Organizations which provide technology transfer referrals and information
- Technology brokers, technology transfer consultants, law firms, and technology transfer conference organizers
- Technology business incubators and research parks. (Carr/Hill 1995, p. 6)

As described by Vaughan/Pollard at the beginning of chapter 4, a region must possess both the facilities to generate promising ideas, as well as mechanisms for transmitting this information. Therefore, tools from both categories will be explored here.

5.5.1.1. Research centers

> "Historically, universities have not been good in transferring technology, except through the people they train and faculty members which may shift into entrepreneurial roles. ...On the other hand, joint industry-university centers for applied research, located away from campus, hold promise." (Schmandt 1991, p. 173)

Using university based research as a development tool through the extension of a research center enjoys growing popularity. There is an increasing number of such specialized, university associated research centers appearing on the scene. The KU Leuven-associated IMEC is one of them, other examples are presented below in chapter 5.5.1.1.2.

Research institutes focus on certain fields of applied research close to industry, and are often located in close proximity to respective industrial clusters. They are frequently associated with successful clusters. They promote this success, because "[s]uch institutions, in which both industry and government can contribute money and scientific talent, create a natural focus for solving industry programs and prompting more vigorous individual company research efforts." (Porter 1994, p. 633) Often, these research efforts are carried out *directly* at the institutes, in institute-industry co-operation formulas where institute money is matched by industry contributions. (ibid.)

While these research institutes draw on the academic excellence of universities to establish themselves, they have a number of advantages as regional development tools, when compared with universities themselves. Universities themselves often do not have the infrastructure to transfer technology to the market, and are often not very good at spin-off generation - despite the exceptional examples of MIT and Stanford which are frequently cited. One reason for this is that the bureaucracy often found at universities inhibits entrepreneurial spirit and discourages risk-taking (Malecki 1986, p. 61) (see also chapter 5.5.2.3).

It is consequently useful to establish a ***separate unit*** such as a research center, whose infrastructure can be tailored to technology transfer and spin-off generation, while the university can remain focused on more fundamental research and its educational mission.

There are certain principles to which the setup of such an institution should adhere:

> "Research institutes should be built around areas of recognized faculty strength and should be in areas of direct value to the local community. Requiring a private match to state contributions is one way of ensuring that the research institute is linked to private industry. Without that linkage the entrepreneurial spirit of the center can rapidly be quenched by the university bureaucracy." (Vaughan/Pollard 1986, p. 237)

It will usually be necessary to subsidize the operation of such centers initially, in order to allow them to built expertise and background information needed to enter into cooperation with industry that benefits both partners. Eventually - once that basis is built and "critical mass" is established - such a research center should finance itself fully through industry contributions. It is useful to define an explicit time frame for the withdrawal of state assistance, allowing long-term planning and providing a sensible amount of entrepreneurial pressure. A center that does not "take off" should ultimately be closed down. A permanent subsidy should not be allowed. (Vaughan/Pollard 1986, p. 274)

5.5.1.1.1. Transferring technology from research centers: best practices

The closeness that these institutes develop to their industries is beneficial to technology transfer. But even they can achieve a more efficient transfer if they adhere to certain rules.

Carr (1992b) identifies a number of best practices when transferring technology from research institutes. Some of them will be listed in order to provide an additional benchmark for IMEC practices.

- *Involve the scientific staff*. Since the scientists are the source of the technology to be transferred, they should be involved in the institute's transfer efforts. Transfer must become an acknowledged and absorbed part of an institute's whole culture. In addition to their research work, some scientists can be charged with a number of technology transfer functions, like updating colleagues on regulatory changes regarding transfer, and relating technological developments and technologies with commercial potential to the transfer group. Modified job descriptions including transfer aims and inclusion of transfer in personnel evaluation systems can help to raise awareness of the issue.
- *Market institute technologies*. Only putting technologies on the shelf and make known a willingness to transfer is not enough. Successful institutes rely heavily on marketing their technology to industry. Marketing targets can be supplied by the inventor of the technology, who will in many cases be aware of potential users (this approach is used successfully by MIT). Additionally, press releases in relevant journals, carefully targeted mailings and newsletters, and regional innovation fairs can be used.
- *Capture intellectual property (IP)*. Research centers should try to capture and collect as much IP from their activities as they can. Only IP that is owned by the institute can be passed on to local industry. (Carr 1992b, pp. 2-3, 5-6)

If an institute follows these best practices, it is more likely to benefit its target industry, and hence its region.

5.5.1.1.2. Examples for effects of research centers

In the benchmark clusters, a number of such institutes have contributed significantly to growth. Examples are the MIT Lincoln Laboratory mentioned in chapter 4.1 for Route 128, and the Stanford Research Institute for Silicon Valley, which contributed highly to their respective cluster's developments (Saxenian 1985, p. 26).

Another well-known example for the application of dedicated research centers is the Ben Franklin Partnership in Pennsylvania. It is built around four advanced technology centers, focusing on robotics, biotechnology, computer-aided design, and manufacturing technology. These centers are distributed throughout the state, each centered on and in a consortium with one or more local universities.

The center's funds must be matched at least equally by non-state sources; upon initiation of the program in 1982, the first US$28 million was already matched by US$84 million from private and philantrophic sources, and this ratio has been maintained. This suggests that the matching-funds formula recommended above does work in practice.

The centers have raised the visibility of local high-technology potential and have helped to improve venture capital availability in Pennsylvania. They have also provided initial seed capital. The centers assist their associated universities with specialized training programs for their students to improve the local labor pool, and set up incubator facilities (science parks) for small businesses, including their own spin-offs. There were 20 such incubator facilities in the state in 1985, more than in any other state of the US (Singermann 1989, pp. 68-71; Schmandt 1991, p. 162).

Another premier, high profile examples of the viability of research centers as incubators of high-tech industry is Austin, Texas. Its recent dynamic growth has to a large extent been built on two research institutes - MCC and SEMATECH[39].

Austin had been a manufacturing outpost for the semiconductor industry since the mid-1970's, but much like Silicon Glen in Scotland it lacked driving innovative potential. While the University of Austin was a center of research excellence, that fact did not profoundly translate into corporate innovative potential in the region. The recruitment of MCC, the US' first private sector, high-technology research consortium in 1983 changed that.

MCC was not conceived for the purpose of regional development, but to promote R&D cooperation between US electronics companies. Its aim was to improve the US's electronic industry's competitiveness in reaction to Japan's electronics industry's rise, and its operation was conceived and financed by the industry, not government. MCC's staff is rather small (150 employees in 1995) and its funding (US$43 million in 1995) relatively limited (Sharp 1994, p. 12). The University of Texas decision makers - who were heavily involved in the recruitment efforts through partial funding and provision of a site for MCC - and regional government were, however, very aware of its potential for regional development through its upgrade effect on the region. They offered aggressive incentives in order for Austin to be selected by the industry as MCC's site (Engelking 1996, p. 3).

The seed effect of MCC has been enormous. It established Austin firmly as a player on the high-technology map.

> "Austin made headlines in the *New York Times*, the *Wall Street Journal*, and the world press as the next great "Silicon Valley." Nicknamed…"Silicon Hills," the area experi-

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[39] MCC and SEMATECH are industry consortia; they are not formally university-associated. But their functioning and effects have been very similar to university associated institutes

> enced an unprecedented wave of enthusiasm because of the perception that it had suddenly become a major technology center." (Smilor et al 1988, p. 52)

While MCC already added significant dynamism to Austin's high-tech industry, it was SEMATECH that had the most profound impact.

SEMATECH, the US' largest and most ambitious private semiconductor R&D consortium, with employment of 800 scientists and engineers, was located in Austin in 1988. SEMATECH, just as MCC, is not an instrument of regional development, but it draws heavily on the region's university resources and cooperates with the regional government. Again, the university helped by providing the site and creating a new university research park (science park) to encourage and nurture the new business formation it expected to arise from SEMATECH's operation (Engelking 1996, p. 1).

SEMATECH has been funded, on a 50:50 basis, by the US semiconductor industry and the US government (through the Ministry of Defense), with a total budget of about US$200 million a year. The 50:50 shared cost rule was in effect from 1988 to 1995. In 1994, SEMATECH had announced that it would relinquish matching government funding by the end of 1996, and slimline its operations. The 1997/98 budget was US$90 million, with employment cut to 450.[40] SEMATECH has gained efficiency since that decision, and its importance in the industry has not diminished. It has, in fact been suggested that the US government had an informal agreement with SEMATECH to end matching funding as soon as the center was operational without assistance. It is clear that the rule stipulated above - that permanent subsidies should not be allowed - has been acknowledged in this instance.

While its mission, like MCC's, has been to promote the US semiconductor industry's competitiveness internationally, it has greatly benefited the region it was located in:

> "MCC and SEMATECH give Austin the "critical mass" of high-tech manufacturers, suppliers and workers that allow businesses to sustain themselves -- and expand. With a large number of companies and research groups, scientists and technicians can change jobs if they are stymied in one organization. And the more firms, the more likely they are to create spin-off concerns." (Sheets 1988, p. 51)

Since SEMATECH's foundation, Austin's "Silicon Hills" region is establishing itself as the third highly innovative and significant electronics cluster in the US. Today, there are about 900 technology-based companies located in Austin. Of the 480,000 people employed in the city, 85,000 work in technology industries[41]. Austin has become a preeminent center for

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[40] Source: http://www.sematech.org (SEMATECH)

[41] This does not contradict the lower percentages cited before for Massachusetts and California - for the *state* of Texas as a whole, the high tech employment percentage is similar in scale to these examples.

the US microelectronics industry, with firms like AMD, Motorola, and many other top semiconductor makers, as well as an estimated 200 equipment manufacturers, including industry heavyweights such as Applied Materials. In parallel, service industries have sprung up, most notably the specialty software industry, whose 440 companies employed 30,000 people alone in 1994. In 1997, the number of companies had risen to 1,200 (Sharp 1994, pp. 5-6; Engelking 1996, p. 2).

The government has been supporting the development of the cluster actively, by providing additional science park space through the Austin Technology Incubator. Acknowledging the importance of the transport / airport proximity determinant, a new municipal airport is being built and is scheduled for completion in late 1998, early 1999. This promises to further strengthen the cluster's competitiveness (Engelking 1996, p. 4).

Although these developments show impressively the viability of research centers as development tools, they must also be seen with caution. Although MCC and SEMATECH had great impact on the innovative capacity and dynamics of Austin's high-tech industry, they had the ***existing high-tech manufacturing base*** of the city to build on. Whether they alone, without that base and only the University of Texas' expertise to build on, would have been able to *create* that high-tech success *from scratch* is much less clear.

An example for a research institute primarily created with that objective - to create a local high-tech industry largely from scratch - is Taiwan's Industrial Technology Research Institute (ITRI). It was set up in 1973, inspired by the example of Stanford University and Stanford Research Park. ITRI was founded with the explicit mission to develop hardware and semiconductor technologies that could fuel start-ups, which would then locate in the 1,430-acre "Hsinchu Science-based Industrial Park" built adjacent to ITRI.

Hsinchu is today the heart of Taiwan's technology industry, with 221 companies employing 60,400 people and revenues of US$12 billion. Some of the most successful companies have been spun off from ITRI, such as United Microelectronics Corp., a US$1 billion semiconductor maker.

Success has not come cheap, however. ITRI and its sister institute for software research consume an astounding US$420 million in annual subsidies - a sum comparable with the Scottish development efforts. On top of that, the Taiwanese government supplies large amounts in grants and tax relief for high-tech companies (Moore 1997, p. 85).

Again, just as in the case of Silicon Glen, the viability of subsidies on comparable scale for smaller countries, or regional governments, is doubtful; application of such a strategy may hence be restricted to a few rich, small nations.

As a conclusion, it can be said nevertheless that ***research institutes are a powerful regional development tool***. This is because they bring innovative potential to a region, in the form of the researchers who perform the R&D. With such an innovative core - providing the region meets the requirements for high-tech cluster development as illustrated in chapter 4 - high-tech industrial growth can be successfully encouraged.

5.5.1.2. Science parks

If the research institutes are powerful generators of innovation, science parks can act as a reinforcement of that power. As an example of Carr's category (2), they can act to bundle and focus the effect that innovation creators have on local industrial growth. In the right context, they will encourage the formation of the small innovative companies that can commercialize the innovative output of the innovation generators.

5.5.1.2.1. Functions and limitations of science parks

The United Kingdom Science Park Association characterizes a science park as "a property based initiative which:

- has formal and operational links with a university or other higher educational or research institute;
- is designed to encourage the foundation and growth of knowledge based business and related organizations;
- has a management function which is actively engaged in the transfer of technology and business skills to the residents on site." (Van-Geenhuizen 1993, p. 17)

Despite that definition - a site designed to house technology businesses - science parks can still vary in size, concept, and level of support offered. Often, they incorporate aspects from intermediary organizations (ibid., pp. 15-17)(see chapter 5.5.1.3 below).

Science parks allow companies to establish collaborative links with a recognized center of excellence - in most cases this will be a department of the university standing behind the park's creation. They can take advantage of an agglomeration of researchers and scientists (Onida/Malerba 1989, p. 505).

It is important to reiterate that these parks are not innovation generators. They make the setup and initial growth of small innovative firms easier, usually by providing cheap office and laboratory space, assist with managerial functions such as marketing, and administrative ones, through providing office resources shared by several occupants of a park. They provide a seedbed for ***existing*** research to be commercialized efficiently; without existing research, they are ineffectual. Therefore, if a science park is located outside urban areas and away from innovation generators in an effort to "develop" remote regions, it will fail (Malecki 1997, pp. 184, 270).

Science parks are therefore a "service function that can strengthen a trend towards high-tech business development, but they cannot create the trend. If Science Parks are to be of significant value in business and job creation, the economic and cultural seedbeds need careful preparation to receive the entrepreneurial seed." (Cox 1985, p. 88)

Empirical evidence supports this prediction. Malecki notes that "[t]here are well over 100 science parks across the USA, but occupancy in existing American parks tends to be significant only in places where high-tech has been successful for other reasons." (Malecki 1997, p. 270).

While the simple absence of technological potential in the region is certain to prevent a science park from developing well, mistakes in approach can lead to failure even in the face of high-tech-supportive environment. The most commonly cited mistake is "losing focus on high-technology". Often, parks fail to consequently select only advanced technological companies as occupants. Especially when the occupancy rate is not growing as quickly as hoped and the viability of the park as a real estate project is put into doubt, the temptation is high to invite other, "lower-tech" companies in. Such "dilution" can destroy the character of the park as a technology seed-bed benefiting from interaction between people engaged in high-tech activities; synergies between high-tech and low-tech production are not so easily found. Hence the attractiveness of the park to prospective high-tech occupants is reduced, and its image tarnished. In the US, only 25% of parks keep their focus on high-tech over time (Van-Geenhuizen 1993, p. 29). Suitable focus and appropriate management is consequently essential is a park is to be successful.

5.5.1.2.2. Examples for effects of science parks

Despite their limitations, science parks have been the most commonly found tool for regional development in the last two decades. Their public image is powerful, they are popular with politicians.

Most projects are very recent, few date back to before the 1980s. The premier benchmark parks, however, are much older. Stanford Research Park was founded in 1951 through Prof. Terman to assist the commercialization efforts of Stanford University. Research Triangle Park was founded in 1959, the British parks Heriot-Watt Edinburgh and Cambridge Science Park in 1971 and 1972, respectively.

Today, the **Cambridge** area counts 1,200 technology companies, has created about 35,000 jobs and pushed regional unemployment levels down to 3.5% (Britain’s average was 5.7%

in 1997). Cambridge homegrown companies' combined annual revenues are US$2.5 billion alone; adding the multinationals who have invested there, such as Microsoft with its recent US$80 million research lab, the figure doubles to more than US$5 billion. The combination of Cambridge university as the innovation creator and Cambridge Science Park as reinforcement has proven to be very fruitful (Flynn 1997, p. 87).

Stanford Research Park essentially formed the nucleus of Silicon Valley, with companies like Hewlett Packard growing on its premises, who employed already 200 people and had sales of over US$2 million when it moved in the park's 3rd year of operation. Another early resident was Shockley Transistor Corporation, one of the earliest semiconductor manufacturers, from which later famous Fairchild Semiconductor Corporation was spun off. Fairchild itself spawned approximately 70 more firms, Intel Corp. being the most famous (Saxenian 1985, p. 25).

Today, the park has about 150 companies, amongst them such heavyweights as Syntex - an international pharmaceutics company with 10,300 employees and sales of US$2 billion in 1993; it also houses spin-offs of the heavyweights, such as Syntex's spin-off ALZA (1,400 employees, US$ 278.8 million in 1995).[42]

None of the parks created in the 1980s has been able to show anything like these results. This serves to show once more the long time scale required for success and early mover's advantage outlined above. Nevertheless, the successful examples show that science parks, when used as a complement to innovation creators such as research institutes, can be a powerful support to local high-technology cluster growth.

5.5.1.3. Intermediary organizations

Intermediary organizations are another example for Carr's category (2) tools. They increase the efficiency of knowledge transfer from innovation creators to industrial users, including ***existing*** industry in the region. They are a tool aimed both at new industry and at ***upgrading*** the technological level of that industry. (for a more detailed debate on upgrading, see chapter 5.6).

Technology transfer from research institutes (and also research universities) contains a problem. Too often, SMEs who could benefit from the research done at those institutions hardly know that they exist at all, are uncertain about what they have to offer, and have no idea how to access them. Contacting and transferring technology to SMEs is a very labor

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[42] Source: http://www.stanford.edu (Stanford University)

and time intensive task for a research institute. The use of intermediaries such as transfer agencies and technology assistance networks can ease that burden (Carr 1992, p. 5).

Transfer agencies are often associated to one specific university or research institute. They take over the laborious task of transferring their institute's know-how to industrial users, using a combination of written, oral, and hardware knowledge. Besides taking a part of the transfer workload off the research personnel, their specialization on transfer allows them to be more efficient. Their role can also be extended beyond pure technology transfer; they can assist with the creation of business plans to commercialize knowledge transferred by them, or assist with patenting and licensing, and assessing an innovation's commercial potential (Van-Geenhuizen 1993, pp. 5-7). In their widest role, they can also be creator of spin-offs. If there is no suitable existing company to take up and commercialize the technology, the creation of a start-up company may be the best and fastest way to use the technology purposefully. They can locate venture capital for the firm, and help it settle in science park facilities that may be nearby (Carr 1992, p. 9).

IMEC's Research Valorization Group (RVG) is an example of such a transfer organization in the widest sense.

Referral organizations, technology search networks etc. are usually more independent and not directly associated to any one knowledge generator. They may provide databases with technologies available and research projects under way in several institutes in the region, which can be searched by users on a self-service or assisted basis. After finding a suitable technology, the respective knowledge producers will be contacted by the SMEs. An example is the "Federal Research in Progress" database, which contains information on over 150,000 research projects under way (Carr/Hill 1995, p. 15).

Such organizations may also manage networks, increasingly using the Internet, that let SMEs looking for technical information pose their questions to the network. Then, automatically or with human assistance, these questions are referred to research institutes, universities and other members of the network (including other SME), who will get in touch with the SMEs and offer solutions if their area of expertise is matching (ibid.).

