Policies to stimulate regional innovation capabilities via university-industry collaboration: an analysis and an assessment

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In this paper, we demonstrate how regional economic policies to stimulate entrepreneurship and innovation, can lead to successes. More specifically, through a detailed theoretical and empirical analysis, we discuss the critical ingredients that can lead to regional innovation and economic success. These critical ingredients consist of a balanced mix based on the presence of research institutes, a texture of endogenous knowledge-intensive start-ups coupled to larger R&D-intensive incumbents, all of them embedded in a professional environment that supports business advice and services. We illustrate the effects of this mix using empirical material from various innovative regions around the world.

1. Introduction

Since the arrival on the scene of Joseph Schumpeter's groundbreaking body of thought, it has been clear that innovation and entrepreneurship are closely interrelated. This interrelation has become the point of departure for a wide range of studies that make the link between innovation, entrepreneurship and economic growth. In particular, in recent years the interaction between innovation, entrepreneurship and regional economic development has become a central theme in many policy circles. Examples such as Cambridge UK and Cambridge USA, and, more emphatically, the phenomenon of Silicon Valley, are the driving forces behind this interest. Today almost every European region is attemping to put together the ingredients necessary for endogenous economic growth, based on the innovative capacity and the enterpreneurial dynamics that can be mobilised in a particular region. The realisation of such endogenous growth does, however, necessitate a deeper insight into the parameters and the dynamics upon which it is based. That is the aim of this article.

On the basis both of a study of the literature and of empirical data, we offer an overview of and an insight into the manner in which knowledge-driven entrepreneurship shapes regional development. The results of this synthesis point to the necessity for a complex and guided interaction between insititutions of learning,

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established businesses and new start-ups, with sufficient attention paid to the network of professional enterprises and infrastructure which frames such interaction. Drawing on examples from the USA, Europe and, more specifically, the Leuven region, this synthesis will be further substantiated.

2. Positioning regional innovation systems

Innovation and the stimulation of innovation requires interaction and connectivity between multiple actors. Besides the corporate world and the knowledge centres present (including universities), (local) governments are also involved. Over the last decade, there has been an increasing consensus on this point in the literature on technology and innovation policy. A particularly important contribution in this regard is the influential work of Michael Porter (1995), as well as the notion of the 'triple helix', which rose to prominence during the second half of the 1990s (Leydesdorff and Etzkowitz, 1996, 1998; Etzkowitz and Leydesdorff, 1997, 1998). The 'triple helix' model can be seen as a way of providing greater insight into the complex dynamics between three types of actors: government, business and knowledge centres. These dynamics influence the creation and the diffusion of knowledge, the production of value added with its attendant market dynamics, and finally, regulation.

The explicit starting point is the notion of co-evolution, in which the various actors influence one another, each with a particular role and capacity along the innovation value chain. Karnoe and Christensen (1999) have recently added a contextualised perpective to this discussion:[1] the most relevant form and trait of economic organisation – and thus of goal-oriented policy as well – are partly function of the specific institutional context of a country or a region. In this sense, it is also possible to speak of a more and more contextualised view on innovation policy. This observation is important for reaching potential policy conclusions. 'Best practices', such as those discussed below, always imply a 'translation' to a particular situation and context. Moreover, this observation fits perfectly into the models dealing with technology-development as described in the work of Nathan Rosenberg (1982), in which the role and the presence of technological interdependencies are outlined.

3. Current insights into regional innovation systems

Recent literature has paid much attention to the various factors that influence the creation and the success of high-tech start-ups. In general, it is possible to distinguish three groups of factors that facilitate this process. In the first place, there are general environmental factors, necessary for innovative starters to be able to establish themselves in a particular place and to develop successfully. Second, recent literature and empirical studies have further distinguished industry-related success factors. Finally, high-tech start-ups must themselves possess a number of qualities and competencies in order to survive and to grow. Each of these groups of factors will be further discussed below.

General environmental factors

In their study on the innovation policy of the Malaysian government, Joseph Tidd and Michael Brocklehurst (1999) point to two important dynamics: on the one hand, innovation implies endogenous growth *while* on the other hand, collaboration with or investment by foreign companies in a country is a highly necessary complement to endogenous growth. Both endogenous and exogenous innovation appear only to be successful when a country or a region has at its disposal a *critical* mass of research *and* production competencies.

Closely related to this, it can be stated that the access to knowledge centres – implying the presence of such centres – is a crucial facilitating factor. This relation, cited in the models of the authors already mentioned, has recently been empirically confirmed in a German study. Research into 18 technology regions in Baden-Würtemberg and Nordrhein-Westfalen (Blind and Grupp, 1999) suggests a clear link between the public institutions of higher education and learning and the technology-output in a particular geographical area or region.

This conclusion can be complemented by further specifying the role of knowledge centres,

including universities. The greater the 'enterpreneurial' character demonstrated by these institutions, the greater the positive impact on the development of a region in terms of its innovation performance (Porter, 1995). Universities can hereby play a crucial dual role, related to the dichotomy of knowledge-creation and knowledge-diffusion. This dual role provides the universities with the status of preferred and natural partners for high-tech innovation and venturing. Likewise, Tijssen and van Wijk (1999) underline the importance of collaboration between academic institutions and industry. The absence of interaction between scholarship and technology is, according to these authors, one of the most important reasons for the technological inferiority of Europe compared with the USA and Japan. This is the so-called 'innovation deficit'. Bibliometric analyses show that Europe is very much present in terms of scientific scholarship, but that European industry has only to a more limited degree been able to translate this knowledge into patented applications (Debackere *et al.*, 1999 Debackere, 2000). This opinion is shared by Porter (1995). It is also confirmed by the recent innovation scoreboards developed and published by the European Commission.

All of this would tend to suggest an increasing complexity in the collaborative relationships between the academic world, industry and government. For instance, Cox *et al.* (2000) mention that the nature of the relationship between the academic world and industry becomes increasingly diversified, a situation which calls for a new balance between collaboration and competition. Universities and companies are partners in collaborative ventures, but they are at the same time also competitors, since universities are increasingly commercialising their knowledge through licensing activities and through spin-off companies. Universities compete with one another for research funds (partially provided for by companies) and for winning companies' sponsorship and financial assistance for training. Cox *et al.* (2000) emphasise the importance of intermediary structures that influence the interaction between research institutions and industry, monitoring it in the 'right' direction while balancing the need for academic freedom on the one hand and the industrial requirements of confidentiality and protection on the other hand. This role can be performed by the institutions themselves, by major laboratories or by special transfer companies set up for exactly this purpose.

A last important environmental factor, found in the literature, is the presence of well-developed financial markets. Starting a company often requires considerable amounts of external financing. Once a company has successfully survived the start-up phase, its continued growth is often only possible by an even greater injection of new capital. Banks are often not well-placed to assess a start-up's chances of success: they are in general averse to risk, opting for relatively safe investments with an early return on investment. For this reason, the availability of venture capital and the accessibility of more informal 'business angels' are of crucial importance for the chances of success of a young high-tech firm (Van Osnabrugge and Robinson, 2000). Such investors are better able to assess the risks and likelihood of success associated with a company based on their experience with risk management at a portfolio level; this also puts them in a position to provide advice on financial, strategic and commercial matters (Bygrave *et al.*, 1999). In addition to the presence of capital, the notion of 'networked incubators' (Hansen *et al.*, 2000) has been advanced as yet another critical contextual success ingredient. Hence the emphasis on both capital and networking as critical ingredients of a stimulating high-tech environment.

