

Evolution of high-technology clusters: Oslo and Trondheim in international comparison

Olav R. Spilling and Jartrud Steinsli

Research Report 1/2003

BI Norwegian School of Management
Department of Innovation and Economic Organisation

Olav R. Spilling and Jartrud Steinsli:
*Evolution of high-technology clusters: Oslo and Trondheim in international
comparison*

© Olav R. Spilling and Jartrud Steinsli
2003

Research Report 1/2003
ISSN: 0803-2610

BI Norwegian School of Management
P.O.B. 580
N-1302 Sandvika
Phone: +47 67 55 70 00

Printing: Nordberg Hurtigtrykk

To be ordered from:

Norli
Phone: 67 55 74 51
Fax: 67 55 74 50
Mail: bi.sandvika@norli.no

Foreword

The purpose of this report is to shed light on the evolution of high-technology clusters, and to explain why Norway, exemplified by the high-tech milieus in Oslo and Trondheim, does not perform well in international comparison. The report is the final report from the project originally named 'Innovation, financing and entrepreneurship', which was funded by the Norwegian Research Council through the FAKTA programme. To reflect changes in the focus of the project, the project was renamed "Evolution of high-technology clusters".

The main objective of the project has been to analyse high-tech industry in Oslo and Trondheim. By comparing the two cities with some of the internationally leading high-technology cities in Europe, the objective has been to explain the relatively poor performance of Oslo and Trondheim. The research project was initially designed to examine the role of entrepreneurs and financial actors in cluster formation, and on the interplay between these two groups of actors. We later changed the focus of the project towards a more holistic approach to analysing clusters and cluster evolution. Partly, this was motivated by recent research in the field of innovative milieu and cluster evolution, and partly by the fact that other projects funded by the Norwegian Research Council in the same period, have worked more explicitly with the role of financial actors.

When working on this project, we have taken advantage of valuable support from various sources.

Statistical data for the Norwegian part of the study were obtained from Statistics Norway. Data for Sweden were obtained during a stay at the Jönköping International Business School in February 2002. Data for Finland were obtained from Statistics Finland.

Data for Sophia Antipolis and other valuable information on the region and its science park were obtained during a stay at CERAM, Sophia Antipolis, during April-May 2002, thanks to Michel Bernasconi and his staff.

Data and other information on Dublin were obtained from various sources, partly Eurostat, the Department of Trade and Industry, Enterprise Ireland and through contacts with a number of people in various institutions. I would like to thank Margaret Wheelan, the Dublin Institute of Technology; Kathleen Quinlan, Enterprise Ireland; and Colm O'Gormann, University College Dublin.

Data and other information on Cambridge were obtained, partly by reading reports and articles on the 'Cambridge Phenomenon', partly by meeting people involved in research and consultancy. In particular, I would

like to thank David Keeble and Thelma Quince at the Centre for Business Research, Cambridge University; Elisabeth Garnsey, Department of Geography, Cambridge University; and Bob Hodgson, consultant, for valuable information and discussions.

During the early stages of this project, I was able to spend time at MERIT – Maastricht Economic Research Institute on Innovation and Technology – a stay which provided ample opportunity to discuss central issues related to recent research on innovation systems.

This project was organised in parallel with other research projects funded by the Norwegian Research Council, on closely related issues. Informal workshops were organised with some of these projects. Special thanks to Heidi Wiig Aslesen, Arne Isaksen, Ove Langeland and Knut Halvorsen for interesting exchanges of information and helpful discussions on issues related to innovation systems, cluster evolution and the role of different actors.

As a part of this project, a survey was organised to collect information on high-technology small firms in Oslo and Trondheim in collaboration with the Centre for Value Creation at BI. I am grateful to Cato Salter and his team, who were responsible for the tedious work of obtaining the sufficient number of completed questionnaires.

Bjørnar Reitan, who participated in the first part of the project, has written a working paper on high-technology industries and institutions in Trondheim, which has provided a valuable basis for our analysis of Trondheim.

Last, but not least, I would like to thank Jartrud Steinsli, who has worked on the project the past fourteen months, for her significant contributions to the project. Without her contributions, it would not have been possible to complete the project in the way it now has been concluded.

Although this is the final report from the project, the issue of high-technology industries in Norway is far from exhausted. To the contrary, this project is one of very few that has addressed this crucial issue in Norway. It is my hope that this report may stimulate the formulation of new research questions, in order to further explore the many interesting and challenging issues involved in the evolution of high-technology industries.

Sandvika, March 25, 2003

Olav R. Spilling

Contents

Summary	7
1 Introduction	10
2 High-technology clusters	12
2.1 The cluster concept	12
2.2 Clusters and regional systems of innovation	15
2.3 The innovative milieu	17
2.4 High-technology	19
2.5 Cluster performance	24
3 Evolution of high-technology clusters	29
3.1 Evolution	29
3.2 Cambridge and the Cambridge Phenomenon	32
3.4 Dublin – the software capital of Europe	48
3.3 Sophia Antipolis – evolution of a Greenfield Cluster	63
3.5 Diversity and similarity of cluster evolution	74
4 Evolution of high-technology clusters in Oslo and Trondheim	78
4.1 High-tech industries in Norway	78
4.2 Oslo and Trondheim in the national context	81
4.3 Evolution of high-tech industries in Oslo	85
4.4 Evolution of high-tech industries in Trondheim	105
4.5 Oslo and Trondheim in international comparison	119
5 Evolution, technology and the role of small firms	126
5.1 Introduction	126
5.2 Case: Evolution of Internet-based businesses in Oslo	126
5.3 The role of different actors	137
5.4 The role of small firms in cluster evolution	139
5.4 The role of small firms in cluster evolution – the dynamic view	141
5.5 Small firms and innovation	144
5.6 Comparisons with Cambridge	148
5.7 Summary	150
6 Cluster Evolution and Policy	152