Examples include the US "Federal Laboratory Consortium", where 81% of users are SME, and the European Network of Innovation Relay Centers under the leadership of the EC's INNOVATION program.

Flanders, home region of IMEC, also operates such a referral network. The "IWT SME-network" was started March 1997 and has seen strongly increasing usership since then (see also chapter 7.5.4). IMEC is one the providers of knowledge in the network to which questions are referred.

5.5.2. Universities and their influence on cluster growth

It has been stressed over and over again that universities and other institutions of higher education are essential to the formation of advanced clusters. New industry, it is asserted, will be a spin-off from fundamental university research, and that high-technology industry will develop around old established and prestigious universities (Hall/Markusen 1985, p. 147). Jaffe (1989) has shown how university research spills over into the local economy via informal contacts with locals. He proved that these local contacts work more efficient for knowledge transfer than publications in scientific journals, which is why the largest economic impact of a research university is local. Additionally, his study found evidence that university R&D attracts industrial R&D to the area (Jaffe 1989, pp. 957, 959).

Still, the nature of these spillovers and the mechanisms found require a qualification of the benefits provided by universities. While they are powerful generators of certain kinds of spillovers, they tend to underperform in regard to others.

5.5.2.1. Extending help to existing firms: the larger the firm, the larger the chance of cooperation

> "Universities provide local firms with a definite cost advantage in the supply of several critical inputs. Research carried on within the university is a major source of new products and processes and may help solve technological problems for new small firms that do not as yet have their own technical research facilities." (Vaughan/Pollard 1986, p. 271)

While Vaughan/Pollard's opinion certainly sounds logical to common sense, it may actually be false. The degree to which universities research spills over to SMEs has been doubted; empirical data suggest otherwise. Myers and Hobbs, in a study covering nearly 300 high-tech firms situated closely to universities, find only indirect effects reported by small firms. In fact, contacts between them and the university were scarce. It was mostly large firms that benefited strongly from direct cooperation, casting doubt on the role of universities as support model for small companies (Myers/Hobbs 1985).

In another study, Oakey found that "...the small Bay Area firms of the study maintained the lowest regional level of contacts with local universities. [These firms] frequently stressed that their technical capacity was totally 'in house' and that they believed universities would not be able to offer technical help for innovation in their highly specialized production niche." (Oakey 1985, pp. 106-107). The study suggests that their innovative capacity springs rather from their flexible internal working environment, they don't have the resources to undertake or incorporate more basic research that is not directly connected to their core product, as done at the university. If they use external information sources, it was mainly to obtain product and process specific technical information, not so much to advance their products through external research results (Oakey 1984, p. 105). Larger Silicon Valley companies with a broader focus and more manpower and financial resources, however, do maintain more formal, and large-scale, contacts with universities such as Stanford and Berkeley University. In this case a sharing and external acquisition of more fundamental research is clearly visible (ibid.).

So while university research does spill over to local economy, it does not primarily benefit SMEs. This puts to question the university's benefits to a local high-tech cluster which is growing "bottom-up". It is likely that concerted efforts must be undertaken by the universities to specifically target SMEs. This can be done using transfer agencies as described in chapter 5.5.1.1.1. The often assumed automatism of transfer to SMEs is a myth.

5.5.2.2. Core competencies: research and training as the most important factors

Malecki (1997) filters three ***principal*** supporting effects of a top-university on the agglomeration of high-tech in its region. No. 1 is the already mentioned research and its spillovers, which is complemented by:

- *Image building.* The development of a university center of excellence in a certain field can create a favorable "high-tech" image for the region.
- *Training & Education.* The pool of highly qualified labor created by the university and the for resulting capability of regional recruiting is an important incentive and advantage for high-tech formation. (Malecki 1997, p. 268).

Regarding *image building*, it must be noted that, besides urban amenities and climate, the pure public perception that a region is "high-tech" can be the deciding factor attracting key personnel. A high-tech image contributes therefore to the "pleasant environment" factor necessary for high-tech cluster formation mentioned above. Universities help building that image, in collaboration with "regional marketing" efforts (ibid.).

The *training effect*, the development of human resources, may well be the most important function of universities in regional development.

At large, human resource development contains a triple challenge:

1) continuously improving the skills of the currently employed workers to allow them to keep up with the competitive upgrading path of their industry,
2) retraining displaced workers, and

3) training the workforce of the future.

(Gross/Weinstein 1986, pp. 263-264)

The continuous updating of skills is largely a task to be assumed by industry. Its importance is being increasingly recognized, as the rise of continuing education and the view of learning as a life-long process take hold. An example for extensive in-house training taking place is the semiconductor / electronics industry in the Bay Area of the US. (Oakey 1984, p. 118)

Public re-training programs, as for instance heavily used in Eastern Germany since 1990[43], have been provided by other public bodies than the university. They have also proved to be expensive and not very successful in genuinely re-integrating displaced workers.

It is the training of the workforce of the future were universities can exercise their greatest leverage. The quickening pace of technological innovation increasingly requires workers who, besides the advanced (technical) skills honed at emerging industries, posses the *ability to learn* - a skill that will allow them to *adapt* to the three or more different careers they may be involved in during a lifetime. While the elementary and secondary education play an important role in that education, it seem to be the role, responsibility, and chance of the universities to ensure a steady stream of graduates who possess such generic and universally applicable skills. (Gross/Weinstein 1986, p. 264)

5.5.2.3. The university as source of spin-offs and start-ups: a limited role

The indirect effects of universities on the growth of clusters have been shown to work for a good number of universities. The *direct creation* of local industry through the university is an effect found less often. It tends to happen only around the very best institutions. The extremely successful examples of Stanford University and MIT in the USA as spin-off creators serve as a role model for other regions. However, to generalize from these outstanding examples may not be viable; they probably have unrealistically inflated the expectations regarding this aspect of the university's influence (Stankiewicz 1985, p. 115). To assume that innovative firms will simply cluster around university "knowledge centers" in the absence of explicit creation efforts and favorable environmental factors is unrealistic (Nijkamp/Mouwen 1987, p. 31).

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[43] called "Arbeitsbeschaffungs-Massnahmen" - Work Provision Measures.

Evidence of this point is provided by such excellent universities as Harvard, Columbia, Chicago, Berkeley and California Institute of Technology, none of which has played a major business incubator role (Malecki 1997, p. 184).

5.5.3. Conclusion

Taking all information provided in this chapter of "bottom-up" approaches to high-tech cluster building, the author would like to single out the *university-industry research center* as the most powerful of all the tools covered. It can serve as an important knowledge generator in a region, and be the core of innovative activity. It will unfold its full potential when it is complemented by supporting tools, such as science parks and referral- and transfer networks.

IMEC, which is exactly such an institute, forms the core of the cluster building efforts described and examined in the case study. From the findings presented in this chapter, it can already be concluded that this choice was a good one.

5.6. Upgrading existing industrial clusters

The approach complementary to both the top-down and bottom-up methods, as mentioned before, is the attempt to upgrade and technologically refurbish industries already existing in the region (Oakey/Pearson 1995, pp. 5-6).

> "High-tech research and production should be recognized as one element in economic regeneration, but across the employment spectrum...[I]t should be seen as only one element...in the struggle to restructure the older industrial areas." (Jowitt 1991, p. 128)

This insight is vital to technology policy. "Sunset" industries are not likely to reclaim their historic importance, but they must not, by all means, be discarded and given up. Purist supporters of Schumpeter's creative destruction theory will object and point out that the very process of replacing aging, end-of-lifecycle technologies with new ones is the driving force of capitalism - something that cannot and should not be interfered with. The protection of an old, non-competitive industry through government intervention will only have a deferring effect and will burden more healthy, competitive industries through increased taxes raised to pay for that intervention. Both points are true.

It must be noted nevertheless that such "old" industries - *when they update their technological level* - can both significantly extend their lifecycle.

> "... the adaptation of advanced design, production, and related manufacturing technologies to older industrial arrangements..promises to revitalize from within the existing industrial base of the nation. Revitalized older industries - and perhaps too the regions in which they are located - can be expected to take their places alongside

> wholly new industries and regional economies in defining a new and advanced industrial era." (Hicks 1986, p. 221)

They may also spin off related high growth industries (Rees et al 1986, p. 190). For example, the "low-tech" food processing industry played a significant role in the birth of "high-tech" biotechnology industry. Old industries can so contribute significantly to the development of low growth regions

Research done at research centers as mentioned above can play a supporting role in that process, with explicit dissemination mechanisms in place to encourage diffusion of that research into industry. (Porter 1994, p. 634) These can be linkages provided by referral organizations, which connect industry with the innovative potential of the research centers. The (academic) transfer agencies mentioned above are an example of such a link - regional fairs for industry and newsletters can be others.

The process is "supportive", since most companies perform that modernization already independently, driven by competitive pressures, and without prodding through government promotion (Hicks 1986, p. 246).

The most important result of this study was that the adoption rate of new technology rose with decreasing distance to the region in which this technology originated. This does suggest a "distance decay" or contagious spread effect in adoption patterns; adoption rates are lower in regions furthest removed from the spawning grounds of these leading edge technologies. (ibid., p. 215)

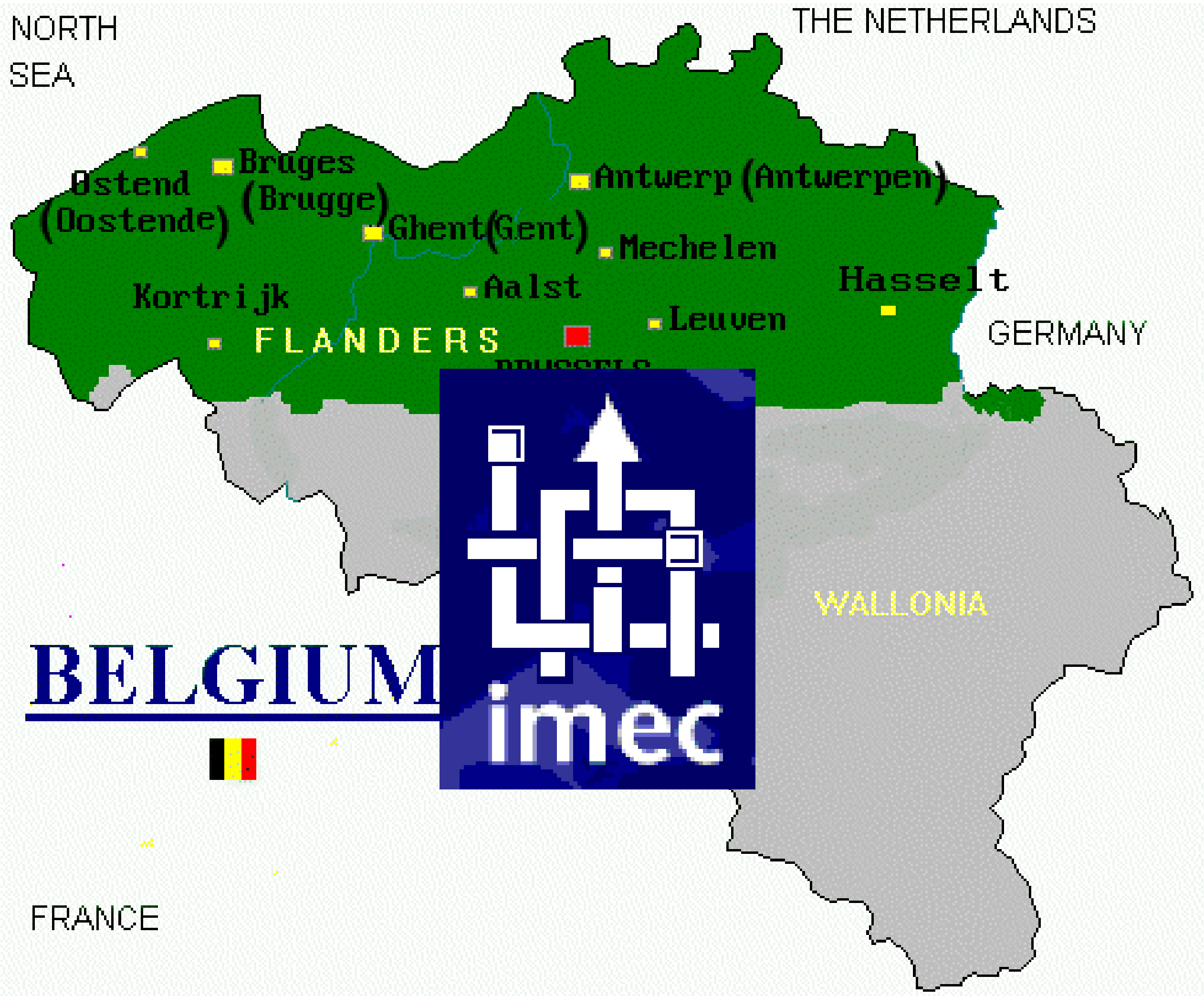
Therefore, the presence of an innovation creator developing technology in a region is beneficial to the adoption rate for that technology by local companies. This shows the support potential of research centers for industrial rejuvenation.

6. Conclusion to the theoretical section

Chapter two to four have been an attempt to answer the four questions raised in the introduction, and to provide an extensive theoretical framework on regional development through the use of innovation and high-technology.

In chapter two, it was shown that industrial clusters promote innovation through competitive pressure and positive externalities provided by agglomeration. The cluster was established as the most innovate and competitive, and hence desirable, form of industrial activity. In chapter three, the focus was put on the specific attributes of high-technology. It was clarified where its potential lies, and which expectations it will not be able to fulfill. In chapter four, methods of cluster creation were analyzed and their effect evaluated, using both examples from existing clusters and academic publications.

In the following part of this work, all these findings will help to analyze the case study subject: the IMEC institute.


NORTH
SEA
THE NETHERLANDS
Bruges
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Kortrijk
Aalst
Hasselt
Leuven
FLANDERS
GERMANY
WALLONIA
BELGIUM
imec
FRANCE

7. Case Study: IMEC - A Flemish approach to regional development via high-technology

In this second part of the paper, a real-life example of a comprehensive cluster building effort will be analyzed, using the framework provided in the chapters above. The author had the chance to spend more than nine month at IMEC, a university-industry research institute situated in Leuven, Flanders (Belgium). During this stay, he had the chance to interview many of the senior managers of the institute (a list of the key interviews is given in Annex 8.3). He also gained a lot of insight from numerous other interviews with people in and outside IMEC. To list these here would claim too much space.

The largest part of the information on IMEC's policies and internal matters is based on these interviews, complemented by IMEC internal information material. All IMEC related data material is derived from the two main, official IMEC publications: The Annual Report 1997 (IMEC 1998) and the Scientific Report 1997 (IMEC 1998b), unless indicated otherwise in the text.

7.1. History of IMEC - from the "third industrial revolution" to the present

In the early 1980's, the Flemish government decided that high-technology industries were not represented enough in the industrial landscape of Flanders. At that time, it was universally assumed that the presence of these industries would be the most important factor to ensure the industrial survival of a region; high-technology was the "holy-grail" of regional development. Consequently, just as many other governments had done or were doing then, the Flemish government in 1982 devised a major high-tech development plan, named "The Third Industrial Revolution".[44]

The aim was to transform Flanders from a region that was strong in mostly "sunset" industries - such as textiles, steel, and plastics - into a leader in three target industries: microelectronics, biotechnology, and new materials.

Biotechnology and new materials already had a base on which they could build. Flemish universities had established themselves internationally as centers of excellence of biotech-

[44] The Flemish government was acknowledging with this "branding strategy" a finding of economists: creating a "regional technology identity" is beneficial to high-tech agglomeration (Pleschak/Sabisch 1996, p. 314).

nology research, and a number of start-up companies had started to form a nucleus of successful biotech industry as early as the late 70s. They also had a strong sector of related industry to build on: the Flemish food processing industry. For instance, breweries like Interbrew, the second largest in the world, were using innovative processes[45] in their production already, and were open to biotechnology.

New materials could build on the metallurgical and plastics industries already present in Flanders.

Microelectronics, however, was a different case. There was no obvious center of excellence for that industry in Flanders. The only place where a core of research competence existed was ESAT, the electrical engineering department of the Catholic University of Leuven (see chapter 7.4.3.1), complemented by some smaller similar departments in Free University of Brussels and University of Gent.

When the funds destined to realize the "third industrial revolution" were allocated, all the various Flemish actors already working on biotechnology and new materials demanded their share. Rivaling universities feared a loss of research income, and influence, if a new player would be established. Consequently, the funds were spread out widely amongst the actors.

For microelectronics, however, there was only obvious focal point: ESAT. Also, the large investment necessary for IC research (clean room facilities, equipment and computers) made it impossible to establish several centers. Therefore, all funds were concentrated at ESAT. Since ESAT recognized that it would not be able to dedicate its activities sufficiently to applied research and cluster building, IMEC was founded as an independent microelectronics institute in 1984. About 50% of ESAT's personnel (including its best researchers) and all usable equipment was transferred to the new institute. In order to use the potential of the other universities, their research activities in the field were closely linked with IMEC's, and incorporated in a cooperation network, of which IMEC was the center (Deschamps 1997, pp. 9-93).

IMEC's foundation was flanked by the creation of INVOMEC, an industrial training program later merged with IMEC, and the set-up of MIETEC, a local IC manufacturing joint venture between then Bell Telephone/ITT and the local government investment company, GIMV. INVOMEC's target was to focus on training IC design professionals to increase availability of qualified labor (see chapter 7.5.2.6), while MIETEC was acting as an indus-

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[45] Belgian beers are brewed using a multitude of additives and treatments to achieve variety in taste.

trial player trying to fill the existing vacuum in the field of IC manufacturing in Flanders (see chapter 7.4.2.3) (De-Man 1997, p. 38).

Since then, IMEC has grown to become the largest institute of its kind in Europe. IMEC currently has a staff of more than 750. Its annual budget is US$74 million (about 60% of that amount comes out of contract research income, the remainder is subsidies from the Flemish government). These numbers make it stand out amongst the crowd.[46] In comparison, the US' most significant semiconductor R&D institute/consortium, SEMATECH, has an annual budget of US$92 million and employs a staff of ca. 450.[47]

IMEC has strong links with international industry, and its scientific credentials are impressive. Research carried out there helps define the cutting edge of semiconductor production.

The general success of the concept of one university-industry research center has led the Flemish government to rethink its strategy on biotechnology and new materials. The scattering of resources in these sectors prevented the establishment of a coherent development force; none of the beneficiaries alone developed critical mass comparable to IMEC. Yet resistance from the actors has so far prevented a replication of the research institute strategy there. In 1992, a new materials research institute (IMO) was founded, followed in 1995 by a biotechnology institute (VIB). Yet both institutes are "virtual", research is still carried out at the university departments (Scientific American 1997, pp. 10-11, 12-13).

7.2. R&D and the semiconductor industry

As a major part of IMEC's activities are targeted at segments of the semiconductor industry, it is helpful to mark out some relevant attributes of that industry that are relevant to IMEC's case.