Industry-related ingredients

Besides the general environmental factors, Tidd and Brocklehurst (1999) also identify several sector-related supply and demand factors that stimulate innovation. The success of new high-tech ventures is partly dependent on the local demand for their products and/or services. If the local market is too small, internationalisation will quickly appear on the agenda, adding to the complexity of the total operation of the company, including the need for financing. An orientation to local, existing needs and markets will allow a company to progress more quickly along the learning curve, with decreased risk and less financing needs.

On the supply side, a sufficient degree of competition appears to provide a stimulus for

companies to innovate. As a result, an innovation policy should not only aim towards the expansion of a few large firms, but ought also to allow for a diversity of competing companies and even stimulate this diversity. Did not Bill Gates say that 'the problem in Europe is not the lack of knowledge, it's the lack of knowledge-based companies'? The number of software firms that was created in the USA in the period 1980–1995 was almost 6000. This is about tenfold what Europe produced in the same period (Second European Report on Science and Technology Indicators, 1997). When 'a thousand flowers or initiatives are allowed to blossom,' the dynamics of competition, innovation and subsequent failure and success can more fully come into play. Or as Lester Thurow, the former dean of MIT Sloan School of Management, aptly and provocatively put it in his insightful book, *Creating Wealth* (1999):

> But when it comes to generating billionnaires, the mystery is not in America, Asia, or Africa. The mystery is in Europe. Why have the Europeans been able to exploit neither the Asian-style developmental disequilibrium opportunities that exist between Western and Eastern Europe nor the American-style technological disequilibrium opportunities that exist because of new technologies? Why haven't they invented some new sociological disequilibriums? (p. 36) … In the century ahead the economic game will be played on three levels. If any nation wants all of its citizens to have first-world earnings, it has to ensure that each of its citizens is as well skilled and educated as any in the world. If they are to participate in the new man-made brainpower industries of the future, their countries will have to be leaders in research and development and have the entrepreneurs to develop some of the big breakthrough ideas into actual products. Companies will play the game based upon the skills they employ, the capital investments they make, their technical prowess, and their ability to globally source and sell new products. Individuals will play the game based upon their education and skills—and their willingness to change. There is no reason to believe that Western Europe cannot play this three-dimensional game. But it has to want to lead change rather than be dragged unwillingly into the very different twenty-first century economy. It has to want entrepreneurs and be willing to reorganize itself to allow them to come into existence (pp. 97–98).

Additional points of interest for an innovation policy clearly include the degree to which and the rate at which young starting companies are exposed to the market (cf. the notion of 'protected niches', as developed by Schot and Rip, 1997). In this respect, it should be emphasised that the growth and the development of high-tech ventures must not be limited to 'making' technology ready for the market. The development of the management experience in a company is equally necessary. Here success demands a certain degree of equilibrium. Too much exposure to excessive competition can also have a very negative influence on a high-tech starter's chances of continued growth, a fact shown clearly in the work of Zahra and Bogner (1999), who document the ups and downs of 116 software start-ups.

Also relevant in this respect are the observations by Deeds *et al.* (1997). In their study on the biotech industry in the USA, they looked at the influence of various factors on the amount of capital that IPOs (Initial Public Offerings) generated. These amounts give an indication of the value and thus the potential success of a start-up. Geographical proximity was shown to be very influential in these cases: a geographical concentration of companies in the same sector leads to the competitive rivalry mentioned above but also to more collaboration between companies (see also Stuart, 1998). Geographical clustering is thereby shown to have a positive effect on a company's market value and on its product-development competencies. This phenomenon will come to light again in our subsequent discussion on a number of specific regional initiatives.

Moreover, in the context of high-tech venturing, this observation can be further developed. Innovation is stimulated not only by the geographical concentration of companies with *similar* technologies, but also by a concentration of companies that are active in *different* technology sectors. New technologies and even completely new sectors of economic activity often arise out of precisely this interplay and the convergence between different knowledge disciplines and

technologies. A good example of this is the sector of bio-informatics, which originated from data-mining/computer science know-how on the one hand, and bio-genetic/biomedical know-how on the other hand. The physical proximity that supports this kind of cross-fertilization is an important facilitating factor in such cases.

Company-specific ingredients

In addition to the above, it is obvious that high-tech venturing implies a number of specific challenges in the area of operational management. Besides the relevance of experienced management, a number of specific points of interest can be further underlined in relation to successful high-tech venturing at the company level (Zahra and Bogner, 1999; Deeds, *et al*., 1997; Griliches, 1990; Narin *et al*., 1987; Cox *et al*., 2000; McCann, 1991; Bruno *et al*., 1992; Stuart, 1998). These relate to the availability of sufficient human capital and talent, to finding a balance between scientific/technical ambitions and market developments and customer imperatives and finally, to the development of a suitable internationalisation strategy (certainly in instances where home markets are small) including the appropriate handling of make-and-buy decisions when teaming up with partners during the search for and the development of complementary assets. Cox *et al*. (2000) emphasise the importance of well-trained employees in all these respects: for high-tech ventures, this is the *sine qua non* for the further expansion of the firm. Once again, the proximity of – and interaction with – knowledge centres (particularly universities) is of vital importance here.

In addition, a balance needs to be found between the technology- and the market-orientation of a high-tech venture in situations characterised by a high degree of uncertainty. In their 1999 study, Deeds *et al*. state that the quality of the research team has an important influence on the product-development competencies of a company. These are then positively influenced by the experience of the entrepreneurs/CEO with the management of product development. The authors further recommend that management and research functions be kept strictly separate. In their opinion, the interference of scientists in the management of a company hampers the successful development and commercialisation of new products, since it diverts attention and time away from R & D. Counterexamples can, however, also be found in this regard. Rather than a strict separation, it results in striking a suitable balance between technological (R&D) ambitions and objectives – the effects of which may be situated in the middle term – and the short-term realisation of turnover and value added. This twofold aim demands an evenly composed management team; the same goes for the organisational structures that are implemented (see also Steyaert, 1995). Attracting experienced, complementary management skills clearly is an important factor (see also McGee and Dowling, 1994).

Finally, it should be noted that high-tech ventures are in general confronted relatively early on in their lives with questions of internationalisation. This observation is linked to the increasing internationalisation so clearly manifested in the area of science and technology. Coupled with this is the observation that high-tech firms often occupy a niche position. The realisation of a sufficient critical mass, in particular in terms of turnover and margin, generally implies some form of internationalisation. In interviews with founders of successful companies in Northern California (Bruno *et al*., 1992), international expansion was identified as one of the critical milestones in the growth of the company. This milestone will be reached more quickly when the entrepreneur/CEO has a positive attitude towards internationalisation, as well as sufficient access to the necessary competencies within the firm (Preece *et al*., 1998). This study shows that a broad or all-inclusive internationalisation in the initial phase is a less appropriate strategy. In order to implement an internationalisation strategy successfully, the company needs to have at its disposal a critical mass of knowledge, experience and resources. The greater the extent to which this critical mass is lacking – a situation usually inherent in starting enterprises – the more appropriate the choice of a dedicated international focus, which is then best limited to a number of well-chosen regions in the world. However, if such competencies are successfully acquired and developed early on in the lifespan of a firm, then the rapid seizure of the opportunities of internationalisation seems to have a positive effect both on the growth of the firm and on the

motivation of the entrepreneurial team (Autio *et al*., 2000).