6.1	Introduction	152
6.2	The role of policy in cluster evolution	153
6.3	Policy approaches in Cambridge, Dublin and Sophia Antipolis	158
6.4	The role of policy in the cases of Oslo and Trondheim	163
6.5	High-tech firms and the role of policy	165
Literature		177
Appendix		
Questionnaire for survey on small high-tech firms (in Norwegian)		
Appendices (separate working papers)		
Steinsli, J. <i>Dublin – the rise of the Celtic Tiger</i>		
Steinsli, J. <i>The Cambridge Phenomenon</i>		
Steinsli, J. <i>Evolution of high-tech industries in Oslo</i>		
Reitan, B. <i>Trondheim as a ‘High tech Hot Spot’</i>		

Summary

The issue addressed in this project is why the Norwegian cities Oslo and Trondheim are not among the internationally leading high-technology cities. While the two cities perform well in a national context and are home to fairly dynamic high-technology industries, it is the purpose of this project to analyse why the two cities are not performing well internationally. To develop insights into this issue, we need to identify the characteristics of dynamic high-tech clusters and determine the key factors – external as well as internal – which facilitate the dynamic processes of clusters. We also summarise policy issues related to cluster development, and in this way provide a basis for analysing policy options and recommendations related to the future development of high-technology industries in Norway.

Based on these objectives, the report sets out by summarising recent theories in the field of clusters, innovation systems and innovative milieu. As illustrated in the report, there are significant similarities between the various approaches. Although the main focus may vary between the approaches, they describe in similar terms the important actors and critical processes which constitute working systems.

This project concerns dynamic processes, i.e. how systems evolve, the main actors involved, and key mechanisms at work in system evolution. After having summarised theory in the field, the cases of Cambridge, Dublin and Sophia Antipolis are presented and discussed. These cases clearly demonstrate the diversity of cluster evolution. Each story is unique and strongly dependent on the specific prerequisites of the regions and the characteristics of their actors. However, there are similar groups of actors involved, and similar mechanisms at work. What varies, is the mix of factors and the extent to which the different mechanisms are at work.

In chapter 4 the report turns to the role of high-tech industries in Norway and how these industries have evolved and currently perform in the cities of Oslo and Trondheim. Based on the definition adopted for high-technology industries, there are a total of about 10 000 firms with some 106 000 people employed in high-tech in Norway. The vast majority of these firms are small; no more than 2-3 per cent employ more than one hundred people. However, these same firms employ close to 60 per cent of all high-tech employees.

Oslo is, by far, the most important Norwegian city in the high-technology field. Close to fifty per cent of the national employment and more than sixty per cent of total turnover is located in the Oslo area. For ICT, the dominance of Oslo is even higher, with 60 per cent of total employment. The cities of Bergen, Stavanger and Trondheim each have between 6 000 and 7 000

employees. In fact, Oslo has more than twice the employment of the other three cities together, and more than seven times that of Trondheim. Given the role of Trondheim as Norway's 'capital of technology', one might have expected the city to be closer to Oslo and significantly ahead of the competing cities Bergen and Stavanger. An explanation for this situation may lie in the poorer industrial environment found in the Trondheim area, which has not provided synergies to the same extent as in the other cities.

After having outlined the main pattern of evolution and the current structure of high-technology industries in Oslo and Trondheim, an international comparison is provided. The general conclusion from this comparison is that high-tech industries in Oslo and Trondheim are outperformed by their counterparts in leading European cities, due to several factors. One aspect of this, is that the manufacturing sectors of Oslo and Trondheim are not well developed. Compared to other cities, larger companies that serve as drivers of industrialisation are missing in the Norwegian cities. In the case of Oslo, there are a few larger manufacturing companies, but the potential that seemed to exist in this field during the 1980s, has gradually fragmented. With a few exceptions, leading international companies are also missing in the case of Trondheim, where the absence of larger firms, national as well as international, is striking.

This situation may partly reflect the inability of the two cities to attract international high-tech companies to settle in the area. Although Oslo has attracted a few multinationals, it is not because of the attractiveness of the local area per se, but because of an interest in exploiting market opportunities. Furthermore, most multinationals in Oslo are in reproductive and distributive functions, and do not contribute to developing uniqueness and competitive advantage. Another explanation for the lack of larger manufacturing companies, may be related to less capacity for developing indigenous firms, i.e. as a result of spin-offs from universities or existing firms.

It is widely recognised that the unavailability of risk capital, particularly in the early stages of development, may represent an important barrier to development. There are weak traditions in this field in Norway, and the Norwegian venture capital market is immature. The situation may also be related to government policies which have allocated less money to the risk capital market. Furthermore, the situation may be explained on the background of limited growth in R&D funding. In particular, there has not been a clear focus on processes of commercialisation and how research institutions and intermediate institutions, may be designed in order to improve these processes.

In Chapter 5, the role of small firms in cluster evolution is discussed. First, to illustrate key evolution mechanisms related to high-technology businesses and the commercialisation of specific technologies, we present details related to one particular case on the development of businesses based on Internet technology in Oslo during the 1990s. This case illustrates how complicated evolutionary processes can be, with a mixture of competing and collaborating actors related in many different ways. In the early stages of development, small firms and entrepreneurs with academic backgrounds were of great importance, while later actors from larger companies with access to adequate financial resources gained significance.

Second, to give a more representative view of the role of small high-tech firms, data based on a survey of firms in Oslo and Trondheim are presented. Although these data, to a large extent, are cross sectional, retrospective data on evolution is also included, in order to reflect important aspects of evolutionary processes. Among other things, the role of small firms in innovation processes is analysed, and it is indicated that small high-tech firms are highly innovative. However, they take on different roles in the innovation systems. A typology of three different innovative behaviours is suggested, i.e. the R&D based innovator, the competition based innovator and the supplier based innovator.