The semiconductor industry displays a number of attributes that are typical to many technology industries at the beginning of the 21st century. These are: drastically rising cost of innovation, overlapping technological areas and increasing interdisciplinarity, a closer link between basic and applied research, and a close link of research with the market demands (see Pleschak/Sabisch 1996, p. 40).

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[46] There are hundreds of independent research institutes in the USA, but less then one hundred can be considered "large" (staff of over 10and annual R&D budget of US$1million or more) (Carr/Hill 1995, pp. 2, 9).

[47] Before 1997, when SEMATECH was still receiving funds in a "matching funds model" similar to IMEC's, it had a budget of close to US$200 million, about half of which came from the US government, and employed more than 800 people. In 1997 it became independent from government funds, and halved both its staff and budget (Carr/Hill 1995, p. 13).

In addition, the semiconductor industry is truly global in nature. The extremely fast pace of innovation, as well as the astronomical costs required to manufacture leading edge products, require a concerted effort of all players in the industry worldwide. Just recently, the SIA (Semiconductor Industry Association) "roadmap", which defines the development targets of the whole industry, was advanced by several months, tightening deadlines for achieving certain technological breakthroughs further. [48]

This forces companies to work ever closer together with institutions of more applied and basic research. The traditional temporal separation between basic research, applied research, and development blur, resulting in a high degree of concurrency between them all (see figure 4).

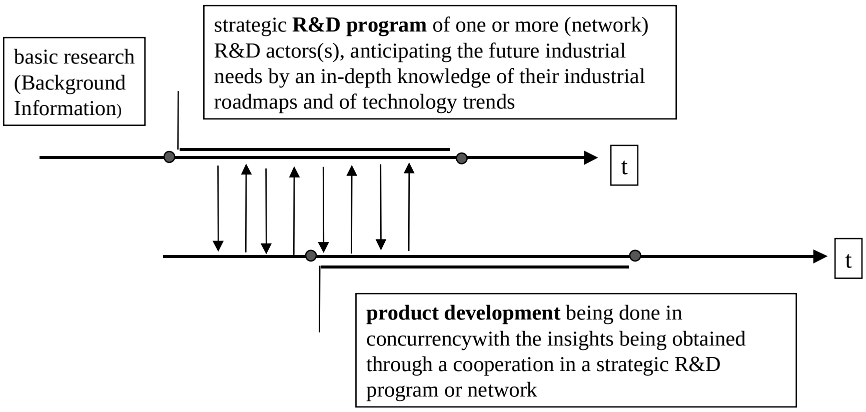

Figure 4: Model of concurrency between R&D and product development (Source: IMEC)

The frantic pace of development means that product lifecycles, and thus windows of commercial opportunity, are extremely short. Instant access to research results and the ensuing shortening of time-to-market is therefore fundamental (see figure 5).

[48] See http://www.sematec.org/public/roadmap/index.htm for details of the SIA roadmap

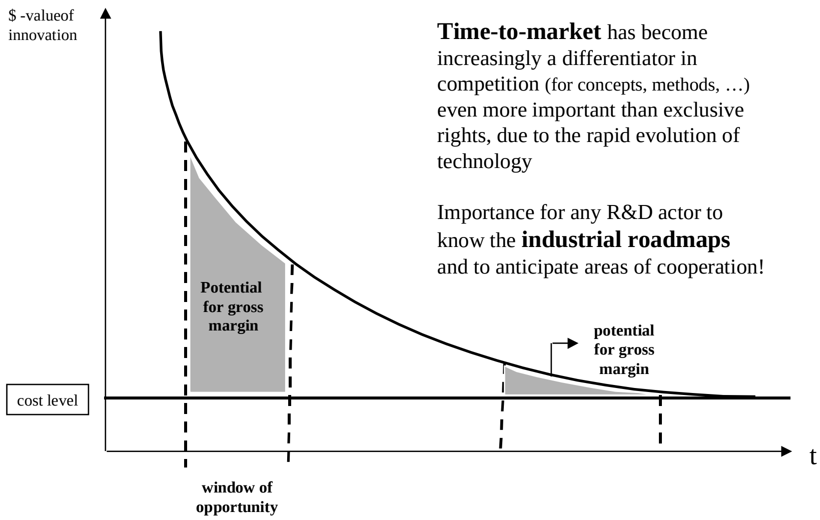

Figure 5: The importance of early market entry: decreasing profit margin potential over time (Source: IMEC)

This factor is even more important than exclusive intellectual property rights. It doesn’t come as a surprise then that alliances across the whole industry are commonplace; the research burden is shared amongst (even competing) companies, and the breakthroughs achieved through that shared research are then incorporated by the whole industry (Van-Helleputte 1997, p. 119).

Alliances and information networks are often grouped around specific technologies, almost all of them have members spread all around the globe. Antonelli notes that "information networks are more and more a substitute for industrial districts: membership to an information network supplies in fact externalities similar to those a firm can obtain from the location in well defined areas." (Antonelli 1992, p. 28) This applies very strongly to the semiconductor industry.

For a regional developer, who wants to attract or build semiconductor industry, this is of significance. A starting cluster, without the support of the strength and connections of established industry players, would waste resources trying to adopt a head-on competition strategy in a technology which more powerful networks have committed themselves to.

The early identification of the right niche to gain a foothold in the industry is of importance for any newcomer. Since the lifetime of a technology generation in semiconductors is extremely short, the windows of opportunity for niche, or alternative, technologies to become adopted into the mainstream are numerous. A smaller initial investment with the right foresight can, pushed by the industry dynamics, be levied into a multi-million industry in a relatively short time (Hilpert 1991b, pp. 293-294).

The Lernout & Hauspie (L&H) inspired "Flanders Language Valley", which is currently under construction in Ieper, West Flanders, is an example for such a niche strategy. L&H is a Belgian company who is world leader in speech recognition software. The Language Valley is a prospective cluster of companies who specialize in that niche and gather around the leader company. Already before completion, 11 companies have secured space, and 250 jobs will be created once the Valley is completed. Microsoft Corporation has taken a financial and cooperative interest in the project, and in L&H. The region promises to become the most innovative hotbed for speech technology worldwide. Since the industry was still in its infant stages when the Valley was conceived, the initial investment required was comparably low, while any region seeking to copy the Language Valley concept now would face higher cost, and lower chances for success.

In the case of IMEC, the early-mover rule has also been proven right. IMEC has attempted a head-on strategy, in IC manufacturing, and an early niche strategy, in Digital Signal Processing (DSP) technology. The attempts to develop IC manufacturing have been much less successful then the ones targeting DSP industry.

In the last years, a new trend has gained increasing momentum in the semiconductor industry: IC customization. ICs have permeated many "older" industries, e.g. the automobile industry; about 25% of the value of a high-end BMW is in specialized microelectronic systems. [49]

Standard "off-the-shelve" computer processors are not suitable to these tasks. A better solution are ASICs, designed specifically for a certain application.

A traditional standard IC fab, as operated by companies like Intel or AMD, concentrates on high volume production of *one* chip designed internally, for instance an Intel Pentium® processor. Because ASICs are tailored to certain customers instead to the mass market, they are produced in lower volume. Therefore it would not be justifiable for a company that designs an ASIC to operate a whole fab. Instead, the manufacturing is contracted out to another firm that specializes in manufacturing ICs designed by others: a foundry. The foundry will then utilize its capacity by accepting manufacturing contracts for many small ASIC batches from different design companies. A *separation* is taking place between low volume, high value added design and high volume, low value added manufacturing.

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[49] Source: http://www.bmw.de

This change from the vertically integrated, monolithic giants to more specialized modular providers matters to regional developers. The rise of the "fabless" design companies has created a sub-section of the industry that can create value with little initial capital investment. Some office space, a number of workstations and qualified people are all that is required, compared to the multi-billion investments necessary to build a fab. It has therefore become easier for a region to enter the semiconductor industry via the establishment of a design industry. Evidence of that effect can be found in IMEC's case, which has found it much easier to establish a design industry.

The direction that the industry will take in the future is unclear. On the one hand, there are the proponents of ever-denser integration. They predict that more and more functions that traditionally resided outside of an IC will be integrated on the chip ("System-on-a-chip"). Therefore, dimensions are going to shrink ever further, and the complexity of the designs on silicon will increase. One result of that trend, if it should materialize, is that *IC manufacturing will regain importance* and move away from the commodity status it has been drifting towards with the rise of the recent fabless design / foundry industry model. *The supporters of that scenario believe that only a return to vertical integration of both design and manufacturing will solve the resulting complexity challenges.* This is the official view of the SIA. IMEC is supporting this view, which is reflected in its strategy.

On the other hand, there are experts who predict that ever-denser integration, while technically possible, will become uneconomical soon. The price of a leading-edge fab has reached US$2 billion today. Equipment cost is rising exponentially with each new product generation. Eventually, the price of an ultra-high-scale integrated chip could exceed what consumers are willing to pay for it. The result would be a forced shift way from "systems-on-a-chip", towards innovative clustering of less dense ICs, which would work in parallel to deliver the performance gains expected by the market.

Such a development would benefit the fabless design / foundry model, since it will use more, but standardized chips, which would benefit from foundry cost-effective production. Vertical integration of design and manufacturing would continue to loose importance. This view is gaining popularity in the industry (Dutton 1997, pp. 144-146; Chatterjee/Doering 1997, pp. 173-176).

As will become clear later, these industry developments have a profound impact on IMEC's chosen regional development strategy, and may well be the most important success factor in the long term.

But before moving on to examine the results of IMEC's industry building efforts, it is necessary to look a little closer at the Flemish region. Has IMEC been building on fertile high-tech ground, or has it been facing an uphill battle against unfavorable environmental conditions?

7.3. Are the requirements for high-tech agglomeration met in Flanders?

In order to judge whether Flanders has the potential to develop high-tech industry, it is helpful to see whether it meets the necessary pre-conditions according to Jowitt as established in chapter 4.

7.3.1. High quality institutions of higher education

There are seven universities in Belgium, the most important ones in Flanders. Their quality is generally regarded as being high, especially in technical fields. The Third Math and Science Study of the International Association for the Evaluation of Educational Achievement rated Flanders' mathematics students No. 5, and its science students No. 11, of 41 countries surveyed. Belgium's R&D facilities, many of them situated within universities, have been one of the most frequently cited reasons for foreign companies investing in Belgium (DOS 1997, p. 2). Catholic University of Leuven (KUL), the country's oldest and most prestigious one, is situated in immediate neighborhood to IMEC. It has a close relationship with IMEC, which is not surprising considering that IMEC was created with the help, and most of the assets, of KUL's electrical engineering department ESAT. IMEC closely cooperates with the other Flemish Universities, it has especially strong ties with Gent University and the Free University of Brussels, where a lot of cooperation takes place in communications technology.

Looking at this educational landscape, it can be concluded that this precondition is met sufficiently.

7.3.2. Advanced manufacturing and research facilities

Besides IMEC, there are numerous research institutes present in Flanders. Amongst the most prominent ones are the VIB biotechnology institute and the IMO materials research institute already mentioned in chapter 7.1. In total, there are 31 such institutes of different size, many of which are associated with one of the three major Flemish universities. This research landscape is very diverse and strong, and has been cited as a competitive advantage of the Flemish region (DOS 1997, p. 2).

While the majority of Belgian economic activity is in services, it has a strong history of manufacturing. The standard example is automobile manufacturing; Belgium has the highest concentration of car factories in Europe. The Flemish manufacturing industry in general has specialized in importing semi-finished product, providing the advanced manufacturing functions, and exporting the finished products (DOS 1997, p. 1).

It can be consequently concluded that this factor is met by the Flemish region.

7.3.3. Military research and development

Belgium, with its population of 10 million, spends about US$3.5 billion annually, or US$350 per capita. This amount is small, both compared to European neighbors and the US, home of the benchmark clusters. Germany spends US$40 billion (US$500 per capita), the US spends US$225 billion (US$850 per capita) in comparison.[50]

Since military spending tends to focus on a few centers of excellence as seen above, the large difference in absolute spending may even be more significant then the smaller difference in per-capita spending. With little national procurement muscle, it doesn't surprise that only a few scatters of military industry are present in Belgium. The one notable company, rifle producer FN, has not been conducting leading-edge research for decades.

High-tech military industry like aerospace and surveillance is absent, and most of the corresponding equipment is imported from NATO partners. Consequently, few impulses from military R&D can be expected.[51]

7.3.4. Venture capital

Sectoral Analysis:

According to the most recent data provided by the Belgian Venturing Association, Belgian venture capital firms, at the end of 1996, were holding about US$1 billion in equity in total. The amount was spread amongst 96 companies, with 62 of these being initial investments taken in 1996.

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[50] Source: http://www.sipri.se (SIPRI Institute Military Expenditure Database)

[51] There is some activity in Flanders in **non-military** space industry; some small Flemish companies are active in some niches of that industry. Also, IMEC has been performing some contract research for the European Space Agency (ESA). This activity is, however, not comparable with the multi-billion dollar programs which are referred to in the context of the rise of the benchmark cluster.

Emphasis was on the following sectors:

Sector	No. of Investments	% of total	Value of Investments in US$ million	% of total
Communications	**17**	**10.8**	**47.2**	**39.6**
Computer related	**21**	**13.3**	**10.2**	**8.6**
Biotechnology	17	10.8	15.6	13.6
Energy	18	11.4	6.6	5.8

Table 2: Dominant areas of venture capital investment in Belgium (Source: Belgian Venture Capital Association)

Communications makes up almost 40% of the total value invested. In the sector-analysis of the communications industry in Flanders (see chapter 7.4.3), the reasons for this dominance will be shown. Second in importance is Biotechnology, followed by Computer related projects. The low 8.6% share of computer projects (which include IC manufacturing), points to a relative weakness in this sectors. Reasons for this will be given in chapter 7.4.2. New Materials, the foundering third target industry, is represented only in a grouped category, "Chemicals and materials", with 8 projects (5.1%) and US$1.7 million (1.4% of total value invested).

Quantitative Analysis:

In the beginning of 1997 there were about BEF 7.8 billion (about US$217 million) in venture capital available for new investment. This is not nearly as much as in the benchmark clusters, with California providing US$1.8 billion in 1996, and US$2.8 billion in 1997, and Massachusetts US$831.5 million. Nevertheless, a suggestion that, today, there is not enough venture capital in Belgium would be wrong. In fact, there is "too much money chasing too few deals". Of the US$172 million available in the beginning of 1996, only about US$120 million were invested in venture capital projects at all. Just 55.7% of these investments were made in Belgium; 34.4% were made in the rest of Europe, and 8.9% outside of Europe. It is hence fairly certain that there is, quantitatively, *enough venture capital available in Belgium/Flanders today*.

It remains to be noted that the bulk of the capital under management has been provided by a player who does not strictly qualify as a venture capital firm: The Flanders Investment Company, GIMV. It is a semi-private government initiative set up in the course of the "third industrial revolution", and has been providing capital to start-up companies in a similar matter as the other government programs assisting SMEs in the US have (see chapter 4.4). Its fund are significant (ECU395 million), and it has played an important role in financing start-ups such as Lernout & Hauspie and Innogenetics. Yet it is no typical venture capitalist, its network is not equivalent, and it has not specialized on any technological area.

As another qualifying note it must be said that the capital abundance is rather recent. Before the "third industrial revolution" and GIMV, there was much less "real" venture capital available in Belgium. It has only been recently that true venture capital funds have emerged in significant numbers. Belgium was not different in that respect from other European countries, and it has been participating in and benefiting from the recent resurgence of European venture capital in general (see chapter 4.4).

Qualitative analysis:

1. In Belgium, too, venture capital is a regional phenomenon:

Initially, this statement may surprise, if one considers the fact that a full 37.3% of investments made were transnationally syndicated, i.e. money was raised by Belgian venture capital firms in co-operation with foreign ones. This would suggest that Belgian entrepreneurs could dip into a European or even global pool of venture capital.

But in most of the cases it was a local Belgian venture capital firm who took the lead, and gathered additional capital from its international network. Examples are the cases of Innogenetics N.V., a biotechnology company, and Lernout & Hauspie, the above mentioned speech technology firm. In the case of the former, the venture capital arm of the local GIMV (Flanders Investment Company), assembled a consortium of two British, one French, one Japanese, and one other Belgian investors; in the case of the latter, the same Belgian actor brought AT&T in to provide supplemental funding. In both cases, the lead of the *local* venture capital firm was essential.[52]

2. Early Stage Funding is not widespread. Of the funds provided, seed capital and start-up capital represent a small share.

Of the total of investment projects, only 7 (4.4%) were seed capital, with an amount invested of only US$1.5 million, or 1.3% of total investment. Start-up projects were more common, numbering 44 (27.8%), though only about US$20 million, or 17.4% of total investment. The lion's share both in number of projects (50%) and value (72.6%) was taken by money provided to companies for expansion plans.

This points to a reluctance of venture capital firms to make the crucial, high-risk initial investments without which high-technology companies will not get off the ground. In this

[52] Source: http://www.evca.com (European Venture Capital Association)

early period, management advice by the venture capitalist is of the highest value to the entrepreneur, as shown above. Even if start-up financing could be obtained from other sources, the assistance of the venture capitalist's network is difficult to replicate by them.

3. Exit via stock market IPO is still an exception, rather than the rule

A total of 90 companies exited the portfolios of the venture capital in 1996, 30 of which were written off. Of the remaining 60 that were sold (for US$65 million), only a fraction, 8 firms, were launched via IPO at a stock market (raising US$4.75 million). A much larger part, 26, were divested via trade sales, i.e., the venture was sold to a larger company in a deal brokered by the venture capitalist. Revenues from this part amounted to US$49 million. Another 26 were divested "by other means", adding income of US$11.25 million.

This shows that in Belgium, IPOs are not the "normal" way of exit, as in the benchmark clusters. Until recently, the Belgian stockmarket provided only very limited opportunity for IPO-type exits; regulation was changed less than three years ago. There have been highly publicized IPOs which have been circumventing this obstacle by using other stockmarkets, like Innogenetics, who went public in 1996 via the new EASDAQ stockmarket, or Lernout & Hauspie, who did so 1995 via NASDAQ in the USA. Although the trend will almost certainly move towards IPOs (see chapter 4.4), they have so far remained the exception, not the rule.

This is a disadvantage. The entrepreneurial spirit of the benchmark clusters is derived to no small degree from the legends of entrepreneurs acquiring fabulous wealth when they took their company public. These role models have been inspiring to the whole area, and have created the "high risk - high gain" attitude that proves to be one of their most beneficial attributes. Any region trying to replicate that success is well advised to promote that spirit. IPOs are an important part of the formula.

It does not surprise that leaders of Flemish technology companies complain that high-tech is not alluring to large parts of the Flemish population. Being a typical "old Europe" country, Belgian and Flemish values have been centered around philosophy, arts, and generally "tradition".

Recent initiatives and successes like L&H are slowly changing this attitude. Some observers attribute the recent rise in venture capital availability to an increased positive perception of high technology and its opportunities. Still, much needs to be done to achieve a dynamic and driving mind-set as the one found in Silicon Valley.

4. Lack of critical mass in any one sector?

As laid out above, one of the most beneficial aspects found with venture capital firms in Silicon Valley is specialization. Venture capitalists often focus their attention to a particular sector, acquiring extensive expertise in the field. They are then able to nurture "their" sector by serving as an information focus point, acting as technology promoter in early development stages, and counseling their companies directly using their special technical expertise.