The interaction between factors: a few recent empirical insights

The various studies mentioned above all emphasise the importance for a high-tech start-up to both think and act locally and globally. A successful internationalisation strategy can, however, only bear fruit if the local/regional environment offers the high-tech start-up enough opportunities to build up its critical mass of both technological and market-oriented competencies (Debackere, 1998, 2000). The importance of this local/regional embedding is further underlined by the empirical research recently carried out on 125 regional statistical entities (the so-called 'Metropolitan Statistical Areas' or MSAs) in official use in the USA (Varga, 1998). The main results of this research are given below in Table 1.

On the basis of this research, the following observations may be made concerning the stimulation of the innovation-output in a particular MSA:

1. R&D employment in the industry sector of a particular region {variable: log (RD: industrial RD employment)} has a positive *main effect* on the innovation-output (as measured in this study) in the MSAs under consideration;
2. The R&D expenditures in the universities of the regions under consideration {variable: log (URD: university RD expenditures)} have in and of themselves a statistically significant yet *negative main effect* on the innovation-output (dependent) variable being used (when *no* interaction-effects with other local variables are taken into consideration). As we shall see, a region's university-level research only has a positive effect on the innovation-output in that region if there is sufficient interaction between the academic research and the high-tech/professional entrepreneurial environment. It is obvious that this calls for a sufficient presence of such a high-tech/professional environment;
3. In contrast to the previous *main effect* (log (URD)), the interaction variable {log (Concentration high-tech ventures)$*$log (URD)} does have a positive *and* statistically significant effect on the dependent variable. In other words, the interaction between the presence of a flourishing texture of high-tech ventures/start-ups, coupled with the presence of a strong basis in a region's university-level research, has a significant and positive impact on the innovation vitality of the MSA;
4. However, the interaction between academic research and the high-tech entrepreneurial environment is not the only factor with a positive effect on the regional innovation-output as identified. The interaction between the presence of a sufficient degree of professional entrepreneurial support systems (such as consultancy, venture capital and legal competencies) in a region and the degree of academic research has a positive and statistically significant effect on innovation-perfor-

Table 1. Regional location-factors promoting innovation.

Model	OLS full	OLS intermediate	OLS final
Constant	−0.230* (0.183)	−0.315* (0.157)	−0.381* (0.154)
Log (RD: industrial RD employment)	0.270* (0.056)	0.283* (0.054)	0.295* (0.054)
Log (URD: university RD expenditures)	−0.302* (0.141)	−0.190* (0.067)	−0.186* (0.067)
Log (Concentration high tech)*log(URD)	0.185* (0.036)	0.184* (0.036)	0.188* (0.036)
Log (Presence business services)*log(URD)	0.081* (0.015)	0.085* (0.014)	0.088* (0.014)
Log (Enrollment)*log(URD)	0.026 (0.029)	—	—
Rank*log(URD)	0.033 (0.020)	0.035 (0.020)	—
Log (% large established firms)*log(URD)	−0.094* (0.025)	−0.096* (0.025)	−0.098* (0.025)
R^2-adjusted	0.737	0.738	0.733

Dependent Variable = Log(Number of innovations counted – specifically, patents and new product-introductions – on MSA level).
N sample = 125 US Metropolitan Statistical Areas,* = Coefficents significant at $p = 0.01$-level.
Standard deviation from the average shown in brackets.
Model: Ordinary Least Squares regression models.
Source: Varga (1999).

mance in the region {interaction variable: log (Presence business services)∗log (URD)};

5. Furthermore, the education-related variables {log enrollment} as well as the interaction between 'ranking' and university research {rank∗log (URD)} appear to have no statistically significant effect on the innovation-output at the regional level. An overly strong presence of large, established firms, in interaction with academic research {interaction variable: log (% large established firms)∗log (URD)}, appears in turn to have a significant yet negative effect on the innovation-output in the regions in question.

In short, the picture that emerges from studies into the influence of regional embeddedness and location factors on regional innovation performance demonstrates the need for sufficient texture and critical mass in terms of the *interactions* beween university research on the one hand and a high-tech, R&D-intensive industrial environment on the other, whereby sufficient attention is also to be paid to a professional support system.

4. Findings regarding the establishment of a high-tech venturing policy

High-tech venturing: a survey of several regions

As mentioned earlier, high-tech venturing benefits from geographical proximity. This comes as no surprise. The creation of new products and services, depending on new insights in both scientific and technological domains, implies interaction and cross-fertilization. In discussions with players actively involved with the development of such initiatives (Leuven, Cambridge, Sophia Antipolis), this connectivity is repeatedly cited as a necessary – yet often overlooked – condition for the creation of a successful breeding-ground for high-tech venturing. In a qualitative study published in *Wired* (August, 2000), a survey is made of regions that occupy a strong position in terms of high-tech venturing. The regions are scored according to four factors: the presence and performance of universities and other knowledge centres, the presence of established firms, the presence of high-tech start-ups and finally, the availability of venture capital. These four factors are each scored on a scale from 1 to 4, where 1 represents 'moderate' and 4 'excellent'. The results of this analysis are shown in Table 2.

In the following paragraphs, a number of specific initiatives for venturing policy are further discussed, while crucial ingredients concerning a policy aimed at stimulating high-tech venturing are identified.

German governmental policy

Over the past 15 years, Germany encountered some difficulties in launching 'new' high-tech industries. The number of high-tech starters was limited. According to Lehrer (2000), these problems were caused by missing links in the innovation chain, at the national, regional and company/employee levels respectively.

At the national level, the absence of well-developed capital markets formed an obstacle to starting up new technology firms. The German financial system was characterised by the domination of banks oriented to existing German industries, with much less interest in – admittedly riskier – investments in new technologies and their related industrial sectors. Moreover, these existing industries were thriving in an institutionalised environment characterised by sector-specific unions and employers' organisations that together with the government shaped economic policy, which again tended to be directed towards already existing sectors, rather than new industries. At a regional level, Lehrer identified a clear lack of the relevant structures and instruments necessary for creating and supporting high-tech networks. At the level of individuals, finally, Lehrer observed a climate of risk-aversion and a shortage of entrepreneurship, a situation encouraged by a public university educational system in which entrepreneurship was not stimulated.

The German government recognised the need for a technology and innovation policy. A Delphi study was carried out in the early 1990s, commissioned by the Federal Ministry of Research. Various problem areas at the individual, regional and national level were identified. The regions had, since the middle of the 1980s, taken on the role of technology stimulators. Regional technology parks and incubators were set up. Industrial networks were developed at a regional

Table 2. High tech venturing 'hot spots' (source: Wired, 2000).