In the final chapter, the role of policy is discussed. In general, cluster development in one specific region is based on a unique mix of preconditions, and cannot be replicated elsewhere. Thus, no general recipe for policy intervention to support cluster evolution may be suggested. However, there is still a lot to learn about the role of policy. In the cases analysed in this report, i.e. Cambridge, Dublin and Sophia Antipolis, public policy has varied considerably. In the case of Cambridge, there are no cluster specific strategies evident in public policy, and consequently, the role of public policy has been rather weak, working indirectly through University and R&D policy. In the cases of Sophia Antipolis and Dublin, the role of public policy has been much more specific.

Based on our analysis of the three areas, as well as a summary of the role of policy in the evolution of Oslo and Trondheim, future policy issues are discussed along the following lines:

- 1) Strengthen the knowledge base
- 2) Strengthen the capacity for commercialisation
- 3) Develop more research-based industrial activity
- 4) Develop regional organisation(s) that can facilitate information and communication between actors and provide the necessary regionally based initiatives
- 5) Develop appropriate physical infrastructure.

1 Introduction

It is widely recognised that Norway does not perform well in terms of high-technology industrial development. Norway is at the forefront in applying new technology and developing infrastructures based on the new technology, but when it comes to developing industries that *produce* the new technology, Norway's performance is comparatively low, lagging, for instance, behind its two neighbours, Sweden and Finland.

When preparations for this project were in the initial stages, Norway's poor performance was highlighted in a ranking of Europe's 22 leading high-technology 'hot spots', published in *Wired Magazine* in 2000. According to *Wired Magazine*, these hot spots are places 'where the Internet of tomorrow is being created today'. The list included, among others, cities like Dublin, Cambridge, Stockholm and Oulu. Not surprisingly, neither Trondheim nor Oslo was found on the list. However, on a longer list of 47 cities, Trondheim was included in the lower end, but Oslo still received no mention.

Although the methodology for ranking the cities may be questioned (see section 2.5), the ranking provides an important reminder about significant weaknesses in the industrial structure and performance of the Norwegian economy.

Against this background, the issue addressed in this project is why Oslo and Trondheim are not among the internationally leading high-technology cities. While the two cities perform well in a national context and are home to a number of dynamic high-technology industries, it is the purpose of this project to analyse why the two cities are not performing well internationally. To develop insights into this issue, we need to identify the characteristics of dynamic high-tech clusters and determine the key factors – external as well as internal – which facilitate the dynamic processes of clusters. We will also summarise policy issues related to cluster development, and in this way provide a basis for analysing policy options and recommendations related to the future development of high-technology industries in Norway.

As we are particularly interested in the *dynamics* of clusters; special attention will be paid to evolutionary approaches to analysing clusters and innovation systems. Within this framework, we are interested in holistic approaches as well as a more specific focus on actors and institutions that may have a key role in the development of clusters.

In order to study the evolution of high-technology clusters, a systemic approach is applied. There are two important aspects or characteristics of business systems and their driving forces that form the point of departure for

our investigations: 1) the importance of technological development as a major driving force in economic development, and 2) the facilitation of this development by industries organised in clusters, i.e. based on physical proximity and the development of a critical mass of competing and complementary actors forming an environment conducive to industrial development.

Regarding the first point, there seems to be broad understanding among scholars that technology is a key driving force in economic development. As, for instance, stated by Edquist (1997:1): 'It is almost universally accepted that technological change and other kinds of innovations are the most important sources of productivity growth and increased material welfare – and that this has been so for centuries.' This understanding is in accordance with a number of other authors (cf. Lundvall 1992, Nelson 1993, Verspagen 2000), and is both widespread and non-controversial. Thus, innovation may be regarded as the most important driving force behind competitive economic growth (Simmie 2001). The main issue for economic development and policy related to industrial development, is to identify the most efficient way of organising activities in order to exploit opportunities provided by technology and technological development.

There are many ways of applying a systemic approach to analyses of industrial evolution (Carlsson et al 2002). Michael Porters concept of *cluster* (Porter 1990, 1998a, 1998b) is the point of departure for this project, in the sense that we focus analytically on regionally confined business systems with various actors related to each other in different ways. Rather than discussing to what extent clusters 'exist', we will use this concept and related concepts like *innovation systems* and *industrial milieu*, as analytical tools to facilitate our understanding of central issues related to the evolution of business systems, and the importance of different mechanisms in determining their 'performance'.

In the following chapter on high-technology clusters, central concepts and approaches are presented. This discussion will be used later as a background and framework for an empirical analysis of high-technology industries in Trondheim and Oslo.

2 High-technology clusters

2.1 The cluster concept

The widely acknowledged importance of clusters in economic development may, to a significant extent, be traced back to Porter's seminal work on competition and the advantages of clusters for developing competitive advantage (Porter 1990). Porter's more recent emphasis on geographical proximity (Porter 1998a, 1998b), has also received a great deal of attention: 'a cluster is a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities.' (Porter 1998b:199). In his discussion, Porter points out that clusters 'encompass an array of linked industries and other entities important to competition' (Porter 1998a:78), including the following factors:

- suppliers of specialised input like components, machinery and services
- providers of specialised infrastructure;
- customers
- manufacturers of complementary products
- companies in industries related by skills, technologies or common inputs
- governmental and other institutions; universities, standards-setting agencies, think tanks, vocational training providers, trade associations.

The main focus of Porter's analysis is on competition and factors affecting competitive advantage. He argues that clusters affect competition in 'three broad ways'; by 1) increasing productivity of companies based in the area; 2) driving the directions and pace of innovation which underpins productivity growth; and 3) by stimulating the formation of new businesses (Porter 1998b:80).

In a recent discussion of clusters, Cooke (2001:24) takes Porter's and other's definitions of clusters as his point of departure, and determines that there is 'nothing wrong with these definitions except that they are all *static*, whereas the key feature of clusters is that they are *dynamic*'. Cooke identifies a number of factors that should be incorporated in definitions of clusters, including: a cluster displays a shared identity and future vision; it is characterised by 'turbulence' (spin-offs, spin-outs and start-ups); and vertical linkages and horizontal inter-firm networks are found within a cluster.