Until recently, such specialization was not common in Belgium. A number of firms can mobilize significant amounts of money, and the initial amount is usually leveraged trough syndication with other foreign venture capital firms. Most Belgian venture capitalists, however, claim to have *no industry preference*; they will invest in any sector.[53] This may be due to the fact that, in Belgium, there are not enough deals around in only *one* sector to justify such specialization. Apparently even a focus on one sector and international investment in that sector only is not deemed feasible.[54]

Without venture capital firms employing their special focus to one field, the nurture effect can, of course, not occur, and the sector will not grow as fast is it would with nourishment. It is unclear which of the two phenomena is cause and which effect; but it is also irrelevant. In combination they form a vicious circle.

Recently, the authorities have begun to address this problem. There have been two funds created which focus exclusively on one field of expertise. The Flanders Language Valley fund, founded in connection with the speech technology cluster mentioned before, is one of them. Its focus is multimedia / electronics, communications, and other technologies vital and complementary to speech technology. With a maximum investment volume of ECU 3 million per project it also has the size necessary to be a significant player in its sector. Located on site of the Flanders Language Valley, it promises to become a powerful growth promoter.

The second example is the IT Partners fund, which will be covered in detail in chapter 7.5.2.7.

Venture capital available locally at IMEC:

Since "face-to-face" contact is essential for the positive effects of venture capital, it is only logical to look for venture capital at the most local level applicable to the IMEC case, which is the city of Leuven and its surroundings, and IMEC itself.

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[53] Source: Belgian venture capital firm profiles from EVCA

[54] It must also be questionable whether deals made in transnational syndication abroad could function as a substitute for deals made locally in regard to building expertise. As such information flow is a "contact sport", local deals may be the only suitable option.

Since 1996, there has been a fund located in the city: Capricorn Venture Partners. It has, however, been lacking both size and focus. It is only a small operation with a staff of two. The maximum amount available per project is only ECU 1 million, its total funds amount to no more than ECU 7.5 million. It professes to have no industry preferences and invests broadly in IT, biotechnology, and other fields. It has consequently no special industry expertise. As a result, Capricorn has not been able to provide many of the beneficial effects of venture capital laid out before.

The situation has been illustrated in the past in many cases where start-up money was required to launch IMEC spin-off companies. Often, IMEC itself was forced to provide most of the capital, which has limited the sums available to the new ventures and hindered their initial growth.

IMEC went to the US venture capital firms for both their specialized networks and deep pockets. An example is the case of CoWare, an IMEC spin-off established in 1996 that specializes in DSP CAD design software. IMEC sought help from the Boston based venture capital firm Greylock, which specializes in the CAD software field. This made CoWare part of Greylock's network and allowed access to the relevant market connections.

Local venture capital of the scale and specialization required was not available.

IMEC has recently taken the initiative to plug the gap. In July 1997, it set up a new venture capital firm: the IT Partners Fund. Currently still located in Zaventem, close to Brussels International Airport, it will eventually move into premises in the vicinity of IMEC (for a detailed discussion of IT Partners, see chapter 7.5.2.7.)

It seems thus safe to conclude that the venture capital requirement is fulfilled now.

7.3.5. Transport and communication

Belgium, especially the Flemish part, has one of the world's most dense networks of highways (142,563 km, including 1,667 km of expressways), railroads (3,396 km, most electrified and double track), and waterways (1,528 km in commercial use). It is easy to access sea shipping through major seaports in Antwerp (the world's second largest - and one of its busiest - ports), Gent, Oostende and Zeebrugge. The country has 6 large airports (CIA 117, p. 7) IMEC itself is situated 15 minutes by car from Zaventem (Brussels) International Airport. The country has a highly competitive cargo/shipping industry; it is the ninth-largest trading country in the world, with imports and exports each equivalent of about 70% of GDP (DOS 1998, p. 2). Trading has been a primary source of income for Belgium's economy for centuries.

This is not surprising considering its central location in Europe, bordering the large markets of Germany in the east and France in the west. The Netherlands and Great Britain are important northern neighbors. A majority of Western European capitals are situated within 1,000 km of Brussels. This European crossroads location is being reinforced by the fact that the majority of the European Union administrative body, as well as NATO headquarters, are located in Belgium's capital, Brussels (CIA 117, p. 2).

It is consequently safe to conclude that the transport precondition is met by IMEC's environment, in fact, it provides one of the major strong points.

The communications precondition is met, as well. Belgium's national telephone system is comparable with other developed countries in principal capability. Belgacom, the national telephone company, has had a rather unflattering reputation of poor efficiency and service and was ranked only 29th in the world in performance (Van-Bastelaer et al 1997, p. 6). This has been improving since the recent liberalization of the European telecommunications markets and the purchase of a 49% stake in Belgacom by ADSB, an international consortium of telecommunication firms (DOS 1998, p. 4) Investments are being made to further upgrade the communications network, using two approaches.

1. Belgacom is currently working on the creation of a new national, high capacity, digital communication network based on fiber-optic transmission.

2. Flanders has the highest rate of cable television penetration in the world - 97%; in fact, more households are connected to the cable network than to the standard telephone network. Cable networks such as the Flemish one provide a high bandwidth and are suitable for forthcoming advanced applications fuelled by the Internet. Since two-way interactivity is necessary for this bandwidth to be used as an access ramp to the global network, *Telenet Flanders* was conceived by the Flemish government in 1994. Telenet is a private company for which the government provided start-up capital, and of which it is a large shareholder (FFIO 1998, p. 9). Since early 1998, Telenet has been operating a complete, leading edge communications network using the cable television network, offering both telephone and data services.[55]

In addition, the region has shown competence in communications. It possesses the world's largest communications equipment company - Alcatel Bell. Alcatel is running a research center and several experimental projects in Antwerp, amongst them an advanced, ATM based Metropolitan Area Network. In addition, IMEC itself, in cooperation with several

[55] Source: http://www.telenet.be

Flemish universities such as Gent University (broadband communications), has strong research capacity in the field (ibid., p. 10) (see also chapter 7.4.3).

7.3.6. Available labor

Belgium's workforce in general is highly skilled. Due to the three official languages of Belgium - Flemish/Dutch, French, and German - and its highly open and trading dominated economy in central Europe, the vast majority of workers are multilingual. The workforce is also very productive; over the last 30 years, Belgium's average annual productivity growth was second only to Japan's in the OECD. Consequently, the level of Belgian wages is generally high (DOS 1998, p. 2; DOS 1997, p. 48).

In regard to the availability of high-tech specialists, the situation is difficult. The unemployment rate among highly skilled workers was only 3.6% in 1997. There is a ***general shortage of professionals trained in information technology*** and related fields; especially hardware, software and automation (DOS 1997, p. 48). Alcatel Bell estimates that, in June 1998, there were ca. 10,000 vacancies to be filled in the Belgian IT industry. But no more than 1150 students with an IT qualification will graduate from Belgian universities and polytechnics in 1998 (De-Morgen 1998, p. 3).

At the same time, there is ***no abundant supply of low-skilled, inexpensive labor***. Belgium has a high unemployment rate, at about 12%. Unemployment in Flanders is 9.4%. Among the low-skilled, unemployment is as high as 14.5%. This would suggest a ready pool of workers willing to accept low wages. However, Belgium's long-term unemployed are virtually unemployable without major retraining - their overall educational level is significantly lower than the Belgian average. At the same time, the high minimum wages and social security contributions present in Belgium (see chapter 7.3.8) make them expensive to employ. The generous social network allows them to live decently without being employed, reducing the motivation to accept lower-paying work. It is also difficult and expensive to fire workers (DOS 1997, pp. 48-49).

As an overall result, labor availability is not satisfactory. There are bottlenecks in both high-tech professionals and low-skilled labor.

7.3.7. Pleasant environment

The quality of life in Belgium, especially in Flanders, is high. Belgium is among the top 20 of countries in the world regarding per capita income. The health care system is excellent. Education is free up to and including high-school, universities charge relatively low fees. The multilingual environment, with English spoken fluently almost everywhere throughout Flanders, makes communication and initial integration for foreigners easy. Belgium is renowned for its easy going attitude to life and emphasis on family values. An emphasis on good food and convenience are the main expressions. Belgian cuisine is reckoned to be as good as the French, and Belgian beer is world-famous. The country in general is blessed with an intense and varied cultural life and is highly regarded for its ready acceptance of foreign persons (DOS 1997, pp. 55-56). One of the few drawbacks is the rather wet climate; rain is frequent especially in summer, though temperatures are generally mild.

It can be generally concluded that Belgium, and Flanders especially, represents a "pleasant environment" and an attractive place for highly mobile high-technology specialists to locate at.

7.3.8. Pro-business environment

Belgium has a highly developed market economy - the tenth largest in the OECD. It has a modest deficit[56], a stable currency low inflation and low interest rates. Industry is concentrated mainly in the populous Flemish part of Belgium (CIA 1997, p. 5). It produces 68% of exports and 61.5% of Belgium's GDP with about 50% of the population.[57] Belgian industry's strength lies in the service sector, which generates more than 70% of GDP (DOS 1997, p. 1).

There are, however, a number of factors that prove problematic They hinder high-technology cluster growth, and effect the whole economy. They concern both Belgium as a whole and Flanders as a region.

High labor cost.

Belgian personal income taxation and social security contributions are very heavy, total taxes are the fourth highest among the OECD countries. Social security contributions by the employer range from 33.03% to 40.79%, depending on income and type of worker. Employee contributions average 13.07%. The top marginal income tax rate is 55% for individuals; corporations pay a standard 39% rate. Small companies face slightly lower rates - between 29% and 37%. Branches and foreign offices are asked to pay a full 43%, although bilateral double taxation treaties can slightly reduce that rate (e.g., for US branches and foreign offices in Belgium that rate is 39%) (DOS 1998, p. 3) (DOS 1997, pp. 43-44, 48).

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[56] However, public debt (which is mostly held by domestic investors) stood at a staggering 130% of GDP in 1997. The planned reduction of this debt, in order to meet the criteria for participation in the European Monetary Union, puts heavy burdens on the government's finances (US Department of State 1998, p. 2).

[57] Source: http://www.ffio.be

This heavy load of payments certainly provides an obstacle to the growth of local industry, as well as foreign companies. The latter ones, however, enjoy some benefits not available to local companies. There are tax incentives and regulatory relaxation for foreign investors who operate "coordination, distribution, or service centers" in Belgium. Also, tax exemptions apply to expatriate executives and research staff, who work in Belgium temporarily. Both arrangements have been beneficial to foreign direct investors (DOS 1997, pp. 43, 45-46). In fact, IMEC claims that the effective tax rate payable by an incoming high-technology company is not more than 20-25%, if all possible deductions are taken into account. This number is, however, not promoted actively by the authorities.

Overall, Belgian authorities are very open to business, investment and free trade. Tax authorities in general, however, have been found guilty of arbitrary definitions and interpretations in the past. Due to the complex government structure, federal, regional, and local authorities, have sometimes conflicting requirements which are difficult to coordinate. There exists no clear hierarchy between them, responsibilities are not clearly divided and tend to overlap. This lack of clarity can lead to bureaucratic delays and inaction, and has produced inconsistent legislation and implementation of national guidelines (DOS 1997, p. 2).

Inflexible labor market

Regulations regarding the labor market are rather **inflexible**, which constitutes another factor disadvantage. About 60% of Belgian workers are members of trade unions. The unions enjoy strong influence in politics, and strikes are tolerated by government, even in vital sectors. Nationwide collective bargaining agreements by the unions apply to both union and non-union members and cover 90% of the workers in Belgium. This makes individual deals on company level difficult. Also, there is a rather **high minimum wage**, set at BEF43,665 (US$1,260) a month. The standard workweek must **not exceed 40 hours** (DOS 1997, p. 7). Comprehensive provisions for worker-safety are mandated by law, e.g., women must not work at night-time.

It can be extremely **difficult and expensive to fire employees** in Belgium. While dismissal for illegal activities is easy, laying off employees in a downturn requires, for white collar workers, at least three months notice or severance pay, for each five year period or fraction thereof during which the person has worked for the company. For blue collar workers, the minimum is two weeks notice or the wage equivalent (DOS 1997, pp. 48-49).

Recently, steps are being taken to increase flexibility; for example, the rule regarding women’s night work has been relaxed.

Attitude towards risk taking and indifference towards high-tech

The business climate of Belgium is characterized by conservatism and an aversion to risk. This hampers the development of high-technology, which is inherently risky. It has also prevented a more widespread adoption of venture capital, because the influence venture capitalists gain by obtaining company equity is contradicting the tradition of family control of businesses, and is seen as unconventional. Only 1.5% of Flemish general managers consider attraction of venture capital as desirable and an important priority. High-technology itself does not possess a particularly high prestige in the population (Van-Bastelaer et al 1997, pp. 3; DOS 1997, p. 7).

From the risk-aversion stems also another related obstacle to high-tech growth: Belgian regulation and taxation of stock-option plans for employees. Stock-options are the vehicle to deliver the wealth that entrepreneurs can gain when their venture is introduced at the stockmarket via an IPO. They have been a major driver of the entrepreneurial spirit in the benchmark clusters. In Belgium, such plans are virtually discouraged by the unfavorable regulation, which has been a cap on entrepreneurial motivation (De-Schamphelaere 1997, p. 111).

7.3.9. Conclusion

As can be seen from the discussion of the factors above, Flanders' position in the high-tech race is not weak. Many of the determinants that allowed high-tech clusters to emerge elsewhere are present.

Obstacles lie mostly in inflexible labor markets, high labor cost and a tendency towards conservatism and risk aversion. Here, the Flemish position compares unfavorably with the benchmark clusters. While high labor cost may be supported by highly productive and innovative industries, the rigidities of inflexible regulation are definitely harmful. So is the aversion to risk taking, which produces an environment in which an entrepreneur who fails will not get a second chance. This disregards the fact that it is previous failure, before all other things, that increases the chances of the future success of a high-tech entrepreneur and his/her start-ups.

Nevertheless, there are signs that this attitude is gradually changing. More and more "exceptions to the rule appear: high-risk, high-gain, high-profile firms such as Lernout & Hauspie or Innogenetics are gradually changing attitudes in Flanders.

It can therefore be concluded that, despite obstacles, Flanders can be a fertile ground for high-tech cluster growth.

7.3.10. High technology in Flanders - the recent numbers

Recent numbers do confirm that analytically derived statement. According to Eurostat-numbers for 1998, Flanders was the ***third most advanced*** of ten European high-technology regions. About 4.1% of the Flemish workforce - 96,000 in total - work in high-tech industries. This is only topped by two German regions: Rhineland-Pfalz, with 4.8%, and Hessen, with 4.6% (FET 1998, pp. 5-6). This compares favorably to the benchmark clusters.

It is apparent that Flanders lives up to its high-technology potential, even in the face of the obstacles cited above.

Nevertheless, there is an important qualification to this finding in regard to IMEC's evaluation. The numbers cited summarize all high-technology industries, and include sectors like biotechnology which are not IMEC's target industries. Therefore, a more detailed exploration of IC production-related industries is necessary.

7.4. Specific analysis of the targeted sector: an analysis of the "IC diamond" in Flanders

7.4.1. IMEC's target sectors: the strategy and the rationale behind it

So far, Flanders' suitability to high-tech industries in general has been analyzed. The IMEC project has, however, not aimed at some unspecified high-tech industry. It has been directed to a large degree at the creation of a microelectronics industry. This can be concluded from the areas of expertise that were consequently targeted and developed from the earliest beginning of the project.

The main targets have always been IC design and IC manufacturing, complemented by other research into fields like microsystems and new materials. IMEC has always been insisting on the need to have both IC design and manufacturing in the cluster it was trying to build. This is based on its industry-prediction on the comeback of the convergence of both, as outlined in chapter 7.2. Conversion would also prove the focus on microsystems to have been far-sighted. Some of the other research fields of IMEC represent "rescue-parachutes", in case that conversion does not materialize as expected.

Trying to trace the effect of all that research in the Flemish industry is, however, beyond the scope of this work. Yet both the design of ICs, and their subsequent production, were major targets of IMEC's cluster building efforts, which is why they have been chosen for analysis here.

In order to judge the wisdom of the attempt to build an IC industry in Flanders, it is necessary to examine the industrial base for it. The question must be whether Belgium's and Flanders' "diamond" in regard to IC production was strong or weak at the time of conception of the "third industrial revolution" in the early 1980's, and how it has developed since then.

At first, the manufacturing side of IC production will be analyzed in regard to its "diamond" in Flanders. After that, the focus will turn to the design side of production

7.4.2. IC manufacturing

The industry that has been shaping the characteristics of IC manufacturing in the US is the Personal Computer (PC) industry, with giant companies like Intel and AMD pushing the performance boundaries of ICs. Therefore, this industry will be used as a proxy to analyze IC manufacturing in Flanders.

7.4.2.1. Factor conditions

Flemish factor conditions in regard to labor cost, availability and skill, capital, infrastructure, and similar factors have already been examined above and will not be repeated here. It can be summarized that Flanders is not endowed with many basic factor advantages. Wages are high, raw materials are scarce and must be imported, and the absolute size of the labor pool is limited by the small population (CIA 1997, pp. 2, 5).

In addition, land is rare in Flanders. Flanders is one of the most densely populated regions in Europe; unused space is the exception (CIA 1997, p. 2). The expansion of IMEC's cluster has been hindered in the past by that; very little land is available in the neighborhood of the institute (see chapter 7.5.2.5).

Advantages must hence be built on advanced factors. As shown above, there are now quite a few of these, as the knowledge based in the region's excellent universities, recently available venture capital, and an advanced infrastructure.

7.4.2.2. Home market

The market that has been pulling the IC manufacturing industry in the US is the large and sophisticated PC market, with its high PC household penetration rate (Booz, Allen & Hamilton 1997, p. 27).

In contrast, the PC market in Flanders is not highly developed. The corporate sector in Flanders has been adopting information technology roughly following the general patterns in Europe since the early 1980's. Yet household penetration of PCs has historically been low and remains so today; it was 13% in 1996, with much of that equipment being outdated. Advanced, cutting edge PCs have only reached about 4 to 5% of households (Van-Bastelaer et al 1997, p. 2, 6). The 1996 average for PC household penetration was 19% in Europe, and 48% in the USA (Booz, Allen & Hamilton 1997, p. 27).

Flemish consumers cannot be classified as very advanced buyers of electronics equipment, hence their directing effect on a national electronics industry must be weak.

In terms of industrial buyers, a similar situation prevails. Flanders has not been a significant manufacturer of computers. Considerably more hardware and components are imported than exported. There are only two bigger players in the electronics field: Alcatel and Siemens Nixdorf / ATEA. They have been mostly active in communication related production, not computer manufacturing. At the time of IMEC's foundation, no company was active in IC manufacturing (Van-Bastelaer et al 1997, pp. 9-10).