Location	Country	Universities/ research	Established companies	Starters	Venture capital	Total score
Silicon Valley	California	4	4	4	4	16
Boston	Massachusetts	4	4	3	4	15
Israël		4	4	4	3	15
Stockholm-Kista	Sweden	3	4	4	4	15
Helsinki	Finland	3	4	4	3	14
London	England	4	3	3	4	14
Raleigh-Durham	North Carolina	4	4	3	3	14
Austin	Texas	3	4	4	2	13
Bangalore	India	3	4	3	3	13
San Francisco	California	3	3	3	4	13
Taipei	Taiwan	4	3	3	3	13
Albuquerque	New Mexico	4	3	3	2	12
Cambridge	England	4	3	3	2	12
Dublin	Ireland	3	3	3	3	12
Montreal	Canada	3	4	2	3	12
New York City	New York	3	3	3	3	12
Seattle	Washington	3	4	3	2	12
Beieren	Germany	3	3	2	3	11
Hsinchu	Taiwan	3	4	1	3	11
Kyoto	Japan	4	1	3	3	11
Los Angeles	California	3	3	2	3	11
Malmö	Sweden	3	3	2	3	11
Copenhagen	Denmark	3	3	2	3	11
Tokyo	Japan	3	2	3	3	11
Flanders	Belgium	4	2	3	2	11
Baden-Wrttemberg	Germany	3	3	2	2	10
Melbourne	Australia	3	2	3	2	10
Oulu	Finland	3	2	3	2	10
Paris	France	2	2	3	3	10
Thames Valley	England	3	3	2	2	10
Virginia		3	3	2	2	10
Chicago	Illinois	3	2	2	2	9
Hong Kong		3	2	2	2	9
Queensland	Australia	2	3	2	2	9
São Paulo	Brazil	1	3	3	2	9
Campinas	Brazil	4	3	1	0	8
Glasgow-Edinburgh	Scotland	3	3	1	1	8
Inchon	South-Korea	2	2	2	2	8
Kuala Lumpur	Malaysia	2	3	1	2	8
Sachsen	Duitsland	3	2	1	2	8
Salt Lake City	Utah	3	2	2	1	8
Santa Fe	New Mexico	3	2	2	1	8
Sophia Antipolis	France	2	3	2	1	8
Singapore		1	2	2	2	7
Trondheim	Norway	2	1	2	1	6
El Ghazala	Tunesia	1	1	1	1	4
Gauteng	South-Africa	1	1	1	1	4

level, while the establishment of new branches of the Fraunhofer Institute, a highly successful centre for technology transfer, was stimulated by the Länder. The regional policy was directed toward the improvement of regional systems of technology transfer in connection with existing industries. There were, however, few if any initiatives to support the launch of new technology sectors. And yet there was – and is – a broad base of knowledge present in the area of basic research and applied scientific research. The weak position of Germany in new high-tech industries was therefore rather to be found in the manner in which this scientific knowledge was translated

into commercialisation in new markets. In addition, there were few collaborative arrangements between public research organisations and companies. Moreover, there was a clear lack of entrepreneurial mindset.

In the middle of the 1990s, the Länder took a number of steps aimed at improving the interaction between scholarly work and industry, as well as at stimulating entrepreneurship. For instance, over the past five years alone, Bavaria has already invested an additional DEM 5.5 billion in setting up a broadband IT infrastructure between governmental bodies and research institutes, in increasing the number of technology-oriented university programmes, in the development of liaison offices to support the knowledge transfer between universities and the business world and also between public research institutes and companies, and finally, in supporting entrepreneurs.

A number of auxiliary measures were further taken. German law – especially the strict rules concerning bankruptcy – was discouraging entrepreneurship. At the beginning of 1999, the law was relaxed in order to decrease risk aversion. The universities attempted to counterbalance the lack of entrepreneurial mindset by appointing specialised professors and by implementing specialised courses.

Problems were being caused not only by the lack of entrepreneurs, but also by the attitudes of those who were already active as entrepreneurs. German entrepreneurs seemed to be highly control-oriented in comparison with their colleagues in the USA. The fact that they wished to keep a firm grip on the financial control over their start-ups sometimes had an inhibiting effect on further expansion as well as on attracting foreign investors and venture capitalists. Since the mid-1990s, the German government has thus been trying actively to finance entrepreneurship. Prizes have been awarded in order to stimulate regional biotechnology centres, business plan competitions have been organised and the promotion of spin-off neworks around universities has been encouraged. The government has also partially taken on the role of a venture capitalist via the creation of various funding mechanisms for start-ups, including R&D soft loan schemes.

Concurrent with all these regional and governmental measures, the economic situation in Germany after the unification also played a role. Entrepreneurship in general and high-tech venturing in particular are indeed increasingly seen as crucial for arriving at a more positive and dynamic business climate.

Silicon Valley

The best known high-tech region – and the one that appeals most to anyone's imagination – is without doubt Silicon Valley. Firms such as Hewlett Packard, SUN Microsystems, Intel and Cisco were born there. However, Silicon Valley is also a gigantic innovation and entrepreneurship laboratory. For every successful tech start-up there are at least ten that fail to realise their goals. In other words, inherent in the success stories in the Valley are the cases of failure. It has become something of a cliché to point out that every Silicon Valley entrepreneur has at least two failures to his or her name before success comes (Nesheim, 2000). Furthermore, not all failures lead eventually to success. Some people never learn from their 'mistakes'. This explains the considerable 'failure rates' in the Valley.

However, the tolerance for failure and the culture of entrepreneurship, and the ability to learn from these failures has turned Silicon Valley into a success story which today we all recognise, admire and to some extent envy. Today Silicon Valley numbers several thousand high-tech firms. The average salary in the region is twice the national average. Silicon Valley has the largest concentration of companies in sectors such as computers, semiconductors, telecommunications equipment, software and internet software and hardware. In addition, it holds a strong position in biotechnology and biomedical applications.

These accomplishments are the result of a process of development that had already begun before the Second World War and in which both Stanford University and UCBerkeley played key roles. Stanford University was founded in 1891. Right from the beginning there was an openness towards 'technical venturing'. For example, the first president of the university, D.S. Jordan, made $500 available to Lee de Forrest, who used it to develop the vacuum tube as a way of intensifying electrical signals (1908). In the 1930s, with the arrival of Frederick Terman as a dean, this approach and attitude gained further momentum. In particular, he encouraged Bill

Hewlett and David Packard, just before the Second World War, to start their own electronics company which concentrated initially on precision-measurement instruments and later diversified very successfully into the direction of computer applications and semiconductors. Terman's role was not limited to offering a stimulating work environment, but also involved networking, thereby creating new combinations and collaborations. For example, he brought the starters Hewlett and Packard into contact with Harold Black from Bell Labs, a specialist in 'negative feedback' for amplifiers in telecommunications. This would result in the development of the audio oscillator, the first product from HP.

This 'Terman effect' – a reference to the enterprising character of the staff and students at Stanford – is perhaps the biggest difference between Stanford and UCBerkeley. The latter university – with 20 Nobel Prize winners – too is a leading world centre of knowledge generation. However, researchers and professors at UCBerkeley seem to opt more exclusively for a career within research, and are inclined to leave high-tech entrepreneuring to their alumni: here Andy Grove and Gordon Moore (the founders of Intel) come immediately to mind. In addition, the region also boasts Santa Clara University and San Jose State University, which together turn out some 4000 new engineers each year.