Cooke's overview of clusters also identifies the presence of representative governance associations.

In his discussion of the dynamics of clusters, Cooke refers to virtually the same factors as Porter, i.e. productivity gains, innovation gains and the formation of new businesses. Thus, there seems to be a strong correspondence in their understanding of the key dynamic mechanisms of clusters.

Other definitions of clusters are similar, although there are some differences. In a comparative European analysis of regional clusters, Isaksen (2001) refers to the influential writings of Porter (op. cit.), but advocates a more 'narrow and precise' definition of the cluster concept. He argues:

We are in favour of restricting regional clusters to geographical concentrations of interconnected firms, and use the concept regional innovation system to denote regional clusters surrounded by 'supporting organisations'. A regional innovation system, then, contains a specialised cluster of firms supported by a developed infrastructure of supplies firms and knowledge and technology diffusion organisations, which tailor their service to the specific need of the dominating regional industry.

Isaksen makes a distinction between the cluster concept and regional innovation systems in the sense that clusters consist of a number of (geographically proximate) interconnected firms, while the supporting infrastructure together with the cluster constitute the wider concept of the regional innovation system. This is a narrower use of the cluster concept than that applied by Porter and Cooke (op. cit.). Kuijper and van der Stappen (1999) move in the same direction as Isaksen. In their analysis they identify clusters as regionally concentrated economic activity linked in vertical supply chains, although they are not explicit whether institutional factors should be included or not.

In a recent study coordinated by David Keeble on high-technology clusters in Europe (Keeble and Wilkinson 2000), there is no explicit definition of high-tech clusters, but the study provides a thorough discussion of clusters in terms of high-technology and SMEs. The cluster phenomenon is analysed in terms of concepts like innovative milieu, learning regions and regional collective learning. Although not stated explicitly, their analysis seems to be based on an approach in which 'the whole system' is included, not least because significant parts of their analysis are influenced by the 'innovative milieu' approach (Camagni and Capello 2000). This approach puts stronger

emphasis on institutional and socio-cultural factors than ‘traditional’ approaches towards innovation systems.

Analyses of clusters have also received the attention of the OECD (1999), which characterises clusters as ‘drivers of national innovation systems’ (OECD 2001). Based on Porter’s definition of clusters, the OECD has adopted the following definition:

Clusters can be characterised as networks of production of strongly interdependent firms (including specialised suppliers) linked to each other in a value-adding production chain. In some cases, clusters also encompass strategic alliances with universities, research institutes, knowledge-intensive business services, bridging institutions (brokers, consultants) and customers. (Roelandt and den Hertog 1999)

Expanding on this definition, Roelandt and den Hertog emphasise differences to traditional sectoral approaches and argue that clusters include strategic groups with primarily complementary and dissimilar network positions. Furthermore, clusters include actors along the value chains as well as complementary and interrelated industries based on, for instance, common technology or skills (Roelandt and den Hertog 1999).

The OECD analysis on clusters is part of a larger work on national innovation systems (NIS), where clusters are related to the NIS concept ‘reduced-scale national innovation systems’ (OECD 1999:8). It follows implicitly from this that the features and processes of clusters are virtually the same as those of national innovation systems, the main difference being that clusters are characterised by geographical proximity, while the national innovation systems (and the original cluster concept) are not.

In their recent volume on ‘Innovative Cluster’ (OECD 2001), the idea of a cluster as a ‘reduced-NIS’ is maintained, but with reference to new analyses of regional innovation systems, the authors take a step further, suggesting that the concept of a ‘*double* reduced-NIS’ is an even better conceptualisation of regional innovation systems (RIS), i.e. ‘consisting of fewer and more locally manageable industrial clusters that share uniquely regional externalities of the type envisioned by Marshall’. The idea of RIS has been floating around for nearly a decade now, usually in conjunction with industrial district and local cluster concepts. The second reduction is two-fold: geographic specificity (rather than national generality); and greater distance from national policy frameworks (Bergman, Charles and den Hertog 2001:9).

2.2 Clusters and regional systems of innovation

Contemporary interest in clusters is closely related to research on innovation systems and technology, and it may be difficult to identify significant differences in these approaches. A common background for research on innovation systems as well as clusters seems to be the emerging interest in Marshallian industrial districts during the 1980s, particularly inspired by the developments in 'the Third Italy' (Becattini 1990, Brusco 1986 and 1990, Garofoli 1984, Pyke et al 1990, Asheim 1992). This triggered considerable research into ongoing processes of industrial change, partly by raising questions related to shifts towards a structure characterised by flexible specialisation (Piore and Sabel 1984), partly by analysing the seemingly growing importance of small firms and the organisation of small scale activity in the economy (Loveman and Sengenberger 1991, Sengenberger et al 1991).

An important aspect of this development was the spatial concentration of firms in agglomerations due to opportunities for taking advantage of external economies (Simmie 2001), including common factors of production such as land, labour, capital, energy etc., which according to Marshall laid the foundation for a special 'industrial atmosphere'. Later, emphasis was given to the importance of skills, information and knowledge and how they are embedded in local structures.

Spatial concentration of firms also means spatial concentrations of innovations, and the phenomenon of industrial districts and flexible specialisation may also be interpreted as 'a strategy of permanent innovation' (Simmie 2001).

According to Edquist (1997:8) and Lundvall (1992), Christopher Freeman (1987) was the first to apply the concept of a national system of innovation, which he defined as 'the network of institutions in public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies'. Freeman's comments stem from an analysis of Japan's national system of innovation in which he introduced elements which are now commonly included in the concept. However, it was not until after the publication of two major books on national innovation systems (Lundvall 1992 and Nelson 1993) that the concept was taken into broad use.