This situation led to the unusual initiative to "custom-build" such a company in parallel with IMEC - MIETEC, a then leading edge semiconductor fab (see chapter 7.1). Without MIETEC, IMEC's semiconductor process research activities would have operated in an industrial vacuum in regard to Belgium.[58]

It can be concluded that home demand, both qualitatively and quantitatively, has been weak in Flanders. It provides little economies of scale, and little guidance as described above for other, stronger markets, like the Japanese.

7.4.2.3. Related and supporting industry / domestic rivalry

While the two other targeted industries, biotechnology and advanced materials, could be expected to benefit at least partly from related industry (food processing for biotechnology and the metal/plastics/textiles industry for advanced materials), IC production in Flanders started essentially from scratch (Scientific American 1997, p. 12).

While neighboring countries had established corporate presence in the field, like Philips in the Netherlands and Siemens in Germany, there was no world class, or even significant, microelectronics manufacturing industry in Flanders. The only concentration of expertise in semiconductor processing was present at KUL's ESAT department, headed by Prof. Roger van Overstraeten. Both related and supporting industry were largely absent at the time of IMEC's foundation. The US firm Lockwood Greene was commissioned with building IMEC's laboratory / clean room facilities (Deschamps 1997, p. 92). Even relatively simple services had to be sourced abroad: when IMEC's cleanroom facilities were built, there was a need to weld large, thin sheets of metal for its construction This process

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[58] MIETEC was later bought by Alcatel and renamed Alcatel Microelectronics

is typical to fab construction, and companies which provide it are found easily in the established clusters. There was no company in Belgium that could provide the service; it was necessary to locate a contractor outside of Belgium.

Looking at the evidence, the plan to create an IC manufacturing industry has been taken without consideration of the existing industrial base. While it may yet become true that the presence of such an industry in Flanders is a prerequisite for the continuing growth of the other Flemish strong field (telecommunications, IC design, DSP), it was unrealistic to expect that industry to evolve smoothly.

Part of the plan to build an IC manufacturing industry may well have been based on a fashion to move into that popular sector of "high-tech industry", following a hype then present in many countries.[59] As is the case with most such "from scratch" attempts, the program has been slow to produce results and build industry.

Until today, Alcatel Microelectronics has remained the only significant firm active in IC production in Flanders. No other IC manufacturers have so far appeared on the scene; the Belgian IC manufacturing sector is basically non-existent, despite the global leadership in research on IC manufacturing found at IMEC.

An IMEC spin-off resulting from that research, called Cobrain, has been bought by Matrix, a US company. Subsequently, its innovative assets have been relocated to Silicon Valley, where the IC manufacturing "diamond" is more favorable. Another one, JSR Electronics, has been bought by a Japanese company; here, the innovative assets were moved to Japan. It can be stated that IMEC is a "cathedral in the desert" in respect to IC manufacturing.

In 1998 CS2, an American company, announced that it would build a plant to package ICs close in Zaventem, 15 car minutes from IMEC. The main reason for the location position was proximity to IMEC, which has developed much of the technology the plant will be using.

The location of CS2 in Flanders seems to contradict the findings above. However, CS2 will be the only packaging facility of its kind in Europe. While there is basically no market for it in Belgium, it will use the strong Flemish transport infrastructure to service IC manufacturers all over Europe.

[59] IMEC is not the only case in which "from scratch" creation through a research institute has been attempted. Another example is the Center for Electronics Research in Goeteborg, Sweden, which has also been built without an significant industrial base in electronics. (Carlsson/Jacobsson 1995, p. 55)

CS2's case suggests that the continuos trend towards European economical integration is diminishing the importance of national industrial sectors for local cluster growth. A more in-depth study of the IC manufacturing industries found in Belgium's neighbor countries may shed a more favorable light on its aspirations to become an IC manufacturing center.

7.4.3. IC design / DSP technology

The sector of IC design that IMEC specializes in - DSP design - is closely linked with telecommunications. Most today's effort in developing telecommunications equipment goes into design of custom ASICs for Digital Signal Processing - DSP is the core technology that leads the ongoing shift from analog to digital communication (Cornu 1997, p. 182). Therefore, in order to apply Porter's "diamond" model to this part of IMEC's industry building efforts, the Belgian telecommunications sector will be examined.

7.4.3.1. Factor conditions

In regard to general factor conditions, the same is true for IC design/ DSP as for IC manufacturing. However, there has been an extra asset to IC design and DSP related industry that was present at KU Leuven's ESAT and later IMEC.

In 1969, Prof. Van Overstraeten established a laboratory for IC design at the KU Leuven. In 1971, it concentrated much of its efforts on computer aided IC design. A that time, this was revolutionary. His team produced a number of breakthroughs in the field, amongst them standard ASIC design cells, which are now the "bread-and-butter" technology of the ASIC industry. In 1976, the KUL's ESAT laboratory was founded to focus these design efforts, and headed by van Overstraeten.

Also before IMEC's creation, Prof. Hugo de Man (an early student of Prof. Van Overstraeten) was a leading researcher in the field of DSP at the KUL. A long time before DSP moved into the spotlight in the wake of mobile telecommunication, he was driving the early exploration of the field with the CATHEDRAL project of ESAT.[60] This project extended standard IC technology to DSP, and enabled a "DSP mindset" amongst his students. This mindset was transferred also to IMEC, and later to industry: many of the leaders of the companies that form DSP Valley have come from this background (De-Man 1997, pp. 28-32).

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[60] The software developed in that project was commercialized through a spin-off (Lisco, in 1977), which merged in 1983 with the US company Lisco, to form Silvar-Lisco. It moved out of the Leuven area, but continues to be a leader in the field of IC design software.

Being an early mover in ASIC design and DSP allowed ESAT / IMEC to be on the cutting edge when the DSP market took off. Today, IMEC is one of the most advanced DSP centers of competence in the world, with a large number of highly skilled people concentrated there. Its own IC design software has been commercialized by the spin-off EDC / Frontier Design and is amongst the leading packages in the world.

IMEC itself has been recognized as a "Large Installation Site" for DSP / IC design by the European Commission. The "early movers asset" has contributed very much to the positive perspective that the DSP industry around IMEC, and in Belgium/Flanders, enjoys today.

7.4.3.2. Home demand

The recent deregulation of the Belgian telecom markets has led to a strong growth. ***Belgium is the fastest growing telecommunications services market in Western Europe*** (see figure 6). Mobile telecommunication is expected to grow by 40% until the year 2000. The continuous decrease of prices for mobile telephones and services is a reason for this. Another is the uniformity of the European mobile telecom market due to the common GSM standard (IDC 1997, p. 2).

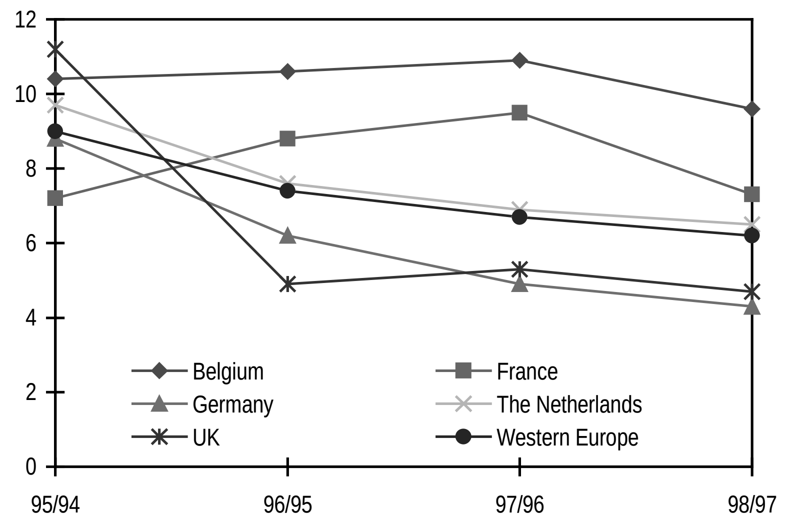

Figure 6: Growth rates of selected European telecommunication markets (Source: EITO 1997)

Also, a number of new competitors to Belgacom are appearing on the scene, providing significant demand for communications equipment (ibid.).

It can hence be concluded that significant and sophisticated home demand is present in Belgium.

7.4.3.3. Related and supporting industry / domestic rivalry

Europe in general has been traditionally stronger in communications related industry then computer manufacturing. Europe has been leading the world since 1990 in investment in telecom infrastructure, and is global leader in the production of switching equipment. About 90% of the switching & transmission market is served by 5 large companies; 3 of them are European (Booz, Allen & Hamilton 1997, p. 16). ***The largest one, Alcatel Bell, is located in Belgium. Another top-five company, Siemens, does much of its communications business at Siemens ATEA in Belgium***. Yet another large player active in communications is the Telinfo Group. The previously mentioned speech technology company, Lernout & Hauspie, can also be counted as communications related: much of its software is used in call centers. There are a number of smaller, niche players who are active in communications in Belgium, and the above mentioned Alcatel Microelectronics (former MIETEC) is also active in design of communications ICs (Van-Bastelaer et al 1997, p. 10).

Europe's leadership in mobile telecommunications is illustrated by the success of the GSM standard. It has originated in Europe and is rapidly winning market share on a global scale due to its first mover advantage and standard leadership; European manufacturers are holding 92% of the global cellular switching and 84% of the global cellular transmission market (Booz, Allen & Hamilton 1997, pp. 14-15).

DSP is the major enabling technology for GSM and other mobile telecommunication systems. It is the fastest growing segment of the semiconductor industry. The European market for DSP related products is currently worth US$1 billion, and forecast to grow dynamically in the next years (EDN 1997, p. 6).

In a 1997 report by the US Department of State, the Belgian communications sector was recommended as sector with which joint ventures are viable because of special expertise (DOS 1997, p. 2) For more evidence, please refer to chapter 7.3.5.

It can consequently be said that both related and supporting industry for IC design / DSP are present in Belgium.

7.4.4. Conclusion

The IC design / DSP "diamond" is stronger in Flanders and around IMEC than the IC manufacturing "diamond". The efforts to build an IC design / DSP industry are therefore more likely to be fruitful than the ones targeting IC manufacturing.

7.5. Development tools used by IMEC: chosen approaches and their effectiveness

IMEC's mission was never going to be easy, given the limitations of the industrial base it could build on. When one analyzes IMEC's strategy, it becomes clear that its founders have always been aware of that. The long-term orientation of the approach is commendable; so is the breadth of the measures employed to transfer technology and build the cluster. If some of IMEC's objectives have not been met so far, it has been because of unfavorable aspects of the environment it operates in, and a short time of operation; not because of fundamental mistakes made at IMEC.

7.5.1. IMEC's "Strategy of Three Stages"

IMEC's strategy has been divided into three stages, building upon each other (see figure 7).

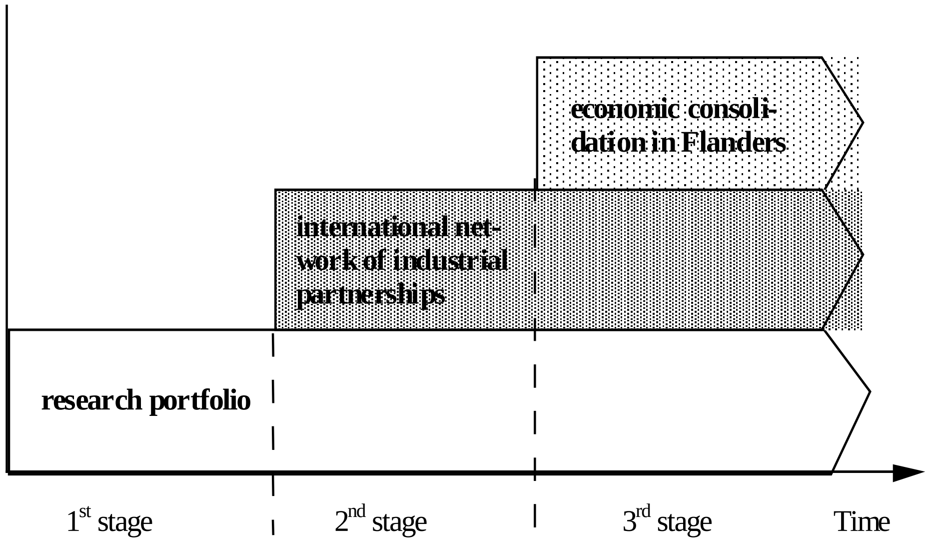

Figure 7: IMEC "strategy of three stages" (Source: IMEC internal presentation, adapted)

Stage one: Achieving excellence in research, and building IMEC (co)owned background information (BI) in the form of a focused technology portfolio.

Stage two: Building up an international network of partnerships with the leading industrial players in the field of microelectronics, and jointly developing technology.

Stage three: Using the intellectual property and experience gathered from stage one and two to build a microelectronics industry in Flanders. (Van-Helleputte 1997, p. 128)

It will be shown that stages one and two have been achieved. The challenges IMEC faces with stage 3 will be elaborated upon.

7.5.1.1. Stage one: Building of research excellence

Because IMEC started out in what amounts to an industrial vacuum, an incentive for the major microelectronics players to cooperate had to be created. IMEC had to acquire "critical mass" to be recognized as strategic partner by industry for co-operation in R&D - the prerequisite to move to stage two.

The background information which would later form the basis for industrial interaction on a global scale was that incentive. Industrial R&D in microelectronics is very advanced itself, therefore IMEC's research goal had to be ambitious. In the mission statement, the research goal of IMEC is defined as follows:

"to perform R&D, ahead of industrial needs by three to ten years, in the field of microelectronics and related technologies." (Van-Helleputte 1997, p. 118).

Such long-term research is valuable to industry because, as shown above, its own research focus tends to be shorter in term.

In order to allow IMEC to get ahead of industrial needs in the first place, it was designed from the start as a high-class research facility, with a large-scale initial investment of ECU 62 million. The approach has worked. Based on the experience of the ESAT team under Prof. van Overstraeten, and boosted by the advanced facilities that were made available, IMEC has been building a valuable base of scientific knowledge. IMEC's number of publications in the relevant scientific journals and accepted papers at international conferences has been rising steadily. It has now a global reputation for research excellence. This is emphasized by the growing number of press articles published on IMEC (see figure 8).

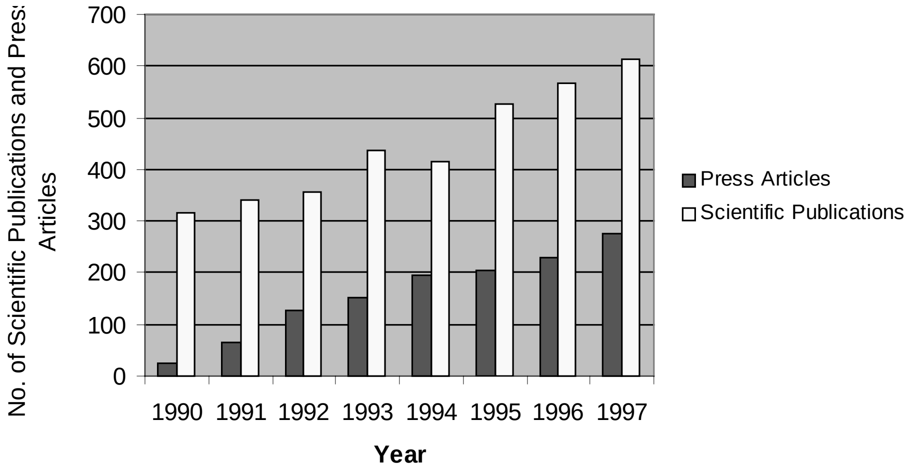

Figure 8: Evolution of scientific publications by and press articles covering IMEC (Source of Data: IMEC)

IMEC participated as a major player in 78 research programs of the European Commission in 1997; it contributes to projects under programs like JESSI/ESPRIT, and MEDEA. Contract research from European programs was 32% of the total in1997. IMEC also co-operates with the European Space Agency (ESA); with a 6% contribution to contract income in 1997. IMEC also co-operates with important international research consortia, such as the US' SEMATECH or Japan's SELETE.

IMEC's strong co-operation with the Flemish universities has contributed to a large degree to the buildup of its BI and the development into an international "Center of Excellence".

It can be concluded that IMEC has reached "critical scientific mass" today; stage one has been achieved.

In the light of its mission, this matters. As has been shown above, *only the best* research institutions will act as strong growth poles to cluster development. IMEC is one of the best research institutes in its field in the world.

Therefore, it has <u>the potential</u> to boost the formation of a Flemish microelectronics industry.

7.5.1.2. Stage two: Joint development of technology with field leaders

There are several functions to stage two. In order to stay three to ten years ahead of industrial needs, IMEC must know the industrial needs thoroughly. Therefore, feedback of future industrial needs from industry is necessary. This feedback is best gained through collaboration in joint research. Joint research also allows IMEC to keep its BI up-to-date in fields in which it does not lead itself.

As the speed of change quickens in microelectronics, concurrency between longer-term research such as IMEC's and shorter-term research such as industries increases. This is another reason why joint development with field leaders is necessary (see chapter 7.2).

Last but not least, joint research has become a major source of income for IMEC (see figure 9). Industrial partners drive IMEC towards shorter-term research suiting their needs and so create a conflict of interest with IMEC's longer-term research. However, they are willing to pay for that privilege. When IMEC was started, the share of contract income as a portion of the total budget was relatively small; IMEC was subsidized to more than 60% by the Flemish government. Today, that share has declined to 40%, as contract income's share of the total budget has risen to about 60% (see also figure 14).

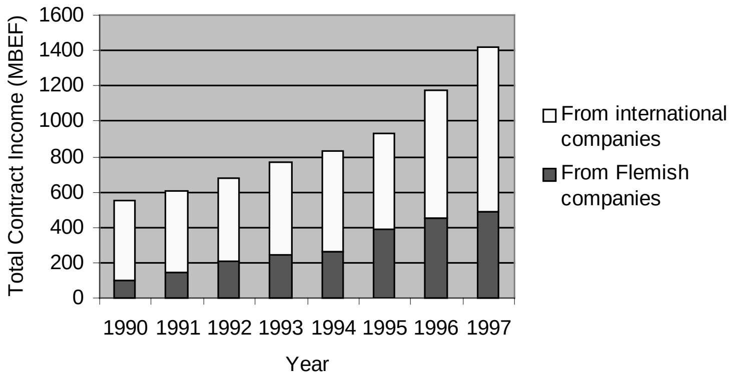

Figure 9: Evolution of IMEC contract income - international and Flemish companies combined (Source of data: IMEC)

IMEC intellectual property policy

IMEC's IP policy reflects its long-term target of building Flemish industry. There are three types of IP within IMEC:

1) Pure Background Information. Research to gain this has been financed and undertaken by IMEC alone. Consequently, the IP resulting from it belongs to IMEC.

2) Shared "Foreground Information". It is the result of joint projects with industry, IP rights are shared between IMEC and the industrial partner(s).

3) Company specific "Foreground Information". Resulting from joint projects, too, these results are confidential to the industrial partner and not owned by IMEC.

IMEC has to balance the interests of the Flemish region and the industry leading companies in this case. The more IP IMEC owns or co-owns, the more it can transfer to Flemish companies and so achieve its mission of building local industry. However, the disclosure of certain vital information would put IMEC's partner companies to strong disadvantage. For these areas, which IMEC tries to keep small, exclusive ownership of IP must be granted, or companies will not cooperate. Without company co-operation, IMEC's mission is not achievable (Van-Helleputte 1997, pp. 123-127).