It is important to note that in the pioneering period the phenomen of 'Silicon Valley' as such did not yet exist. Even at the end of the 1960s, there was no reference to Silicon Valley as we know it today. Intel was founded in 1968, attaining a turnover of less than $600,000 in 1970. By the mid 1980s, IBM sold its 20% participation in Intel because it had lost its belief in the future of the company (Pugh, 1995). During the War years, high-tech venturing activities on the West Coast remained relatively insignificant, especially when compared with the Boston area (MIT). In a region where agriculture dominated, the only expertise worth mentioning around 1940 was in the field of radio engineering and a number of related sectors and technologies.

Since 1932, Litton Engineering Laboratories had been active as a specialised maker of vacuum tubes and instruments for glass processing. Among their important customers were the Manhattan project, led by Robert Oppenheimer, and the Department of Defense 'at large'. Other important pioneers were the Varian brothers, who started their work in the thirties, again with the support of Stanford University.[2] By the end of the decade they had invented the Klystron, one of the most important components of radar systems. In 1948, they started their own company. In this sense, it was possible to speak of a growing but still small electronics centre by the end of the 1940s. In 1943, some 25 Californian firms – including 13 from Northern California – united under the banner of the West Coast Electronic Manufacturers Association, the precursor to what later would become the American Electronics Association.

In 1951, Stanford University made a decision unique for its time: it opened the Stanford Industrial Park, thus making available 234ha of university land for industial projects. The first company that set up there was Varian Industries, the second Hewlett Packard. Today this park numbers 150 firms active in the areas of electronics, software, biotechnology, financing, strategic management consulting and venture capital.

The presence of Stanford and UCBerkeley was not the only important element in this scenario. The very early presence of Fairchild Semiconductors (founded in 1957), itself a spin-off of Bell Laboratories, was also important. In this connection, it is interesting to observe that it was Frederick Terman who convinced William Shockley, one of the co-inventors of the transistor within Bell Laboratories, to come back to the area where he was born, Palo Alto, in order to set up Shockley Semiconductors. Despite his brilliance as a scientist, his performance as a manager was less successful. Eight of his best engineers left to create Fairchild Semiconductors several years later (Kenney and von Burg, 1997). The collaborators at Fairchild Semiconductors in their turn laid the basis for a multitude of high-tech companies (the 'Fairchildren'), among which we count AMD and Intel. It is clear that besides 'enterpreneurial universities', the presence of companies and a professional support network – with its own knowledge and expertise – each took part in creating regional dynamics of economic development and growth. The research laboratories set up by IBM (San Jose Laboratory, in 1952) and later the Xerox Palo Alto Research Center (PARC) should also be mentioned in this regard. In a similar way, regional knowledge-networks came into being, quickly becoming

recognised and legitimate nodes in a global network of knowledge and entrepreneurship (Van Dierdonck *et al.*, 1991). In other words, the advantage of well-developed regional networks of knowledge and entrepreneurship is that they quickly become part of similar networks at a global level. There is thus an evolution from an isolated network to a network within and between other networks.

In the sixties and seventies, Silicon Valley grew quickly. The number of start-ups in the period 1956–65 within the semiconductor industry was 'only' ten. In the period 1966–76 there were already 60, while ten years later (1977–87) it amounted to 157. And yet the 1980s marked the beginning of a difficult period for Silicon Valley. The semiconductor industry evolved more and more into a situation in which operational excellence and mass production were making the difference when it came to a firm's performance. In particular, a number of Japanese companies emerged as leaders, and the consequences were felt all the way to Silicon Valley. For example, in the eighties, Intel was forced to lay off 8000 employees, pulling out of the memory market and devoting itself completely to microprocessors. In this sense, the point of view of Kenney and von Burg (1997) becomes clear, when they rightly point out that many factors play a role when it comes to the creation of a high-tech entrepreneurial region (see also above). And we are here not only dealing with 'cultural' aspects such as entrepreneurial values or even organisational structures; the technologies themselves and their intrinsic paths of development (cf. the notions, inspired by Joseph Schumpeter and Thomas Kuhn, of 'technology trajectories' and 'paradigms,' Dosi (1984); see also Nelson and Winter (1982), Arthur (1988) and David (1986)) equally play a role, in combination with the strategy of and its implementation by the dominant players.

In other words, the success of a number of regions – and thus the relevance of a number of competencies – cannot be separated from the life cycle of the technologies implied (see also Langlois and Robertson, 1992, 1995). Equally, this explains the need, on a regional level, to avoid the 'Not-Invented-Here' syndrome (Debackere, 2000). A healthy high-tech region needs a mix of technologies. Technological monocultures are to be avoided at all costs if a regional innovation dynamic is to be maintained. A healthy diversity in the regional technology-basis is thus desirable and highly recommended. In its absence, there is a danger of becoming too dependent on the ups and downs of one particular technological growth cycle, with all the possible negative consequences that this entails. Hence, if the diversity of the (regional) technology-base is poorly monitored (and here technology forecasts clearly prove their usefulness, Zimmerman *et al.* (2000)) by the actors in the 'Triple Helix', then the consequences can be dramatic whenever competing or new technologies take off.

What makes Silicon Valley so distinctive and so competitive is the breadth of the knowledge and technology available as well as the fact that the region clearly possesses the skills to continue to develop, to reinvigorate itself and to diversify. The presence of a sufficient critical mass across a wide range of competencies, in combination with its geographical proximity, are seen by the Stanford Research Institute as key elements:

> The region possesses a special kind of infrastructure that has in effect institutionalized innovation in technical fields across the board. The Bay Area is unrivalled in sheer variety of companies and level of formal and informal networking among companies in technical fields. Hardware and software are closely aligned. Prototype development and engineering is particularly strong. It is this cross-cutting strength – and economic infrastructure comprising strong technology, human resources, capital input, and numerous industrial synergies – that makes Northern California a magnet for top engineering talent, innovative start-ups, and major breakthroughs in technical fields across the board (SRI International, 1988).

This characteristic is also emphasised by Saxenian (1994):

> Most companies or stable regions pursue a single technical option and, over time, become increasingly committed to a single technological trajectory. A network-based regional economy like Silicon Valley, alternatively, generates and pursues a *rich array* of technological and organisational alternatives.

Equally striking is the emphasis by many authors (see, among others, Collins & Porras (1994)) on the management style on the one hand and the dynamics in the region on the other hand. In terms of management, the role model of HP has set the tone within the literature. Particular attention is paid to the concept of participation within a non-hierarchical, informal management style, in which status differences are minimised. Within the region, there exists, besides competition, a great deal of interaction, in the form of meetings and discussions, both between company personnel and academic partners. These authors also note a remarkable degree of openness in exchanges of information between experts and 'juniors', concerning both technical and company-related matters. The region further is, as it were, naturally bounded by the ocean on one side and by the Santa Cruz mountains on the other. In fact, we are dealing here with an area 'only' 80 kilometers long and a few dozen kilometers wide. Thus, physical proximity plays a role equal to that of technical affinity. This facilitates the necessary interaction between a diversity of actors and competencies, so important for creating and nurturing innovative entrepreneurship. This sort of interaction is characterised by an openness and informal style that is in stark contrast to the more classic hierarchical company organisations. The authors cited above point out that this more network-oriented style of organising, in combination with an atmosphere and a culture in which risk – and thus failure – are considered to be normal[3] and even positive, allowed the Valley to survive the crisis of the 1980s and emerge strengthened. This is in marked contrast to, for example, the less diversified Route 128 region (Boston), where firms such as DEC never quite recovered from their problems in the 1980s.