After defining a system as 'anything that is not chaos', Lundvall (1992) goes on to define a system of innovation as a system 'constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge and that a national system encompasses elements and relationships, either located within or rooted inside the borders of a nation state' (Lundvall 1992:2). In his discussion, Lundvall makes a distinction between innovation systems in a narrow sense and these systems

in a broad sense. In a narrow sense, the system includes organisations and institutions ‘involved in searching and exploring’, like universities and R&D departments and technological institutes, while the system in a broad sense includes ‘all parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring – the production system, the marketing system and the system of finance present themselves as sub-systems in which learning takes place’ (Lundvall 1992:12).

Elaborating on this, Lundvall emphasises that a definition of innovation systems to some degree must be kept open and flexible regarding which sub-systems and which processes should be studied. Furthermore, he argues that there is not one single, legitimate approach to an analysis of innovation systems, as different theoretical perspectives may illuminate different aspects of the system. However, a main focus of the approach is clearly on knowledge and learning; knowledge is the most important resource in the modern economy, and the most important process is learning. Thus, the most important aspect of the ‘performance’ of an innovation system is related to ‘effectiveness in producing, diffusing and exploiting economically useful knowledge’ (Lundvall 1992:6).

In Nelson’s book on national innovation systems, published the year after Lundvall’s, he defines innovation in a broad sense; ‘to encompass the processes by which firms master and get into practice product designs and manufacturing processes that are new to them, if not to the universe or even to the nation’ (Nelson 1993:4). As pioneering firms are often *not* the firms that capture the bulk of economic rents associated with innovation, analyses of innovation are not restricted to firms in the forefront of high-technology or the most advanced scientific research institutions, ‘but more broadly on the factors influencing national technological capabilities’ (p4).

In contrast to the industrial district and agglomeration literature which has a clear regional or localised perspective, the initial literature on innovation systems was national in scope. This national focus was in keeping with Porter’s (1990) early concept of clusters, which did not pay much attention to innovation as a process localised and embedded in local structures.

A significant change of perspective was introduced by the concept of regional innovation systems (Braczyk, Cooke and Heidenreich 1998), in which the previous tradition related to industrial districts was integrated in an analysis of innovation systems. Drawing ties with Marshallian industrial districts, Cooke (1998) discusses an evolutionary approach to regional innovation systems. Instead of ‘tightly defined districts’, Cooke’s model encompasses ‘loosely defined *clusters* of inter-firm relationships’. He provides the following definition:

The *innovative regional cluster* will consist of firms, large and small, comprising an industry sector in which network relationships exist or can be commercially envisaged, research and higher education institutes, private R&D laboratories, technology transfer agencies, chamber of commerce, agencies and appropriate government departments. (Cooke 1998:10)

Here, Cooke refers to the learning aspect of clusters, drawing upon the concept of the learning economy as elaborated by Dalum, Johnson and Lundvall 1992 (see also Asheim 1996, 1998), who discuss various stages of learning; i.e. learning by doing, learning by using, learning by interaction and eventually learning by learning.

As very few regions have all the attributes of a regional innovation system, Cooke introduces a RIS typology. The typology is based on two dimensions grouped into three categories, i.e. the governance infrastructure which is classified into grassroots, network and dirigiste; and the business interrelationship which is classified into three different kinds of innovative milieu, i.e. the globalised, the interactive and the localist. (Cooke 1998:22, cf. Figure 1.2).

The conclusion of this review is that there are not significant differences between the concepts of industrial districts, regional innovation systems and regional clusters. Each of these concepts refers to a similar construct. However due to different stages of research slight variations in the main focus of the approaches may be found.

2.3 The innovative milieu

A somewhat different concept found in the literature on innovation systems, is the concept of the innovative milieu as developed by the GREMI-school¹ (Simmie 2001). The idea of the innovative milieu is referred to frequently in analyses of clusters and cluster performance (e.g. Keeble 1994; Keeble and Wilkinson 1999, 2000; Maillat 1995, 1998; Capello 1999; Camagni and Capello 2000). Keeble has defined the concept in the following way:

The core characteristic of an 'innovative milieu' is a form of networking characterised both by vertical subcontracting chains and horizontal linkages with the providers of financial, technical, fashion, design,

¹ *Groupement Européen des Milieux Innovateurs*

marketing and training services and advice. The consequent Marshallian-type 'industrial district' generates economies which are external to the firm, and include specialisation of product and service supply, pools of skilled labour, and synergetic flows of technical, scientific and other strategic information. (Keeble 1994:208)

A slightly different definition of the concept is the following: 'a set of territorial relationships encompassing in a coherent way a production system, different economic and social actors, a specific culture and a representation system, and generating a dynamic process of collective learning' (Camagni and Capello 2000, Keeble et al 1999).

While geographic proximity is a necessary prerequisite, it is in no way a sufficient condition for forming an innovative milieu. As pointed out by Camagni and Capello, in addition to forming a simple agglomeration of economic activities based on geographical proximity, there should be a set of close inter-firm relations, based on a) an economic element characterised by backward and forward linkages as well as horizontal networks and based on market as well as non-market exchanges of goods, services, information and human capital. Furthermore, there should be b) a socio-cultural element characterised by the relatively homogenous cultural and social background that link economic agents; and c) an institutional element characterised by a network of public and private institutions supporting economic agents and the cluster (Camagni and Capello 2000).

Based on this, Camagni and Capello argue that within the milieu there are two kinds of co-operative processes at work: informal, 'non-traded' relationships (Storper 1995) between the different actors of the cluster, like tacit transfers of knowledge through professional mobility and inter-firm imitation processes; and more formalised co-operation agreements. It is the first set of processes that is regarded as the 'glue' that creates the milieu effect (Camagni and Capello 2000). An effect of the innovative milieu is that it reduces the uncertainty inherent in innovation (Simmie 2001) and reduces obstacles to change.