IMEC applied for 36 patents in 1997, 11 of which were granted. This may not sound much. However, another conflict of interest is at work here. There is a trade-off between patent application and publication. Each breakthrough that IMEC publicizes in international journals cannot be captured as IP anymore. Yet publications are necessary to build IMEC's image in the industry.

IMEC's IP policy is a compromise between the best practice of maximum caption for transfer as stipulated in chapter 5.5.1.1.1, and the need to build visibility in, and co-operate with, the global semiconductor industry.

IMEC Industrial Affiliation Program (IIAP)

The IIAPs are the main vehicle for co-operation with leading companies. They generate the most contract income that IMEC needs to earn in order to fulfill its minimum own contribution to its budget (40%). IIAPs can also be used to measure the degree of IMEC's interaction with international field leaders according to stage two.

IIAPs are launched in focus points of IMEC research where IMEC has BI which is valuable to companies. The research topic is defined, and selected companies are invited to join the program. They will usually send one or more researchers, "industrial residents", to join the IMEC team and jointly perform the research. Being a member of an IIAP, they can access the BI of IMEC and enjoy a research pooling effect, where they have access to results generated by the whole IIAP team, including the work of other company's researchers (except type 3 IP). The mixed teams give IMEC efficient industrial feedback, cross-fertilize the research efforts, and shorten the technology transfer cycle and learning curve at implementation of the project results at the member companies, resulting in time-to-market advantages. The duration of such a program is at least one year. Participating companies pay a membership fee (Van-Helleputte 1997, pp. 125-126).

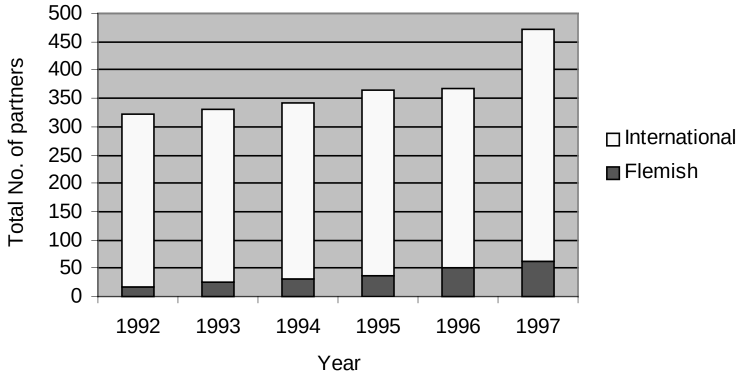

Figure 10: Evolution of number of IMEC contract partners (Source of data: IMEC)

The number of IIAPs, and the number of companies participating, has been rising steadily. On the total, IMEC co-operated with nearly 500 companies and research institutes worldwide in 1997, and the number is growing (see figure 10). The majority of partners are located in Europe, followed by the USA and Asia.

This is a good indicator of IMEC's strong interaction with leading industrial players, and shows that Stage two has been achieved.

IMEC is an active player in the microelectronics world of today, and part of a global network of competence (like the one Antonelli sees as increasingly replacing industrial districts).

It therefore has <u>the potential</u> to be a link between a Flemish microelectronics industry (when and if it eventually gains momentum) and the global microelectronics world.

7.5.1.3. Stage three: Transfer the technology to Flanders

Stage three is the most important stage in IMEC's strategy. The initial idea behind the foundation of IMEC was to provide Flanders with a microelectronics industry. Stage one and two were prerequisites for moving to this final objective. They have been achieved, and the potential of IMEC to benefit its region has been proven. Yet it is the realization of that potential that proves to be the most difficult stage. Looking at the industrial-base analysis above, this doesn't come as a surprise.

7.5.2. Building new industry: Evaluating IMEC's tools aimed at stage three

IMEC has used both top-down and bottom-up approaches for building new industry, as well as policies to upgrade existing Flemish industry, to varying degrees of success. The will be analyzed in the following chapters.

7.5.2.1. Top-down component: Foreign Direct Investment

IMEC's strategy towards building an IC *manufacturing* industry in Flanders has been dominated by the top-down approach of attracting FDI. As has been shown above, the results of these efforts have not been impressive. This is not surprising, given the limited suitability of IC manufacturing for the Flemish industrial landscape.

IMEC insists that its efforts at attracting IC manufacturing industry are fundamental to its strategy, based on future conversion-based industry development (see chapter 7.4.1). There is, however, also a political dimension to the issue. As seen from the experience in other clusters, fabs provide instant, sizeable, and very visible benefits to regional employment. The fact that they are a poor seed for indigenous cluster growth, probably no good value-for-money, and inferior to home grown companies in regard to regional development, is not popular knowledge and not obvious at first. Politics tends to be short-term in outlook, and results must be "sellable" to the public. One big fab "sells" better, and produces faster results, than five small spin-offs, which need time and money to develop their full potential.

IMEC is still funded to a significant portion by the Flemish government. Therefore, it is a fair guess that IMEC's fab attraction efforts owe as much to politics as to regional development reasoning.

Leaving aside the doubts about general feasibility, IMEC's top-down portion of approach will be analyzed in short.

Attracting fabs manufacturing ICs to Flanders has been a target of IMEC for several years. It has, however, not succeeded so far. Besides the "diamond" obstacles cited above, the reason for this was most likely a lack of sufficient financial incentives offered by the Flemish government, and bad marketing of the region.[61] Without good marketing, and the

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[61] For example, it took about 200 days before a decision was made on whether to allow an FDI investment project in Flanders. Investors were sent from one office to the other, with confusion and frustration as the result.

willingness to spend several hundred million US$ on a 30%-40% assistance package, it is virtually impossible to attract fabs today. Such a package was not available.

In 1996, the Flemish government recognized its misjudgment and announced a US$300 million package (plus other incentives) that is competitive compared to other regions' offerings. The Flanders Foreign Investment Office (FFIO) became more become more professional, globally present, and started acting as a one-stop-shop provider similar to the successful LIS in Scotland. IMEC also focused its efforts by transferring its fab attraction efforts to a dedicated senior manager, who now focuses full time on the task in cooperation with the FFIO.

While this setup has significantly increased IMEC's chances of success, the downturn that the semiconductor industry entered in 1996 has kept potential investors waiting for better times, and no fab has been attracted yet despite very active talks to potential investors. It is likely that results will follow the recovery of the industry.

Besides that "classical" approach to FDI, the pressure to succeed has in 1997 resulted in the announcement of a very innovative and potentially industry changing variety of FDI attraction. On one of the sites selected for the fab attraction efforts, a new fab will be built. It was, however, not a semiconductor maker that ordered it; Meissner & Wurst, a German company that specializes in building fabs, will use its own capital to build it, and then offer the facilities to semiconductor makers ***on a lease basis***. In a possible extension of plans, equipment makers are considering to place their equipment in the fab, also on lease basis. This would result in a fully equipped, "turn-key" fab, ready for hire.

There are two reasons why this approach is very sensible. Building a fab is a significant financial risk for a semiconductor company, and it takes time. Demand for products is often difficult to forecast, resulting in over- or undercapacity of production and cash flow shortages. Lease fabs could provide a solution to both the financial and capacity risk.

If the fab will be fully equipped, it will be *de facto* a leading edge, European foundry. Most of the world's foundry capacity, as well as the technically most advanced foundries, are situated in Taiwan today. An advanced European foundry would both have a considerable European market for its capacity, and would complement the fabless design activities taking place in DSP Valley (see chapter 7.5.2.2) to form a more complete production environment.

7.5.2.2. Bottom-up component: spin-offs

With the top-down measures producing few results and facing limits as to their usefulness in creating sustainable regional development, the focus must be on the bottom-up measures employed by IMEC. The creation of spin-offs has been the centerpoint of IMEC's bottom-up strategy.

The spin-off efforts have produced the most visible results of IMEC's cluster building activity. Between 1986 and 1998, fourteen spin-offs were created by IMEC (refer to Annex 8.2 for a list).

The efforts had been off to a slow start. In the eleven years between 1984 and 1995, IMEC only succeeded in launching seven spin-offs. From 1995 on, the pace quickened considerably. Another seven spin-offs were created just between 1995 and 1998, more than two per year.

Of course, the delay can be attributed to the time lag that all cluster-building projects have, as discussed in chapter 5.3. The innovative potential needs to be built up before it can be dispensed to the region. But the rapid acceleration from 1995 on has not only been due to that effect. Both changes in the environment of IMEC, and its internal policies, have played a considerable role.

In IMEC's starting years, a technology-centered approach was employed in the spin-off creation process. Once a mature technology appeared within IMEC, the technology transfer department RVG executed a market survey and a feasibility study to quantify the potential for establishing a new company. *After* that, the search for a "volunteer" willing to leave IMEC to head the new company began. Finding such a good "candidate entrepreneur" was often very difficult. If no one was found within IMEC, RVG worked out a complete business plan and tried to spark interest in leading the spin-off in outside candidates. Too often, this did not succeed either. Many initiatives had to be dropped because of a lack of entrepreneurs (Van-Helleputte 1997, pp. 133-134). This experience corresponds with the tendency towards risk-aversion mentioned in chapter 7.3.8. It also contradicts a best practice in technology transfer, because it does not involve the scientific staff enough in the commercialization of the technology (see chapter 5.5.1.1.1).

In the last couple of years, IMEC has adapted its approach. In response to the entrepreneur scarcity, the initiation of the creating of spin-offs has been "delegated" down. The activities to form a new venture are now initiated, bottom-up, by researchers who have championed the technology behind it and are willing to leave IMEC to lead the venture. IMEC aims to involve them from the very beginning, and to give them a say in choosing the often necessary outside management experts who are brought in to complement the technical expertise of the researcher-entrepreneur. This way, a fit of people's personalities is guaranteed. It does not happen, as it has in the past, that people are forced together on the basis of expertise, which did not get along personally (ibid.). Best practice in technology transfer is served much better that way, and the increase in spin-offs since the policy change is prove of that.

The involvement of the scientific staff in general, however, is still insufficient. The largest part of IMEC's research personnel is not aware of IMEC's regional development strategy; most of them are not even aware of the fact that IMEC has such a mission at all. The author of this paper had to go all the way to the second-most senior manager of IMEC in order to gain comprehensive insight into the strategy.

Therefore, some measures to involve the staff more, as suggested in chapter 5.5.1.1.1, should be established. This would increase the likelihood of entrepreneur-scientists to emerge from IMEC.

It must be acknowledged that, in addition to the internal policy changes, outside changes in IMEC's environment played an important role in the acceleration of the spin-off launches.

The increasing willingness by IMEC employees to lead spin-offs has been aided by the recently increased popularity of risky high-tech and entrepreneurship through the success of Flemish high-tech ventures such as Lernout & Hauspie (see chapter 7.3.4)

Furthermore, seed capital was very difficult to obtain in Flanders throughout the 1980s (as was the case in most other regions in Europe). This lack of capital hampered the set-up of new companies by IMEC. When spin-offs did emerge from the technology commercialization efforts, they were often under-financed. A shown in chapter 7.3.4, venture/seed capital has been increasingly available in Flanders in the last years, and the creation of IT Partners fund has vastly expanded the availability of such capital for IMEC spin-offs (see chapter 7.5.2.7). Consequently, more (and better-funded) spin-offs could be launched.

DSP Valley: IMEC efforts to cluster its spin-offs and leverage their regional impact

IMEC has been trying to leverage the regional impact of its spin-offs, and to increase their visibility. It has done so by creating "DSP Valley" in 1993.

Since most of the spin-offs operate in IC design and related activities, it was feasible to group them into a cluster. In addition, the relevant departments of the local universities and IMEC's IC design division have become part of this construct, as well as Alcatel Microelectronics. All relevant DSP issues are represented by at least one cluster member, which makes DSP Valley a one-stop-shop solution provider. There are regular meetings of the leading executives of the cluster members in order to exchange information and plan the cluster's future strategy.

In 1997, there were 400+ DSP experts working in the context of DSP Valley. There is significant cooperation going on between the cluster companies themselves, as well as between them and the universities and IMEC. The cluster companies also organize training sessions on DSP for industry.

The "diamond" component *presence of supporting and related industry* is well developed, and the externalities as described by Antonelli above are already materializing. As shown above, the telecommunications market in Belgium provides vital *home demand* guidance. The *advanced factor* supply is aided by both the cluster's and INVOMEC's training programs.

However, no significant *rivalry* is yet present in the cluster. Each of the players covers a different field, which is why direct competition is not occurring often. But already now, certain companies display some overlaps in competence fields. If the cluster continues to grow, some duplication, and the resulting desirable rivalry, is likely to occur.

Marketing will support the growth trend: DSP Valley is being aggressively promoted as a unique center of DSP excellence in the IMEC area, very similarly to the way the above mentioned Flanders Language Valley has been marketed.

It can consequently be stated that DSP Valley displays favorable "diamond" characteristics, and it is realistic to expect further growth.

7.5.2.3. Evaluation of IMEC's new-industry-building efforts

As has been shown, IMEC's top-down measures have so far not been very successful. If they had been standing alone, they would not have sufficed to advance the fulfillment of its industry-building mission. It is due mostly to the success of the bottom-up measures, and here mostly the spin-off performance, that IMEC's mission has not been unsuccessful.

The fields that the spin-offs operate in clearly reflect the Flemish IC "diamond". The overwhelming majority is active in IC design / DSP. The two spin-offs active in the IC manufacturing sector have been acquired, and their innovative activities shifted abroad, where they find a more favorable "diamond" (please refer to the list in Annex 8.2 for a description of all spin-off's and their activities).

Whether IMEC's top-down measures are beneficial or not depends on the course which the semiconductor industry will take in the future (see chapter 7.2). As shown in chapter 7.4.2, the Flemish IC manufacturing "diamond" is weak, and trying to improve it will require the commitment of significant resources.

If the industry continues to move towards the fabless design / foundry polarized model, these resources might be put to better use in strengthening the existing IC design / DSP seed.

If the other scenario - ever denser and more complex integration - prevails, it may be sensible to continue the top-down measures to attract IC manufacturing. In that case, the presence of both design and manufacturing capabilities in the area would be a strong competitive advantage. It would also be a "first-to-move-back" advantage in a time when much of the industry has moved to the separated model, and integration capabilities are rare.

Even if former scenario prevails, the top-down efforts may still prove to be useful, because they could provide visibility and "critical mass" to IMEC's bottom-up cluster building efforts.

In addition, in a recent shift of policy, IMEC is increasingly targeting IC manufacturing equipment suppliers in its top-down measures. In an industrial trend towards "total solution" offerings, these equipment manufacturers are facing pressure to bundle process know-how with their equipment into a complete package. There are only a few independent providers of process know-how in the world; IMEC is the most important one of them. This could pull equipment manufacturers to Flanders in the future. IMEC claims to be close to several agreements in that field. Not only would equipment manufacturers be more attracted to set-up shop close to IMEC than classic fabs, they would also fit better into the industrial environment of Flanders, which has a long history in machine tool making (see also chapter 3.3.3).

It can be concluded that IMEC's new industry creation tools have been a mixed success. As was to be expected from the theoretical consideration presented on top-down measures above, they have not been very fruitful in IMEC's case. However, they may yet prove valuable if IMEC's predictions about the future of the semiconductor industry prove to be right. The bottom-up measures have been fairly successful, and IMEC is taking the right steps to improve them. The involvement of research staff remains to be addressed.

7.5.2.4. Supporting new industry creation: Auxiliary efforts of IMEC to improve the suitability of its environment for high-technology growth

While IMEC's direct policies at creation of industry are important, they do not work in a vacuum. The bottleneck of available labor as described in chapter 7.3.6, as well as the space problem (see chapter 7.4.2.1) still hamper high-tech growth around IMEC. Additionally, the lack of IT-specialized venture capital in the region has been an obstacle to growth (see chapter 7.3.4).

The institute has tried to address them with a number of initiatives, mainly the creation of science parks to provide suitable space for industry, the operation of its INVOMEC training division to improve the regional labor force, and the creation of IT Partners, a specialized IT venture capital firm.

7.5.2.5. IMEC's science parks

As mentioned in chapter 7.4.2.1, the lack of available space in its vicinity for companies to build facilities on has been hindering IMEC's industry building efforts. At the same time, science parks can be a powerful reinforcement and accelerator of already existing initial high-tech development (see chapter 5.5.1.2), a development that is visible in IMEC's case. How does IMEC address this issue?

IMEC's own small science park, the "incubation and innovation center" that it shares with the KU Leuven, has been designed modestly in size. It ran out of space and has not been able to accept any more new ventures. Another independent science park nearby, Interleuven Research Park, has also been full for some time. Therefore, science park capacity is needed urgently.

Since 1993, IMEC has been working on the establishment of a new large (ca. 33 ha) science park adjacent to its own campus, which would offer relief to the space crisis.

Yet until today construction has not started[62]. This has mostly been due to bureaucracy and lengthy approval and permit procedures required by the Flemish authorities. In contrast, the two Limburg sites for the politically strongly supported fab attraction efforts have been provided quickly and with minimal bureaucracy; approval speed has been aided by the fact that they are situated in an area which is considered economically depressed, and which qualifies for EU development funds. The planned science park appears to be less of a "high-profile", "sellable" project and has not enjoyed the same level of political support.

In the meantime, the KU Leuven has been building a smaller "University Park" for its own spin-off efforts, which will open still in 1998 and be also accessible to IMEC initiated ventures. It will bridge the gap until the large park eventually opens (Van-Helleputte 1997, p. 136).

[62] In 1998, final permissions have been grated. Construction is now expected to start in 1999.

Evaluation

It can be said that IMEC is aware of the functions of science parks as tools of regional development and has acted accordingly. It has, however, been hampered by bureaucracy.

7.5.2.6. INVOMEC training activities

Highly qualified labor is the current No.1 location factor for high-tech industries (see chapter 4.7). As shown in chapter 7.3.6, the availability of qualified personnel has been a problem for Flanders. Certainly, there is *no area* in the world where such specialists are readily and abundantly available; this shortage is a global and universal one. But even in the face of shortage, steps must be taken to alleviate it, in order to be attractive for high-technology development.

IMEC has been addressing the issue with an extensive training program for both industry and academia, which is carried out by its INVOMEC division. Interestingly, the training targets almost exclusively IC design; training on IC manufacturing issues is not a focus of INVOMEC. It is probable that this fact originates both from the early strength of IMEC / ESAT in design and the more favorable design "diamond" in Flanders, and acknowledges of the weak Flemish IC manufacturing "diamond".

In order to stay on the cutting edge of design methodology, access to the latest design software is essential. IMEC makes this software and its know-how available to both academia and industry in Flanders. This way, "new" specialists are created at the schools, and the knowledge of specialists who are already working is updated.

As a positive side effect, the training program is promoting the products of the evolving DSP Valley cluster. This is because much of the most advanced software for IC design is developed there, and users trained on that software are likely to promote its acquisition and use in their respective companies.