Hinoul (1999) goes on to list a number of these ingredients. As we have seen, the presence of knowledge centres (in this case Stanford *and* UCBerkeley) is crucial. Besides their technical expertise and know-how, these institutions also provide other essential specialists, chief among which are people with management skills and legal expertise. Silicon Valley is further characterised by its international orientation, according to Hinoul. The continuous influx of people from other regions of the USA as well as Europe and Asia is seen as an essential, moderating element. The resulting diversity once again helps to create the right kind of breeding-ground, suitable for (international) high-tech venturing. In terms of the work culture, a certain degree of homogeneity is noted nonetheless: the region is characterised by a 'freedom of exchange of ideas', an informal style of collaboration, and a culture in which entrepreneurship is stimulated, even if it leads to failure. This philosophy is shared by the academic world, the business world and the government.

Complementary to this is the strong presence of venture capitalists *and* private investors: the region accounts for a third of all the venture capital in the USA. A crucial element here is the intensity of the collaboration between investors and innovators/entrepreneurs. Collaboration and guidance involve much more than financial participation: the active contribution to the development of a professional organisation, as well as networking and the elaboration of strategic alliances all point into the same direction (see also Hansen *et al*., 2000).

In addition, the USA possesses well-developed capital markets which make it relatively easy to realise second and third rounds of financing efficiently. Such markets form, moreover, a necessary (exit) condition for venture capitalists to pursue their goals. An additional virtue of Silicon Valley is the region's quality of life, both in terms of its climate and its culture. Finally, the connection to the large American market is a crucial macro-economic factor: the extent of this connection allows for faster growth on a larger scale.

Cambridge

In 1954, the government of the region around Cambridge made an explicit policy-planning decision to limit the flow of immigration into the region. There was a desire to maintain the historic character of the university city by keeping large-scale industry out of the region. Since these measures greatly hindered the collaboration between Cambridge University and industries dependent on scholarship and research, a proposal was worked out whereby certain forms of growth – in particular, the establishment of high-tech firms – would be allowed. The proposal was approved in 1970 by the regional government and

has since then formed the guideline for development around Cambridge.

A number of high-tech spin-offs and consulting firms emerged from the university's competencies in the areas of electronics, instrument development and computing. This resulted, in turn, in the creation of new companies. The consulting firms coordinated the collaboration between industry and the academic world. Entrepreneurs from other parts of the UK choose to locate in the university area and large multinationals, too, established small branch offices in the region.

In 1996, the population of Cambridgeshire was over 700,000. Of these, 28,000 were employed in high-tech companies. In the period 1994–95, some 87 new firms were set up in high-tech sectors. According to Jim Martin of the 3iGroup, the success of the technology valley around Cambridge is a result of the presence of several determinants: sources of innovation (knowledge), possibilities for financing, a high quality of life in the region, a sufficient critical mass of competencies in terms of management and organisation, and finally the interaction between local initiatives and international collaboration.

The first determinant is the *presence of sources of innovation*. Cambridge University is one of the most renowned universities in the world, with a very strong knowledge base both in the scientific and management areas. It is worth noting that here, too, there was a conscious choice to become an 'enterpreneurial' university. A second factor are the *numerous possibilities for financing* start-ups: the proximity of London's financial centre guarantees sufficient venture capital of high quality. A third factor identified by Jim Martin is the *healthy fiscal and cultural environment*. An environment that guarantees a high quality of life makes it much easier for a region and its companies to attract the best international talent. Specifically in terms of running a business, the author emphasises the importance of the management capabilities available and the general marketing and sales skills of the companies around Cambridge. As a final factor, he points to the importance of a *balance between endogenous and foreign investment* (*exogenous growth*) in the Cambridge area. Each time a foreign firm establishes offices in the region, the local high-tech firms have an increased chance to learn. An over-concentration of foreign companies is, however, undesirable, since the region hopes to keep the resulting economic and social benefits close to home.

All these factors were advantageous for starting high-tech ventures around Cambridge University. However, at the end of the 1980s, the successfully launched firms were confronted with increasing growth pains. In 'The Cambridge Phenomenon: the Growth of High Technology Industry in a University Town' by Segal Quince Wicksteed Limited (1990), the most common problems were identified to be the unwillingness of company founders to allow their firms to grow, as well as a lack of support by large companies, financial institutions and the government for the small company texture. There were also not yet large, successful endogenous firms in the area that could serve as role models for the small start-ups. Finally, there was a shortage of highly-trained personnel and an increasing pressure because of the demographic expansion, traffic problems, housing shortages and environmental problems. The local population began to protest against the continual expansion of the industry zone. The strain on the quality of life also made it increasingly difficult to attract top international personnel. By the end of the 1990s, the ICT model (information and telecommunication technology) was proposed as a possible solution to this problem. Concepts such as teleworking, telegovernment, telelearning, telemedicine, e-commerce and smart cards were embraced in order to facilitate the technology zone's growth with a minimal effect on the quality of life. This growth to the north and south is now well underway.

Sophia Antipolis

Cambridge's best-known European rival is Sophia Antipolis on the French Côte d'Azur. In 1962, an industry zone was created in Valbonne, where, among others, IBM and Texas Instruments located. In 1965, Sophia Antipolis University was founded in Nice. As an incubator for public and private, scientific, industrial and tertiary activities, the Sophia Antipolis science park was set up. From 1974 onward, various companies and educational institutions located on the site.

By the beginning of 1999, 1164 companies had been located, of which more than 300 were active in the ICT, electronics and health sciences sectors.

Of the 20,530 people employed in all these companies, some 10,000 work in these three sectors. More than 5000 researchers and students work for public education and research institutions in the region. Foreign companies have also established themselves on the plateau: there are 110 foreign firms in Sophia Antipolis, of which 48 are European and 43 North American.

The evolution of the science park shows clearly the importance of a local scientific infrastructure and how slow and complex the establishment of a 'scientific conurbation' is. Sophia Antipolis, hoping to become less dependent on seasonal tourism, was established in a region with no industrial tradition. The idea began as a private project, led by Pierre Laffitte, director of the 'Ecole Nationale des Mines de Paris', but was quickly taken over by the public sector because of a lack of financial resources. Large firms such as France Télécom located on site. Over time, two main activities emerged: ICT (65% of the park's employment) and life and health sciences (20%). The park's progress was, in fact, stimulated only by the contribution made by the large firms that settled there. In the 1980s, a number of positive changes occurred. In the first place, the region's endogenous knowledge basis was broadened considerably. The University of Nice was expanded, while schools of engineering, specialised in ICT, were established. Over time, all the major French research institutions had a presence in the park. All of this resulted in a generous local supply of highly-trained talent and in an increased interaction between research and industry, via the students.

A second positive factor was the arrival of companies offering specialised services to established high-tech firms. A final positive evolution was the creation of spin-off companies out of the most important research institutions, and the creation of SMEs. Both groups were interested in making use of the research potential in the area. However, the growth of Sophia Antipolis was still overly dependent on the R&D departments of large companies and not on the endogenous interactions and initiatives resulting from them.