It follows from this definition that the concept of the innovative milieu is very similar to that of the innovation system, as it includes many of the same components, although they are conceptualised slightly differently. For instance, emphasising the importance of 'non-traded' interdependencies, a concept introduced by Storper in 1995, is common in recent literature on innovation systems. There may also be differences in the way that the innovative milieu approach pays greater attention to social and cultural aspects of

the environments, but even this is not obvious, as social aspects also are included in the innovation system approach.

One important aspect of the innovative milieu approach is its strong focus on processes of learning and the concept of *collective learning*. This is explained as the capacity 'to generate or facilitate innovative behaviour by the firms which are members of the milieu' (Keeble et al 1999), or, as outlined by Capello (1999), this is at the heart of the *milieu innovateur* theory: 'The presence of common knowledge which goes beyond the boundaries of the firm, but which remains within the spatial boundaries of the innovative milieu, gives rise to a process of cumulative local know-how.' The phenomenon of collective learning may be regarded as the 'highest' level of system 'performance'. Capello points to the following preconditions for forming different types of systems (based on Capello 1999, Figure 1):

- inter SME stable linkages and stable local labour market (specialised area)
- presence of cultural and organisational proximity (industrial district)
- presence of strong and stable innovative synergies among local actors and labour force (milieu characterised by the presence of collective learning)
- exploitation of collective learning (milieu innovateur).

In this regard, the innovative milieu approach is comparable to learning economy approaches (Lundvall 1992) and learning regions (Asheim 1996, 1998).

2.4 High-technology

Like many other concepts in the social sciences, there is ambiguity related to the concept of high-technology. The concept implies that it is possible to distinguish between different 'levels' of technology in the sense that some kinds of industrial activity is based on a more 'advanced' technology than other industries, which is often related to the level of 'knowledge' which the technology is based on. However, it is important to be aware that there is no easy way to distinguish 'high' technology from other forms of technology, in particular when it comes to operationalisations. Among those sceptical of the concept, is Porter, who refutes the idea of low tech industry (1998a):

In fact, there is no such thing as a low-tech industry. There are only low-tech companies - that is, companies that fail to use world-class technology and practices to enhance productivity and innovation. A vibrant cluster can help any company in any industry compete in the most

sophisticated ways, using the most advanced, relevant skills and technologies. (Porter 1998a:86)

The main point here is that technology at the firm level may be regarded as something relative, i.e. relative to the industry. In industries which are exposed to international competition, 'high' technology is defined through the practices of the leading and most competitive companies. Thus, in each industry the leading companies define 'high-tech'; it does not make sense to distinguish between high- and low-tech industries. For the same reason it does not make sense to identify specific industries as particularly knowledge-based, as doing so immediately raises the question whether some industries are *not* knowledge-based. Of course, all industries and firms are in some way based on knowledge.

However, as we will return to later, it may be possible to analyse industries based on the role of knowledge resources in the production process, and the extent to which businesses develop 'new' knowledge and 'new' technology.

Reflecting on the problem of identifying high-tech industries, Segal-Quince-Wicksteed (1998) claims that:

High-tech industry constitutes an archetypal 'chaotic concept', which is very difficult to define in any functional sense as it is not united by any common product, process, skill or market. One consequence is that it is almost impossible to draw meaningful generalisations. For instance, some firms that manufacture a high-tech product rely on processes that are - by any definition - low skilled, so the labour market implications of 'high-tech' growth are very ambiguous. Equally, the range of high-tech activities is simply vast: from Internet service providers to those engaged in genomics research, and from the manufacture of scientific instruments to telecommunications. As a result, the nature and implications of any measure of (say) local sourcing across such a differentiated group is far from clear. Arguing that Cambridge (or anywhere else) has a 'functional cluster' of 'high-tech' firms is, therefore, conceptually ambiguous.

Similar reflections have been presented by others, for instance Keeble and Wilkinson (2000). However, in spite of problems related to definitions, there is so much interest in the concept, that it is obviously a phenomenon that needs to be identified.

An analysis that has received a great deal of attention in the field, is Butchart's article from 1987. Taking the point of departure that 'no one doubts the significance of the high-technology industries', and based on a review of previous definitions of high-technology industries, he suggests a definition of high-tech firms mainly based on the R&D intensity of the industry and their proportion of scientists, professional engineers and technicians in the workforce. His analysis resulted in the list of industries presented in Table 2.1.

In an analysis of the role of technology in various industries, the OECD (1999) has differentiated between high-technology, medium high-technology, medium low technology, and low technology. For reasons of available statistics, this definition is based on indicators of direct as well as indirect technology intensity, which reflect to some degree 'technology producers' as well as 'technology users'. The indicators are the following:

- a) R&D expenditures divided by value added;
- b) R&D expenditures divided by production;
- c) R&D expenditures plus technology embodied in intermediate and capital goods divided by production.

Table 2.1: Classification of high-technology industries in the UK. Based on Standard Industrial Classification (SIC) 1980.

2514	Synthetic resins and plastic materials
2515	Synthetic rubber
2570	Pharmaceuticals products
2571	Office machinery manufacture
2572	Electronic data-processing equipment manufacture (computer hardware)
2573	Basic electrical equipment
2574	Telegraph & telephone apparatus & equipment
2575	Electrical instruments & control systems
2576	Radio and electronic capital goods
2577	Components other than active components mainly for electrical equipment
2578	Active components and electronic subassemblies
2579	Aerospace equipment manufacturing and repairing
2580	Measuring, checking & precision instruments & apparatus
2581	Medical & surgical equipment & orthopaedic appliances
2582	Optical precision instruments
2583	Photographic and cinematographic equipment
2584	Telecommunications
2585	Computing services
2586	Research and development

Source: Butchart 1987.

According to the OECD, this classification is useful for analysing industry information, for example on employment or value added by technology intensity (OECD 1999:60). The classification covers at present only the manufacturing industry since no data is available for the service sectors, cf. Table 2.2.

Table 2.2: Classification of manufacturing industries by level of technology.