7.5.2.6.1. Training for Flemish universities

INVOMEC co-operates, in an educational network, with 3 universities and 13 polytechnic schools in Flanders. It provides these higher schools with UNIX workstations (installed base in 1997: about 100), which are equipped with the latest design software. Professors and teaching staff at the schools use these workstations to teach advanced IC design methodologies to their students, with a very practical orientation. The professors and staff themselves are trained regularly at INVOMEC to refresh and update their skills. This way, each trained teacher leverages his/her knowledge through educating a much larger number of students. These services are provided free of charge to the schools. The system produced about 400 graduates of IC design in 1997.

In the future, INVOMEC plans to expand the system, on a fee basis, to other European and non-European universities outside of Flanders.

7.5.2.6.2. Training for Flemish industry

Similar to the training programs for academic staff, INVOMEC offers retraining programs for Flemish IC design engineers from industry. They allow these experts to update their skills and apply them in their companies. They are, however, not offered free of charge; fees from this part of the training program constitute a large part of IMEC's income originating from Flemish industry.

Evaluation

The design-training program of INVOMEC is clearly of benefit to IMEC's region, as it produces a very rare resource: highly skilled labor. Of course, it must be recognized that these graduates are especially mobile. Not all of them stay in Flanders to benefit local industry, a certain proportion leaves for other clusters, most notably to the US. The majority of them, however, do stay in Flanders.[63]

Whether it is viable to extend the academic training services to universities outside of IMEC's region is not so clear. The plan seems motivated both by an understandable desire to generate extra income, as well as a desire for increased visibility in Europe.

Such an expansion would require elevating INVOMEC's activities to a much larger scale. In the ideal case, INVOMEC could become a leading edge European, and eventually global, "university" for IC design. This would certainly benefit IMEC's region and draw more industrial activity in design there.

In the worst case, such expansion could result in a loss of focus and overstretching, leading to a loss of quality of training for the primary Flemish clients. The future will show which scenario will be the outcome of the ambitious expansion plans.

Overall, it can be said that IMEC's training activities are well designed, take advantage of multiplier effects, and are truly beneficial to the quantity and quality of the local labor pool. The quality of the design has been acknowledged abroad, as well. IMEC was consultant to the creation of Scotland's training efforts in the context of "Project Alba" (see Annex 8.1).

"Brain-drain" to foreign companies does exist, even though it is lower than one would expect looking at the industrial environment. As long as there are business climate obstacles

[63] A reason for this is the Belgian culture centered on home and family values, which causes a very low international mobility. Even domestic mobility is low; upon leaving their parents, young people do mostly settle down close to their home-towns.

to high-tech growth in Flanders, brain-drain will draw talent from the region, and INVO-MEC's training efforts will at least partly benefit rival regions. Nevertheless, the program has the potential to exercise a pull effect on foreign investors (top-down) and a seed effect for local entrepreneurs (bottom up). ***It is a strong element of IMEC's approach.***

7.5.2.7. Venture capital through the IT Partners fund

As already mentioned in the section on venture capital availability in Belgium (see chapter 7.3.4), IMEC has faced a lack of electronics-focused, local venture capital. Therefore, in July 1997, it set up a new venture capital firm: the IT Partners Fund. Currently still located in Zaventem, close to Brussels International Airport, it will eventually move into premises in the vicinity of IMEC

IT Partners will focus exclusively on Information Technology, especially systems-oriented, design-oriented, fabless companies, as well as IC fabs and packaging industry. It will be one of the first European funds specializing that way.

Its close proximity to IMEC, and IMEC's direct involvement in the investment decision (IMEC's president, Roger van Overstraeten, will be chairman of the Board of Directors and the Investment Committee) should ensure that IMEC's expertise in that field can be used in a synergetic effect. The fund will be managed by two experienced venture capitalists recruited from EuroVentures based in the Netherlands. It has drawn US$35 million in the first closing and aims at attracting US$85 million with the second closing in 1998. IMEC is expected to put up 10% of the initial value of the fund.

In addition, the stated goal is to use the network of the two industry veterans to assemble syndicates where necessary to finance bigger investments, providing extra financial leverage. IT Partners will always retain a leading role.

Focus will be start-up financing through equity investment, focusing on the medium term (5-7 years). The fund will provide "active hands-on support" and aims to influence strategic decisions, such as recruitment of leading personnel, mergers & acquisitions, co-operation agreements, and the financing of the enterprise. Geographically, the fund will prefer companies within close proximity, defined as "one-day travel distance" (Clarke 1997[64]; Van-Helleputte 1997, p. 135).

[64] article retrieved from **online archive** [no pagination]

Evaluation

The setup of IT Partners has the capacity to create the "nurture-effect" for IMEC spin-offs, and for companies attracted by IMEC to locate close by. It could make the Flanders region a more fertile seedbed for the growth of IT industry in general. IT Partners could both vitalize the cluster and be the glue that holds it together. It may also put a cap on cluster-damaging, premature buyouts of young cluster companies by foreign companies.

The fund promises to alleviate the shortfall with regard to venture capital for the IMEC cluster. It has already lead the financing efforts for a new IC packaging plant, CS2, which will be built in IMEC's proximity in 1998. More projects of that kind are very conceivable.

7.5.3. Upgrading existing industry

Besides IMEC's efforts at creating new companies, there are a number of activities of IMEC to upgrade existing Flemish industry. With this, IMEC recognizes the necessity to see high-tech not only as an industry in itself, but as a tool to improve competitiveness in older industries, as laid out in chapters 3.3.3 and 5.6.

7.5.3.1. Marketing IMEC's activities to Flemish industry

In order for local industry to benefit from IMEC's activities, they must be known to them. Therefore IMEC has taken numerous steps to *market* its technologies. There are several information channels used for this:

- General publications (Annual Report, Scientific Report)
- IMEC Newsletter (international distribution) and InterConnect Newsletter (in Flemish, for local SME, since February 1997)
- Technical seminars on certain topics (ca. 130 in 1997)
- IMEC summer courses
- think tank sessions with industry, where information can flow both from and towards IMEC
- scientific publications and contributions in international magazines (see graphs above)
- active participation in international conferences (ca. 370 in 1997)
- IMEC WWW pages on the internet

In order to increase the ease of access to this information for IMEC's target group, the *IMEC Partnership Program* was created in 1991. Although the program is mainly aimed at

Flemish SMEs, anyone interested in IMEC's activities can become a member. There were over 200 members in 1997.

Members automatically receive the general publications and one of the newsletters, are notified of upcoming technical seminars via e-mail and can participate in them free of charge. Each year, a two-day Annual Research Review Meeting (ARRM) is organized at IMEC to inform program members of its current activities and future plans, demonstrate technologies hands-on, and illustrate how IMEC technologies is relevant to the members' businesses. In 1997, more then 120 senior executives and researchers attended ARRM; about a third of them from Flemish companies. Because of this international mix of companies, the ARRM gives the Flemish companies the chance to build contacts with foreign companies in a local setting which is familiar to them. This significantly lowers the entry barrier for international co-operation. (Van-Helleputte 1997, p. 127.128)

Yet IMEC has had to recognize that, for the less advanced Flemish companies amongst the target group, ARRM is still "too big", and "too international". In a more aggressive move to encourage industrial upgrading in the region, IMEC has set up a second program in 1997, which is exclusively targeted at Flemish SMEs: the *Regional Fair IVB.* It is taking place each year, in different target regions of Flanders, and aims at "old" industries like fishing, textiles etc. Again, like at ARRM, IMEC's technology and know-how is offered to SMEs attending the fair. This way, IMEC hopes to reach the companies who are initially not interested enough to join the partnership program, but will spare the time to attend a local fair, as well as companies intimidated by the international character of ARRM. IVB complements the regional Flemish newsletter InterConnect, which was also launched in 1997.

Finally, in April 1998, IMEC launched a new "SME-IT" Center (in cooperation with the Flemish authorities). This is an initiative aiming to promote the use of information technology in Flemish SMEs. It will both offer seminars on IT and send advisors into interested SMEs. The latter will perform "audits" at the SMEs facilities, trying to identify opportunities for product and process innovation, using IT.

Evaluation

It can be seen that IMEC's marketing is aggressive; it does not lay back and hope that its technology will be requested by local SMEs, but takes active steps to inform them of its activities and convince them of their value for them. Especially with the newly introduced "SME-only" information channels IVB and InterConnect, IMEC is targeting SMEs in a very focused manner.

Therefore it can be said that IMEC employs best practices in this field as recommended in chapter 5.5.1.1.1.

7.5.3.2. Technology transfer through joint projects with Flemish companies

IMEC's technology marketing efforts have resulted in a number of bilateral co-operation projects with Flemish industry; 34% of its contract research stems from Flemish firms (see figure 11).

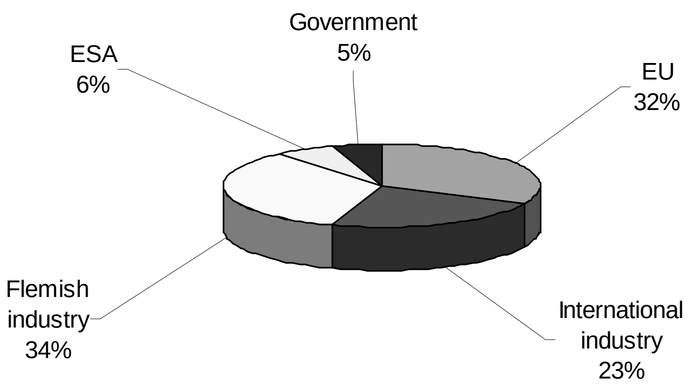

Figure 11: Sources of IMEC contract income, 1997 (Source of data: IMEC)

Its clientele has however been rather homogeneously high-tech based. IMEC's focus on leading-edge technology makes it a suitable partner for global IT corporations, as well as such smaller high-technology companies. The average local SME has little affinity to such technology (Claus 1997, p. 203).

This is represented in the type of local company IMEC cooperates with. There was cooperation with 62 Flemish companies in 1997, most of which already operate in a high-technology / IT related field (see figure 12).

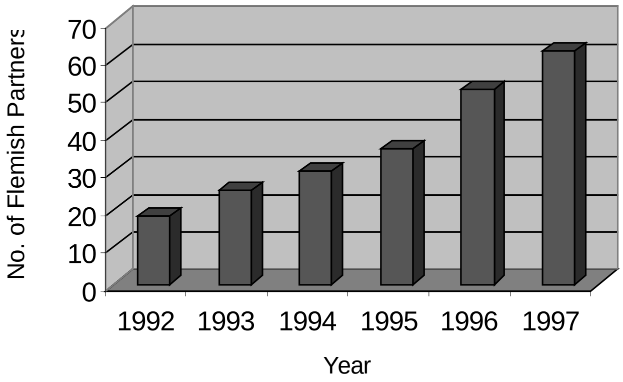

Figure 12: Evolution of number of Flemish partner companies (Source of data: IMEC)

Therefore, these projects could as well be classified as contract research work, instead of industrial upgrading. It has proven much harder to establish joint projects with "low-tech" SMEs, who are harder to reach and more difficult to convince of the benefits of high-technology in their fields. It is them, however, who face the biggest threat of obsolescence and employment losses, and who would benefit most from industrial upgrading (see chapter 5.6).

IMEC has recently taken more aggressive steps to reach such firms, as laid out in chapter 7.5.3.1.

Cooperation with the high-tech SMEs is taking place on a wide variety of topics, but is dominated by three technological fields: IC design & telecommunications, IC manufacturing technology, and Microsystems (see figure 13). Many of the projects were related to IMEC via the IWT-SME-network (see chapter 7.5.4).

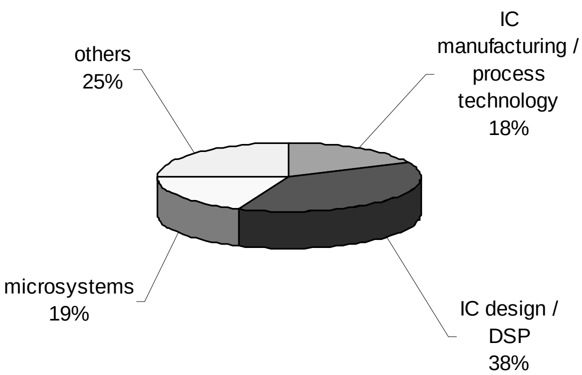

Figure 13: Areas of cooperation with Flemish companies, 1997 (Source of data: IMEC)

Yet even amongst these 62 firms, projects are not evenly spread. Much of the cooperation, both in terms of number of projects and value of contract income earned, takes place with **the one** large Belgian company: Alcatel.

Alcatel Bell (IC design and telecommunications) and Alcatel Microelectronics (IC manufacturing), with which IMEC has had the closest association since its foundation, have accounted for **more than a quarter** of all projects from 1992 to 1998.[65] It has been estimated that, of all of IMEC's Flemish contract research income, between one-third and half come from Alcatel.

The explanation for this mirrors the tendency of the universities to co-operate with larger companies more than with SMEs. Keeping in personal touch to efficiently serve a large number of SMEs requires a lot of time and effort. Serving a limited number of large firms can be done easily by a smaller staff. Furthermore, many contacts with SMEs are not going to lead to any research income, or to no result at all. But once a relationship with a large company is established, the income and project size can be considerable, as the Alcatel example shows. Therefore, from an efficiency perspective, large companies are "better" for both universities and research institutes such as IMEC.

Evaluation

IMEC reaches a good number of Flemish firms and co-operates with them. However, the cooperation is less broad and less "upgrading-oriented" than it seems, because of the already existing high-tech focus of much of its clientele, and the large share of co-operation with one large industrial player.

IMEC needs to reach more SMEs, and more "low-tech" ones, with its efforts. It needs to keep a focus on its regional development mission, and resist the temptation of "easy money" from a small number of large companies. The burdensome way of aggressively contacting many skeptical "low-tech" SMEs will eventually lead to widespread upgrading of the Flemish industry. Judging from the recent assertive marketing efforts targeting such SMEs, it is conceivable that IMEC will reach more of them in the future.

7.5.3.3. The upgrading activities of INVOMEC

Besides training IC design specialists, INVOMEC also tries to upgrade Flemish industry to a higher technological level. It does that by encouraging the use of ASICs in Flemish SMEs in the framework of the IMEC coordinated FUSE/EUROPRACTICE of the EC.

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[65] 79 projects out of a total of close to 300

INVOMEC first helps the Flemish SMEs to identify applications where ASICs would be beneficial to them, and then assists them in designing them.

The limitations laid out above also apply to this program. An SME has to be already on a more advanced level in order to take advantage of it. Yet for the SMEs that are on that level, the program is very beneficial. It provides an opportunity for SMEs without IC expertise and little funds to upgrade their technological level. The normal ASIC market cannot provide this function, because the volumes of industrial ASIC orders, despite being smaller than standard IC production volumes, are still much too large for most SME. Foundries either refuse to process the small batches required by SMEs, or charge too high prices for them.

The program offers inexpensive assistance in design and low cost, small volume production of the ASICs. Eventually, once SMEs become accustomed to the use of ASICs in their products and improved their competitive position through that upgrading process, the numbers of ASICs they use will increase. They can then gradually shift into the normal ASIC marketplace.

IMEC offers these services also to other European firms in the EC's First-User program (FUSE). FUSE is aimed at encouraging ASIC-use by European SMEs who haven't used them before, and provides funding for such projects. It is currently running 12 FUSE projects.

When an ASIC has been designed, it is then produced in small volume and low cost (5% - 10% of standard cost) by foundries in Europe. A Multi Project Wafer approach is used to achieve that, at which several designs of different FUSE clients are processed together on one wafer.

The ASICs are then used in the SMEs' products, upgrading their competitive position.

Between the start of the program in 1995 and 1997, 994 ASICs have been prototyped, and the number of customers has increased from 143 in 1995 to 217 in 1997. It must be critically remarked that, in 1997, only 20% of these customers were SMEs; the program is open to universities and research labs, as well, and they represented 80% of the customers. But the proportion of SMEs is rising quickly, in 1997, the number of SME users doubled compared to 1996. ***It is interesting to note that Belgian SMEs are the second largest customer group of the program***, with a 10% share[66] (Europractice 1998, p. 12).

[66] German firms lead with 23%.

This confirms the *technology contagion effect* as presented in the theory section on industrial upgrading (chapter 5.6) above, where the extent of adoption of advanced technology by SME increases with decreasing proximity to the source of the technology, in this case IMEC.

Evaluation

The EUROPRACTICE initiative is a typical example of upgrading encouragement as illustrated in chapter 5.6. It attempts to upgrade Flemish "sunset" industries to a new competitive level, and succeeds to do so bearing in mind the limitations laid out before. It also does so by using a technology that has a favorable local "diamond", and that has already grown some roots in the region: IC design. In time, links are likely to develop between upgraded Flemish industry and the local IC design companies. This can be the seed for a mutually beneficial partnership between "old" Flemish industries and Flemish high-tech industries. Therefore, INVOMEC's upgrading efforts are very intelligently designed.

7.5.3.4. Transfer of trained IMEC employees to Flemish companies

IMEC actively encourages a high turnover of its research personnel. During the last years, it has averaged about 17% annually. Every year, the leaving staff is replaced by new researchers, 75% of which come directly from university and gain their first work experience at IMEC. The rest is hired from industry and academia, about 20% come from abroad. This way, IMEC stays young and gives newcomers a chance to work in their field in Flanders, but also does retain links to the "outside world".

IMEC claims that the majority (about 80% on average) of the people that are leaving are going to Flanders based industry, increasing Flemish competitiveness. However, in certain fields, more than 20% leave IMEC for foreign clusters. Especially personnel leaving the IC manufacturing research groups seems to join US companies much more frequently then Flemish ones. This is not surprising considering the virtual absence of the IC manufacturing sector in Flanders, and the US dominance in the field. Contacts to these companies are obligatory and frequent due to the international presence of IMEC, and since the wages paid by them are usually higher than IMEC's and career development options attractive, a good number of people are hired away each year. Researchers leaving other groups, like the ones focusing on IC design, are more likely to join the better-developed local industry, be it established players or the new spin-offs in the field created by IMEC.

Of course, researchers leaving IMEC for other countries can act as "ambassadors" to IMEC. They can raise visibility of IMEC abroad, and help to put Flanders on the microelectronics map". The same is true for the ca. 20% of international personnel that is working at IMEC, once they return to their countries.

It is also hoped that the Flemish people will eventually return to their home region, equipped with experience and a network acquired abroad. Such "returnees" are, of course, of even greater benefit to the region than people who did not collect experience abroad. For this reason, IMEC keeps track of all its alumni. There have been several cases of people returning, and if the high-tech cluster around IMEC continues to grow, there may be more in the future. Additionally, some of the researchers attracted from abroad do stay in Flanders, with a similar effect as the "returnees".

Evaluation

The idea of an encouraged personnel turnover to benefit local industry is certainly a very good one, because it provides additional input to the available high-tech labor pool of the region, and because people leaving IMEC have applicable experience which the graduates entering it have not. They are hence more useful to local industry.