Only at the beginning of the 1990s, with the crisis in the computer industry, did this situation change drastically. The large firms had to tighten their belts and started to farm out some activities. With the well-developed local knowledge basis, there was an opportunity to deal with this situation locally, resulting in the establishment of new companies, both 'new' start-ups and spin-offs from larger firms. When these larger firms were reorganised, many of their employees wanted to stay on living in the region. They looked for new employment opportunities, leading to the creation of new companies. Large concerns such as IBM and Texas Instruments realised the necessity of collaborative ventures in order to cope with the crisis. Professional associations and clubs were set up in the region. Large and small enterprises started to work together, sharing resources, which ultimately stimulated endogenous growth.

In contrast, activities in which no endogenous growth or diffusion of knowledge was created and no local collaboration was undertaken, as in health sciences, have seen little success in Sophia Antipolis, despite the fact that a local market for such activities does in fact exist. The present success of Sophia Antipolis is thus due to the presence of the set of factors previously described in this article, which in this case came into being sequentially, rather than the multiplex, multifactorial environment encountered in Silicon Valley.

At present, the Sophia Antipolis region offers a critical mass of knowledge and industrial activity. Established companies as well as research institutions and universities have at their disposal the competencies crucial to develop and to grow in the areas of natural and health sciences and ICT. Public educational and research institutions have developed in such a way that they can meet the requirements of (large) companies. Collaborations and partnerships between public institutions and companies have led not only to excellent results for industry, but also the educational and research programmes have as a result been validated and improved, much to the benefit of the international reputation of these programmes. The international character of the companies and their employees has tended to encourage this process.

The presence of two international schools has also contributed to this situation. The attractive environment and the quality of life in the South of France represent additional environmental factors that have led to the success of Sophia Antipolis. This environment has made it possible to attract high quality personnel, who are enticed by both the working and living standards. The

region has an infrastructure able to support international cultural, scientific and political events. The advanced telecommunications infrastructure and the proximity of the Nice airport make it possible for companies to work internationally. Finally, the broad spectrum of services and relations between firms on the site also constitute an important success factor. Service and consulting firms, hotels and other facilities provide the necessary support system for businesses. Perhaps even more important are the many socio-professional associations, discussion groups and clubs, where business people can meet the partners they need for starting and successfully developing their activities. This dynamic of endogenous growth has, however, only taken place over the last ten years. All the necessary ingredients were in fact present before this, but a shock to the business economy was needed in order to unleash the culture shock that legitimated and stimulated 'entrepreneurship'.

Leuven

As early as the 1970s, a liaison office was created at the Katholieke Universiteit Leuven – KU Leuven R&D – geared to transferring scientific and technological knowledge to society-at-large and to the business world in particular. In order to support this transfer, many initiatives were undertaken and several instruments were developed. This evolution was – and is – supported by a university policy, one of the core elements of which is also the concept of the 'enterpreneurial university'.

K.U. Leuven R&D consists of a multidisciplinary staff of legal experts, economists and engineers/scientists, as well as specialised administrative and financial personnel. They offer advisory (legal, financial, technical), coordinating, administrative and information support in the areas of:

- *Innovation advice and technology mediation*. Innovation advisors help companies and university researchers to frame the possibilities of a potential collaboration. On an individual basis, they attempt to coordinate the needs of the industry with what the university has to offer. Once this coordination has been worked out, support is also offered for starting and developing the collaboration. Based on the university's many international and regional contacts, its role in technology mediation extends far beyond local boundaries.
- *Information exchange and training*. This is done through industrial collaborative programmes and "on campus" or "residential" training programmes.
- *Contracts for consultancy, research and development*, in connection with new products, production techniques and technologies. This comprehends fundamental research, feasibility and prototype studies, experiments and the use of equipment. Confidentiality, rights of ownership, a realistic business plan and respect for the objectives of all the partners form the basis of a successful collaboration.
- An active *patenting and licensing policy*. This objective is pursued with regard to the results of the university's research in order to generate funds for further scientific research and to create the necessary conditions for its successful commercialisation by the business world. Licensing and sublicensing agreements are regularly concluded with Belgian and foreign companies. The strategy, which aims to exploit the research, involved the creation of a patent fund in order to facilitate and encourage the general accessibility to patenting for the results of innovative research.
- *The creation of new, research-oriented and innovative companies*. This is stimulated by offering advice and support to entrepreneurs, and offering them access to risk capital through the *Innovatiefonds Gemma-Frisius I&II* (since 15/10/1997 with a first fund, since 3/7/2002 with a second fund). This venture fund was created by K.U. Leuven in partnership with two major financial conglomerates: Fortis group and KBC group. The Gemma-Frisius Fund I has financed the launch of 15 spin-offs. Gemma Frisius II has already invested in two new initiatives since the summer of 2002. This brings the total number of spin-offs from the K.U. Leuven to 51 by mid 2002. Accommodation and management support are available from the *Innovatie- en Incubatiecentrum*, which, with its location on the campus, stimulates close cooperation between the univerity laboratories and the research units. *The success of a number of spin-offs* enjoying international renown is the result of the technology transfer policy which has developed

over the years and serves as a role model for new initiatives.

- *The creation of business activities for national and international research-intensive firms in the science park*. New, innovative firms, spin-offs from universities and research institutions, and R&D departments of existing firms can take advantage of the science park's location, close to the K.U. Leuven and IMEC, the Inter-university Center for Micro-Electronics. This creates a stimulating environment for the transfer of knowledge and technology between internationally renowned researchers and entrepreneurs. K.U. Leuven R&D and IMEC created Leuven.Inc in 1999, in which the local business environment, professional advisors and the university are undertaking a number of joint initiatives aimed at increasing the development of the region. The ambition of this project, supported by the university, IMEC, the local spin-off entrepreneurs, and the municipal and provincial governments, is to increase prosperity through endogenous and exogenous creativity and through the growth of knowledge-intensive companies in the region. Besides providing the necessary infrastructure, the project aims at stimulating actively the exchange of ideas and the creation of networks (both formal and informal). This networking is of vital importance for attracting and supporting new firms and spin-offs.