Level of Technology	Industries
High	aircraft, office and computing equipment, drugs and medicines, radio, TV and communication equipment
Medium High	professional goods, motor vehicles, electrical machinery excluding communication equipment, chemicals excluding drugs, other transport equipment, non-electrical machinery
Medium Low	rubber and plastic products, shipbuilding and repairing, other manufacturing, non-ferrous metals, non-metallic mineral products, metal products, petroleum refineries and products, ferrous metals
Low	paper, paper products and printing, textiles, apparel and leather, food, beverages and tobacco, wood products and furniture

Source: OECD 1999.

Comparing Butchart's definition of high-technology to the OECD's, it may be observed that Butchart's definition is more specific than the OECD's. The OECD definition is based on two-digit NACE codes, while the UK definition is developed at a more detailed level. The OECD restricts their specification of high-technology to manufacturing, while Butchart's specification also includes telecommunication services, computing services and R&D.

Butchart's definition of high-technology (cf. Table 2.1) has been applied to a European analysis of high-technology clusters (Keeble and Wilkinson 2000), but as they emphasise in their report, there are 'many research-based firms producing technology-intensive goods and services to be found in other sectors' (p.5). Thus, the list has been a starting point for identifying high-technology firms, and other firms have been included when they have met the criteria of being research-based and involved in producing technology-intensive goods and services.

A similar strategy has been pursued in this project. However, as we need to identify firms by their industrial classification, we had to translate and define the list based on the new industrial classifications (SN94 based on NACE codes) as illustrated in Table 2.3.

When considering what to include in high-technology sectors, it is important to reflect on the functions involved in the development and distribution of new technology. Processes related to this may be divided into three groups: a) developing and producing the technology, b) implementing and applying the technology in production processes, and c) spreading the technology. This means that in addition to processes related to R&D and manufacturing, relevant industries may also include functions like teaching, consultancy, marketing, selling and support. This leads us to a somewhat broader definition of high-technology industries than applied in other analyses, in particular by including sectors related to wholesale and retail sale of high-technology equipment, and technical consultancy and technical testing and analysis.

Table 2.3: High-technology industry sectors as applied in this project, classification based on SN94

Nace 2	Detailed classification
24	24.13 Manufacture of other inorganic basic chemicals
	24.14 Manufacture of other organic basic chemicals
	24.16 Manufacture of plastics in primary forms
	24.4 Manufacture of pharmaceuticals, medicinal chemicals and botanical products
30	30 Manufacture of office machinery and computers (whole group)
31	31.2 Manufacture of electricity distribution and control apparatus
	31.6 Manufacture of electrical equipment n.e.c.
32	32 Manufacture of radio, television and communication equipment and apparatus
33	33.1 Manufacture of medical and surgical equipment and orthopaedic appliances
	33.2 Manufacture of instruments and appliances for measuring, checking etc
	33.4 Manufacture of optical instruments and photographic equipment
35	35.3 Manufacture of aircraft and spacecraft
51	51.64 Wholesale of office machinery and equipment
52	52.485 Retail sale of computers, office equipment and telecommunication equipment
64	64.2 Telecommunications, except 64.201 'chat lines'
72	72 Computer and related activities (whole group)
73	73.1 Research and experimental development on natural sciences and engineering
74	74.209 Other technical consultancy work
	74.3 Technical testing and analysis

2.5 Cluster performance

The rationale for analysing clusters, or more generally systems of firms, is that specific ways of organising industrial activity may contribute positively to the overall industrial performance of a region or country. Thus, it is important to reflect on the concept of ‘performance’ and the focus of the different systemic approaches to analyses of industrial evolution.

Generally, it may be useful to distinguish between the internal and external performance of a system. External performance is related to the output of the system in terms of production and value creation. It may be measured in different ways, like GDP, employment, turnover, exports etc., and is the main concern of economic development. Internal performance, on the other hand, is related to processes within the system and may be measured by the numbers and quality of innovations, start-ups, technology-based spin-offs etc. Alternatively, a measure of internal performance may focus on the quality and quantity of the interaction between the actors in the system in terms of, for instance, information flow and learning relationships.

The main idea or hypothesis behind most system approaches, although often not explicitly formulated, is that there is a positive relationship between internal and external performance. For instance, it may be assumed, that a high level of innovative activity will have a positive effect on the total long term value creation of the system. However, relationships between internal and external system performance are often very complicated or unclear. The extent to which firms located inside a system perform better than other firms is subject to debate as well as interesting research activity.

When conducting research in this field, it is very important to specify whether performance is related to internal or external processes, and which part of the system performance criteria are related to. It is also important to be aware of the main focus of different system approaches, whether it be competition, productivity, technological change, innovation, learning, commercialisations, start-ups, entrepreneurial activity etc, as each concept focuses on different aspects of a system and its ‘performance’.

The main focus of Porter’s cluster concept continues to be on competition. This is true of his previous works on the ‘Competitive advantage of nations’ (Porter 1990), and still holds in his recent works on clusters as geographic concentrations of interconnected companies. According to Porter, the key to competition is productivity, and ‘productivity rests on *how* companies compete, not on the particular fields they compete in’ (Porter 1998a). The purpose of focusing on locations, then, is that the quality of the local business environment strongly influences the way businesses compete.

According to Porter, clusters affect competition in three ways:

1. by increasing the productivity of companies based in the area
2. by driving the direction and pace of innovation
3. by stimulating the formation of new businesses, which expands and strengthens the cluster itself.

The advantage of organising industries in clusters is that each member benefits as if it had a greater scale or as if it had joined with others formally, without requiring it to sacrifice its flexibility (Porter 1998a:80).

A recent Norwegian analysis of clusters (Reve and Jakobsen 2001), distinguishes between internal and external performance. Table 2.4 summarises the set of indicators applied to internal performance, referred to as cluster 'strength'. Table 2.5 summarises the set of indicators applied to external performance.