The international component of this flow has its up- and downsides. Certainly, the broadening of the international network of IMEC is a good objective. Without the presence of significant local industry, however, such a flow benefits other companies outside of the region, and the experience-drain within IMEC is not compensated by a higher social return in Flanders. Whether and if a significant number of people do return to "fertilize" their region will be seen in the future. The Flemish culture of home-attachment certainly is a supporting factor here, which makes the "returnee-scenario" not unlikely.

7.5.4. Technology programs and initiatives outside and independent of IMEC

There are numerous Flemish programs and organizations promoting innovation and R&D. They have been created by different government bodies, and there is a constant stream of new initiatives. Giving a useful overview of them is very difficult.

Most of the originally focused organizations have mutated into "one-stop-shops", aiming to provide a multitude of services to industry. They compete for government funds amongst each other, and try to portray themselves as crucial to any SME having any problem. Additionally, there are EU programs targeting the same "innovation advice marketplace". The result is duplication and confusion on a large-scale. To clearly lay out this program landscape is beyond the scope of this work.

Only the organization with the (arguably) highest profile will be mentioned here: the Flemish Institute for the Promotion Scientific-Technological Research in Industry (IWT). It:

- finances scientific and technological research undertaken within Flemish companies
- manages other regional technology stimulation programs
- advises Flemish companies on the benefits they can obtain from various EU technology programs
- Co-ordinates all Flemish intermediary organizations which provide technology advice to SMEs, and advises itself in the issue, also
- operates the above mentioned referral network for technology for SME: "IWT-SME-Network" [67]

While IWT claims Flemish leadership in the field of innovation and technology programs, many other programs have denied their subordination to it; the most prominent example are the Flemish GOMs, a network of province-based bodies who advise industry on a wide range of issues including innovation and technologies.

It is because of this confusing situation that the analysis in this paper is largely confined to activities undertaken by IMEC itself. The co-operation with IWT, especially through the recently established internet-based IWT-SME-Network, has been helping IMEC to reach SME and establish bilateral co-operation with them. It is expected to become a more powerful tool in the future with increasing usership.

7.5.5. The local universities' influence on Flemish high-tech industry

It has been shown in chapter 5.5.2 that most universities' potential in cluster stimulation lie in their educational function. This is not different in the Flemish case. The network of universities, who coordinate their research in IT related fields with IMEC, has been very beneficial to the quality and extent of the research performed at all institutions. Scientific collaboration and work sharing are boosting research output (Oosterlinck 1997, pp. 98-100).

Yet the universities' direct impact on firm formation is less clear-cut. A recent study of 31 Flemish high-tech SMEs found that, of a total of 321 ongoing R&D projects, only a minority involved cooperation with a local university (Debackere et al 1995, p. 25). This suggests that the above-cited findings - that most universities are weak in cooperating with smaller firms - are valid for the Flemish case.

Still, spin-offs have originated from the local universities. The KU Leuven has been operating an academic transfer agency as described in chapter 5.5.1.3 since 1973, with permanent staff of 8 employees. It was one of the first universities in Europe to encourage tech-

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[67] Source: IWT promotion material

nology transfer to industry in that way (Inno 1995, p. 81). It has set up 15 spin-off companies in various technological fields.[68] Amongst them are two firms that were set up jointly with IMEC and are members of DSP Valley. One, Leuven Measurement Systems, has grown into an international player since its foundation in 1979 (400 employees). Most of the spin-offs from KUL, however, operate in material science-related fields, and technology consulting. It can be said that KUL has been fairly successful in new firm creation, but most of its share of influence on the Flemish IC industry has been contributed through the transfer of experienced personnel from its ESAT institute upon IMEC's foundation.

As can be seen, the influence of Flemish universities on high-tech industries in their region is complex and cannot be covered in a few paragraphs. Since the focus of the case study is IMEC and its impact on its target industry, a more detailed analysis of the role of the universities is beyond the scope of this paper, and will not be attempted here.

[68] For a list (in Dutch language only) of spin-offs from KU Leuven, please refer to http://www.kuleuven.ac.be/admin/lr/niv2/so-i02.htm

7.6. Reporting results: tangibles and intangibles

7.6.1. Jobs created at IMEC itself, and jobs created in Flemish industry by IMEC

One of the most obvious and visible gauges of success of a regional development tool is, naturally, *created employment*. IMEC generates a fair number of jobs. IMEC's own staff has risen steadily. In 1984, upon its foundation, it employed a mere 68 researchers. In 1997, more than 750 people were directly on its payroll. Most of these jobs are well-paid, high-profile research assignments. In addition, IMEC has about 300 people directly under contract, who perform outsourced services. Another 1600 jobs were the result of its direct activities in Flanders; only employment that was clearly attributable to IMEC was counted.

Table 3: Flemish employment created by IMEC (IMEC estimates)

Direct and indirect employment by IMEC	**1,050**
Indirect employment by: spin-offs, investments in Flanders triggered by IMEC, Alcatel Microelectronics	**1,600**
TOTAL	**2,650**

Table 4: Employment created by IMEC, 1997 (Source of data: IMEC)

If one compares these numbers with the benchmark clusters, they appear small. Yet IMEC has only been in existence for 15 years. If the lead-time is considered that IMEC needed to establish a reputation and transferable technology from scratch, an active period of maybe ten years remains. Considering that the average lead-time for comparable projects is 15 to 30 years as shown in chapter 5.3 above, this result is not unimpressive.

In 1997, the Flemish government subsidized IMEC with a little over BEF1 billion, or close to US$29 million. At 2650 jobs supported by IMEC this results in a subsidy of about **US$ 10,000 per job per year**. Also, this amount is **decreasing steadily**, as the proportion of Flemish government subsidy falls, and employment rises, as both have in the past (see figures 14 and 15).

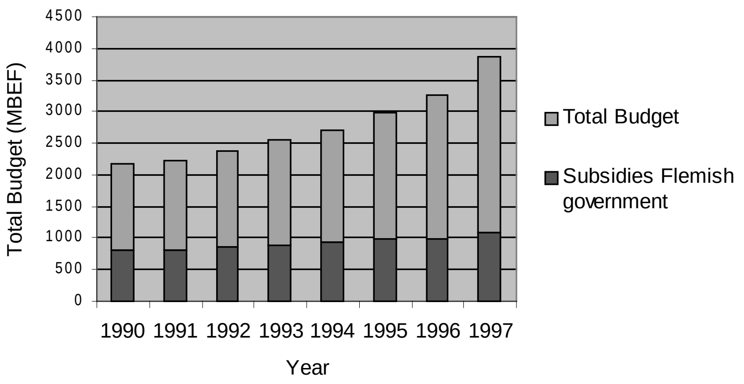

Figure 14: Declining share of Flemish government subsidies in IMEC's total budget (Source of data: IMEC)

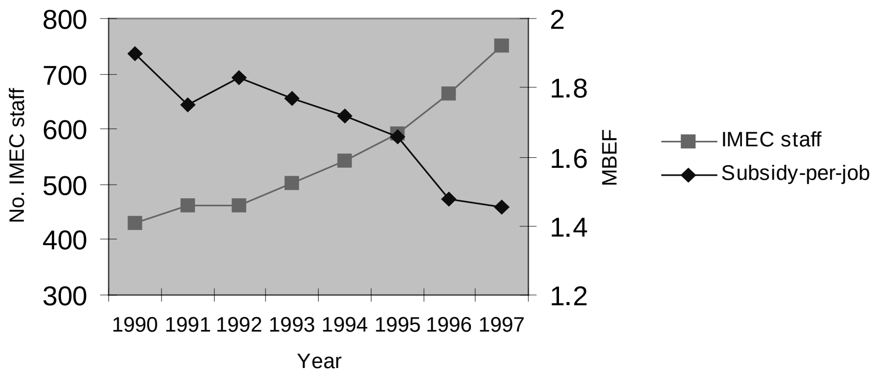

Figure 15: Decreasing subsidy-per-job, in Million BEF (Source of data: IMEC)

On sheer numbers alone, this compares favorably with the US$ 500,000+ subsidy required for each job in an FDI type fab, as shown in chapter 5.4.2. Assuming an optimistic 20-year period of operation for a fab, and no subsidies to its operation after the initial package, such a fab job is still subsidized with **US$ 25,000 per year**.[69] In the face of rising competition

[69] Calculation ignores time-value of money for the sake of simplicity.

for fabs, the size of the subsidy packages has also been increasing. Therefore, the subsidy for fab jobs displays a **rising trend**.

Additionally, it has been shown that spin-offs and start-ups, which are the backbone of endogenous regional high-tech development, originate predominantly from research work, and are undertaken by researchers (see chapter 3.2). Therefore, the jobs created by IMEC have a much higher intrinsic value to the region than any "blue collar" IC manufacturing jobs. They have a multiplier potential in the region, which is unmatched by manufacturing jobs. Also, they are much more locally rooted than any fab operation would be, and are less likely to share the fate of facilities like Siemens' in the U.K., which have been closed down quickly on headquarters' orders in times of crisis.

It can therefore be concluded that IMEC's bottom-up activities have provided much better value-for-money than a comparable FDI-strategy would have.

7.6.2. Intangible results

It is always hard to put a dollar value on the intangible results of regional development. But it can be assumed that the **publicity** IMEC has been creating in the electronics community has raised the profile of its area considerably. The rising numbers of both scientific publications by IMEC, its multitude of international cooperation agreements, and the increasing coverage in the media of IMEC are signs of that.

The Leuven/Flanders region has been put on the "microelectronics map" through IMEC's activities, not least through the people it has trained and that have left the Flanders to work in other clusters. This high-tech image is especially valuable for attracting FDI complementary to bottom-up endogenous growth.

In addition, IMEC's activity may be helping to **raise the prestige** of high-technology amongst Flanders' population, and increase awareness of high-technology's potential in Flemish industry. This way, the entrepreneurial climate and the appetite for high-risk, high-gain ventures can be raised, and productivity boosted.

Step-by-step, IMEC and its effects could prod its "client population" to **develop a mindset** similar to the one found in Silicon Valley - an attitude which is intangible yet so important to its success formula. IMEC's aggressive marketing of its activities, combined with the concerted training effort, points to that direction.

7.7. Summary and outlook to the future

In this case study, it has been shown that the predictions of Porter's "diamond" model are applicable to the regional development efforts of the IMEC institute. The Flemish industrial base that IMEC has had to work with has provided important evidence to explain why some of its efforts have been more successful than others.[70]

Furthermore, it was demonstrated that the conceptual superiority of "bottom-up" growth measures holds true in IMEC's case, as well. They have provided visible results, while IMEC's "top-down" efforts have largely failed so far.

And yet: The results that IMEC has produced, and the cost efficiency with which they were achieved, shows impressively that research institutes, with the right policies, can be very powerful regional development tools, as has been stated in the theory section above. The emergence of DSP Valley proves that fact.

In addition, the limitations of pure high-technology industry as a relief to the decline of old industries have been recognized by IMEC. Its industrial upgrading efforts are broad and well designed.

This completeness of IMEC's development measures - the use of all the approaches illustrated in the theory section - is the reason why IMEC has had a significant, beneficial effect on the development of a microelectronics industry in Flanders, despite a difficult starting position.

In the future, IMEC plans to leverage the impact of the existing high-technology "pockets" in Flanders (like DSP Valley and the Flanders Language Valley) by connecting them with a communications network. The hoped-for result - a group of cooperating high-technology clusters - is to be promoted as a "virtual IT-park" in Flanders. This plan, if executed mindfully, could produce a new, extended cluster, with both more rivalry and synergies. The plan is a further indicator that IMEC's policy designers are not standing still.

If the significant time lag inherent in regional development measures is taken into account, IMEC has already achieved much in its 14-year history. With the current policies, and assuming a continuous adaptation to the path that its industry will take, IMEC has the poten-

[70] The author recognizes that other players in the Flemish innovation-landscape have played - and continue to play - an important role to Flemish high-technology cluster growth. A more in-depth analysis of both the local universities' influence, as well as of the effect of the numerous technology-assistance organizations, would shed more light on the complex picture. Attempting to include that analysis in this thesis, however, would have exceeded both the time and space limitations that the author has faced in its creation. In this instance, focus has been chosen over breadth.

tial to eventually accomplish the vision of its founders: to create a sprawling microelectronics industry in Flanders.

8. Annex

8.1. Silicon Glen - Project Alba

In a new program called "Project Alba", Scottish Enterprise and Cadence Design Systems, Inc., the worlds biggest maker of chip design automation software, hopes to boosts exactly the R&D capabilities that Silicon Glen is missing so far. Cadence will set up a major design center, employing up to 1,800 designers (about 10% of the total global workforce in the field) by the year 2004. It will focus on the design of "systems-on-a-chip", a part of the semiconductor market with double digit growth rates, including related issues such as development, protection, and exchange of intellectual property building blocks used in the design of these chips.

This time, however, the assistance will not only come through financial assistance, although a 30% contribution to the proposed US$ 160 million investment is part of the package. The plan includes the creation of the world’s first "Systems-Level Integration Institute", a specialized college jointly operated by the four mayor Scottish universities in close collaboration with Cadence and an international panel of SLI experts[71]. This will ensure a steady stream of graduates well-tuned to the design company’s needs. Attracting 1,800 designers from outside Scotland would be close to impossible, as a severe shortage of designers causes problems for companies even in more attractive regions with higher living standards, notably Silicon Valley in the USA. By providing such a resource, and advanced factor, Silicon Glen is beginning the upgrade process crucial to its growth. (Semiconductor Business News 1997)[72].

It is reckoned that this setup of industry-university collaboration has the potential to spur a host of new spin-offs in the future, and thus fundamentally alter the mix of businesses found in Silicon Glen. With application of the standard 30% financial assistance package, it also provides much more value to the UK taxpayer: ca. US$ 50m will finance 1,800 well-paid jobs, not counting the many more that are likely to come as a result of the expected spin-offs.

Flanking these educational measures will be the creation of a new exchange system for the intellectual property building blocks, or "core designs", mentioned above. The Scottish

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[71] IMEC has contributed to this project through consulting. IMEC’s INVOMEC designer training program has served as a model for project Alba

[72] article retrieved from **online archive** [no pagination]

government has already made adaptations to its laws on intellectual property which make it easy to develop, protect and trade such blocks without the high costs associated with that in the USA. On top of these, the "Virtual Component Exchange", modeled on a stock market, will attempt to provide optimum condition for system-on-a-chip design activities by streamlining transactions, saving buyers the effort of negotiating separately with every core vendor (Clarke 1998).[73]

The problem of risk capital access is also being addressed by the setup of two venture capital funds called Scottish Equity Partnership and Scottish Technology Fund in 1997. Both concentrate on investment in high-technology start-ups. Scottish Enterprise hopes that this will improve capital availability for small firms.[74]

As evident by these recent measures taken, Scotland’s developers have altered their course in an attempt to adapt their traditional "top-down" approach and complement it with more sustainable, organic growth rising "from the bottom".

[73] article retrieved from **online archive** [no pagination]

[74] Source: http://www.scotent.co.uk (Scottish Enterprise)

8.2. List of IMEC spin-offs - by area of activity

IC design

Name	Activity	Year of creation
Frontier Design (EDC)	Development of CAE design software	1989
Easics	Design of VLSI-ASICs	1992
HP-Belgium (former Alphabit)	Development of CAE software packages for the de-sign of high-frequency and high-speed elec-tronics	1992
Sirius Communi-cations	Satellite communication ICs based on spread spectrum and IMEC design technology	1996
Target Compiler Technologies	"Retargetable" code generation for design and pro-gramming of DSP processors	1996
CoWare	Hardware/software co-de-sign	1996
SmartMove Technology	Development of a telematics platform	1996
AnSem	Analog design services	1998

IC manufacturing

Name	Activity	Year of creation
JSR Electronics	Marketing and services of JSR photoresists and Plasmamask®	1986
Cobrain/Matrix	Optical lithography, etch and surface treatment	1987

Microsystems

Name	Activity	Year of creation
Destin	New measuring method for reliability of electrical and electronic components	1992
C-Cam Technologies	CMOS image sensors and cameras based on the FUGA technology	1995
LCI-Smartpen	Commercialization of the smartpen concept	1996
OligoSense	Production of a new type of smell-sensor for an "electronic nose"	1998

Solar Cells

Name	Activity	Year of creation
Soltech	Solar panel assembly	1989

8.3. List of Key Interview Partners

Name	Position	Date interviewed
Prof. Koenraad Debackere	Catholic University of Leuven, Professor Innovation Management	9.3.98
Kristin Deneffe	IMEC, Head of Flanders Technology Transfer Group	15.4.98
Niek van Dierdonck	IMEC, Head of Telecom Technology Transfer Group	15.5.98
Bob Grietens	IMEC, RVG (responsible for spin-offs)	19.5.98
Karel Derevaux	IWT, Scientific Advisor	19.5.98
Luc Van den Hove	IMEC, Head Optical Lithography Division	2.6.98
Gilbert Declerck	IMEC, Vice President ASP	2.6.98
Roger de Keersmaecker	IMEC, Vice President responsible for attraction of FDI-type investment	3.6.98
Etienne Bourdeaud'hiu	IMEC, Vice President INVOMEC	15.7.98
Johan van Ginderdeuren	Philips ITCL, Technology Liaison Officer	15.7.98
Ivo Bolsens	IMEC, Vice President VSDM	16.7.98
Kris van de Voorde	IMEC, RVG (responsible for contact with Flemish industry)	15.6.98
Johan van Helleputte	IMEC, Vice President Research Valorization	4.8.98
Erik Daenen	IMEC, Vice President Personnel	5.8.98

8.4. List of Abbreviations

AEA	American Engineering Association
ARRM	Annual Research Review Meeting
ASIC	Application Specific Integrated Circuit
ATM	Asynchronous Transfer Mode (network technology)
BI	Background information
KUL	Catholic University of Leuven
DEC	Digital Equipment Corporation
DSP	Digital signal processing
EC	European Commission
EITO	European Information Technology Observatory
EU	European Union
FDI	Foreign Direct Investment
FFIO	Flanders Foreign Investment Office
GDP	Gross Domestic Product
GIMV	Flanders Investment Company
GOM	Flemish regional business assistance agency
High-tech	high-technology
IC	Integrated Circuit
IMEC	Inter-university Microelectronics Center
IMO	Flemish Advanced Materials Institute
INVOMEC	IMEC training division
IIAP	IMEC Industrial Affiliation Program
IP	Intellectual property
IPO	Initial public offering
IT	Information technology
ITRI	Industrial Technology Research Institute
IWT	Flemish Institute for the Promotion Scientific-Technological Research in Industry
KU Leuven, KUL	Catholic University of Leuven
ESAT	KU Leuven electrical engineering department
MCC	Microelectronics and Computer Technology Corporation
SEMATECH	Semiconductor Manufacturing Technology Consortium
MIT	Massachusetts Institute of Technology
R&D	Research and Development
RVG	Research Valorization Group
SDA	Scottish Development Agency

L&H	Lernout & Hauspie
LIS	Locate in Scotland
Fab	Semiconductor manufacturing plant
FUSE	First User Program
SIA	Semiconductor Industry Association
SIC	Standard Industrial Classification Code
SBIC	Small Business Investment Company
SME	Small and medium sized enterprise
VIB	Flemish Institute for Biotechnology

8.5. List of Figures

8.6. List of Tables

8.7. References

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