To this end the multidisciplinary team at K.U. Leuven R&D is involved with the following activities:

- *Encouraging entrepreneurship*. In cooperation with the Faculty of Economic and Applied Economic Science, courses on entrepreneurship are offered to researchers and students, regardless of their specialisation. Entrepreneurship is also continually stimulated through internal and external publications and presentations of success stories.
- *Elaborating a business plan*. Researchers are taken step-by-step through the process leading 'from idea to company' with the aid of internal and, if necessary, external advisors. Considering the highly innovative character of the products and services offered, the elaboration of a business plan is a complex and **highly individual** undertaking for any spin-off project.
- *Seeking sources of financing and industrial partners*. K.U. Leuven R&D and the Gemma-Frisius Fonds (together with the two financial partners) are able to contribute to a business's starting capital. Through an extensive national and international network of relations, the multidisciplinary team, together with the founders, considers whether participation by other commercial partners can offer value added. If necessary, contacts can of course be established with external sources of investment and venture capital.
- *Protecting intellectual property*. Protecting one's own knowledge is a very important element in the successful start and growth of a company. Elaborating an effective patent strategy and defining collaborative and licensing agreements are essential in this regard.
- *Supporting company set-up*. The formulation of statutes, as well as shareholders agreements, and remuneration policies, are important elements of the advice offered.
- *Supporting company management*. Advice concerning strategic decision-making in the area of international growth is facilitated by participation on the boards of directors, contacts with K.U. Leuven R&D advisors and, through involvement with the Gemma Frisius-Fonds and its financial partners, the presence of external, independent board members.
- *Providing infrastructure*. In collaboration with K.U. Leuven R&D, the Innovation and Incubation Center and the science parks, a suitable infrastructure is available for each spin-off. The Innovation and Incubation Center of the K.U. Leuven offers premises and services for use by research-oriented and innovative start-ups, allowing them to concentrate on their core activities. Besides general infrastructure such as meeting rooms, a cafeteria and a car park, the center provides services such as the advice of an experienced manager, secretarial support and financial management support. K.U. Leuven has at its disposal a science park in Haasrode (120 ha), where many high-tech firms are located, including the university's own spin-offs, such as LMS, ICOS Vision Systems and Materialise, but also important international firms such as Heraeus and ITCL (Philips). In total, over 5000 people work there. In the near future, the Arenberg and Termunck science parks will be

made available, offering an additional surface area of more than 50 ha.

The growing culture of entrepreneurship at the K.U. Leuven has already resulted in 51 spin-offs over a period of 20 years, some of which are highly active on the international scene. Their combined turnover at the end of 2000 was BEF15 billion, with a workforce of more than 2000.

5. High-tech venturing: some final considerations concerning regional dynamics

In order to continue to stimulate a region's economic growth based on knowledge-intensive entrepreneurship, the technology portfolio of the region must maintain a balance between routine technological activities (which are often oriented towards process innovation and incremental development as the technology's life cycle matures) and non-routine technological activities (which are often oriented towards products and more fundamental development). The local knowledge centers – in particular universities and research institutes – can play a major role in this process. Those knowledge centres are more solidly embedded in the local and supra-regional context than are the young start-ups. This embeddedness can assume both structural and non-structural forms. Table 3 presents a survey of the mechanisms that knowledge centers can adopt in order to support sustainable technology transfer and its economic application on both local and supra-regional levels. Of crucial importance is the exploration of new domains of knowledge – often not yet routinized – and the subsequent spread of that knowledge among the actors in the region.

It is precisely because of this duality that knowledge centres should occupy a central place and a fundamental role in any regional innovation network; such institutions are indeed best able to give visible support to the dual challenge of local and global knowledge development. If this dual task fails to be a priority in regional innovation policy, then the region can fall prey to the threats inherent in the growth-stagnation-decline model which characterises the technological life cycle. A region's adoption of a 'dominant technology model' leads inevitably to limitations in terms of diversity and thus to a possible 'lock-in' phenomenon into the dominant technological knowledge basis present in the region. This existing knowledge base is generally geared towards efficiency improvements, and can over the longer term lead to 'less' innovation. In order to counterbalance this dominant logic inherent in 'technological trajectories', we underline the pivotal role played by knowledge centres when they pursue non-routine research activities and when they emphasise their role in a supra-regional context. Every regional innovation network thus clearly requires knowledge centres that are both regionally active and internationally competitive.

6. Conclusion: ingredients for a policy aimed at stimulating regional high-tech venturing

It will be clear from the above analyses that high-tech venturing, and in particular the development

Table 3. Knowledge centers and supra-regional dynamics

	Emphasis on local development and embeddedness	Emphasis on supra-regional development and embeddedness
Structural arrangements	Incubators Research parks Spin-offs Education and training	R&D collaborations Affiliation programmes Licenses Consortiums
Non-structural arrangements	Labour markets for researchers and technologists Seminars Professional associations Local networking	Consulting and professional advice Publications Seminars Professional associations International networking

of a policy to encourage it, is a complex process, implying a multitude of elements, instruments and actors. Moreover, the development of a regional venturing process implies a long-term approach: the seeds of today's Silicon Valley phenomenon were sown before the Second World War; Germany spent some 30 years developing a (lasting) dynamic in this area; and the examples in Leuven and Cambridge also illustrate how their foundations were laid in the 1970s and how the effects that are now visible imply a genesis of several decades.

The dynamics of high-tech venturing presuppose active roles for government, the business community and the available knowledge centres. If governments can take supporting measures in the interest of a favourable climate, a more 'entrepreneurial' attitude is demanded of the knowledge centres and the firms themselves.

As has become clear, the presence of knowledge centres in a region is a primary pre-condition for developing high-tech ventures. Both companies and knowledge centres can together provide the necessary critical mass of knowledge and experience. In this respect it is important that a broad spectrum of competencies be available. *Innovative* entrepreneurship implies a process of cross-fertilisation, involving a diversity of knowledge domains. This conclusion forms the clearest substantiation for the importance of physical proximity: the creation of new entrepreneurial combinations involves interactions.

The ability to generate this dynamic assumes that the various actors make their expertise visible and accessible. Companies must be prepared to collaborate, while knowledge centres need to play the role of 'enterpreneurial universities'.

In this regard, the importance of supportive instruments cannot be stressed enough. Liaison offices, built on crucial expertise and networking capabilities, stimulate the interaction and the collaboration between the different actors. Besides these supportive instruments, an essential role is played by the 'project champions' and 'sponsors'. Both within the liaison offices and in the business, academic and governmental communities there must exist strong, motivated pivotal figures who are driving forces in the high-tech developments in the region and who have extensive know-how and networks at their disposal.

In addition, it must not be forgotten that innovative or high-tech entrepreneurship calls for solid management expertise. An entrepreneurial attitude and high-tech know-how need to be complemented by skills in professional management. When dealing with new technology, those skills quickly gain an international dimension. The presence of both knowledge centres (universities/polytechnics with a curriculum oriented towards business economics and law) and established enterprises is an important facilitator in this regard.

When it comes to financing, the presence of venture capital is essential. On the one hand this takes the form of risk-capital with all that this implies: in particular, both the provision of capital and the support – strategic/commercial/organisational – for the development of a balanced and sustainable business. On the other hand, the accessibility of well-functioning financial markets is also important. The presence of such markets – Nasdaq and Nasdaq Europe – geared towards technological growth-firms is crucial for generating a dynamic in the 'early/first-stage investments'.

Finally, a number of socio-cultural elements are equally relevant. Regional cultures characterised by openness, informal networks and interactions, a willingness to take risks facilitate innovative entrepreneurship. This 'culture' is of course partly developed through concrete projects and accomplishments. Complementary to this, the general quality of life should not be underestimated when attracting, international, human capital.

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Notes

1. For an illustration see also Galbraith and De Noble (1992).
2. Besides a grant for the purchase of material (US$100), this consisted chiefly of access to the laboratories at Stanford, in exchange for a 50% share in any patents that might be developed.
3. In this connecton, Lehrer (2000) refers to the relevance of other ways of working together than the dominant German 'authority model'. He goes on to note that 'in America, if you are an entrepreneur with a new idea and you lose people's money in your venture, they'll ask you if you've got another idea. In Germany they call the District Attorney'. (op.cit., p. 100).