While the main idea of clusters is to identify a system of industrial organisation which facilitates competition and economic growth, it may be questioned whether there is a clear relationship between cluster organisation and high (external) performance. In order to test this, clusters first have to be identified by criteria related to the physical formation of firms, i.e. the structure of agglomeration and relationships between firms and other actors which integrate this structure into a system. Obviously, to test the hypothesis of a positive relationship between cluster formation and external performance, criteria related to external performance cannot be used to identify clusters.

Table 2.4: Indicators for evaluating cluster strength as applied by the Norwegian Cluster Project (Reve and Jakobsen 2001:54-55)

Indicators for Cluster Strength	Definition
Competition	The firms' own evaluation of competition in the home market
Collaboration	Collaboration with competing firms on R&D Collaboration with competing firms on competence development
Incentives	The extent to which companies apply incentives like bonus programs, share option programs etc.
Market Conditions	Demanding customer: - innovation as strategy to improving market position Internationalisation: - export relative to total sales - internationalisation strategy
Networks and Linkages	R&D: - share of companies without contacts with R&D institutions Cluster composition: - companies' evaluation of access to qualified suppliers - outsourcing and strategy focus on core competence
Factor Conditions	Factor quality: - supply factors – labour, capital, infrastructure and R&D-results Competence development: - exploitation of international competence - competence strategy based on recruitment, further education, R&D collaboration and on-the-job-training

Table 2.5: Criteria for measuring performance as applied by the Norwegian Cluster Project (Reve and Jakobsen 2001:56-59)

Performance indicator	Explanation
Growth of industry	Relative growth (of turnover and value added) compared to other industries
Factor return	Return on capital, labour, public infrastructure and services
Productivity growth	Growth of value added per employee
International competitiveness	Change of international market shares

However, in some cases it seems to be the case that successful external performance is the main criterion for the identification of clusters. This is clear in a Danish study on ‘competence clusters’, in which clusters are defined in the following way: ‘A group of firms that via interrelationships creates common competencies that make them able to produce at a high performance in terms of sales, profits and employment’ (*Ervhervsfremme Styrelsen* 2001:39).² The three components of this definition are cluster structure, common competencies and performance measured as sales, profits and employment.

While the ultimate interest in clusters and their performance is related to criteria mentioned above, the focus of much of the cluster and innovation literature is on factors that can explain development and internal performance. The focus is more on the existence and quality of inherent processes in clusters than on the actual final output.

The point of departure for our research project was a ranking, published by *Wired Magazine* in 2000, of the internationally leading high-tech hot spots. As this ranking is of interest regarding the assessment of dynamic milieus, the details are worth considering. The ranking was based on the following criteria:

1. the ability of area universities and research facilities to train skilled workers or develop new technologies
2. the presence of established companies and multinationals to provide expertise and economic stability
3. the population’s entrepreneurial drive to start new ventures
4. the availability of venture capital to ensure that the ideas make it to market.

² Our translation. The original text in Danish is: ‘En gruppe af virksomheder, som via deres indbyrdes relationer skaber fælles kompetencer, der gør dem i stand til at producere med relativt høje præstationer i form af indtjening, indkomst og beskæftigelse.’

The ranking is based on scores given to each ‘participating’ city by observers belonging to the network of *Wired Magazine*. Each ‘hot spot’ was evaluated according to the four criteria above and graded on a scale from 1 (low performance) to 4 (high performance). The points were added to a total score which was used to establish the ranking of the cluster.

One obvious issue related to this ranking, is its reliability, as different observers judged different clusters, and nothing is said about how consistency between scores is controlled for. Furthermore, there is the issue of the validity of the four criteria chosen to assess a ‘hot spot’. One would assume that the concept of ‘hot spot’ would be related to high performance in terms of ‘output’ from the system, i.e. external performance, yet the four criteria used are all related to what we previously have referred to as internal performance. It seems reasonable to hypothesise a positive relationship between each of the four criteria and external performance, but this has yet to be investigated. There is always the risk that a city may constitute a ‘hot spot’ in terms of having a ‘high temperature’ on all internal processes, but that does not deliver in the market, a feature typical of the IT hype of the late 1990s.

While the cluster literature focuses on external performance, this dimension is weaker in the other system approaches discussed previously. For instance, aspects of external performance and the relationship between internal and external performance are only occasionally discussed in the innovation system approaches.

In his study on the performance of national systems of innovation, Lundvall (1992) posits that key performance criteria ‘should reflect the efficiency and effectiveness in producing, diffusing and exploiting economically useful knowledge.’ (p6). It is about *economically useful* knowledge, and to become useful in this sense it has to be exploited in a commercial way. Although most innovation research is related to technological development, it is not technical progress that is a goal in itself, but the economic growth that may be facilitated by innovation. A similar view is held by McKelvey (1997), who maintains that innovative activities are defined as ‘knowledge-seeking activities to develop novelty of economic value’, and Asheim (2001), quoting Lundvall and Borrás (1999:35): ...‘what really matters for economic performance is the ability to learn (and forget) and not the stock of knowledge’.

3 Evolution of high-technology clusters

3.1 Evolution

In the previous chapter we reviewed various definitions of the cluster concept and related issues. In this chapter we are concerned with the *evolution* of clusters; i.e. how clusters emerge and evolve, and the key patterns and mechanisms in their evolution.

The basic purpose of an evolutionary approach to an analysis of clusters and innovation systems is to explain change over time. This may be related to fundamental issues like the rise-and-fall pattern of clusters (Pouder and St John 1996) or about birth, evolution and decline (Porter 1998b). It may also involve a more detailed focus on the mechanisms of development at work in the cluster and the interaction between organisations or actors that constitute the cluster, and how evolution at a certain stage depends on previous patterns of evolution. Or, to put it in another way: an evolutionary explanation is an explanation of a fact of economic life by reference to previous facts as well as to causal links (Andersen 1994).

An important departure for many authors in this field, is the classic work of Schumpeter (1934, 1943). Many books on innovation systems refer to him (e.g. Lundvall 1992, Nelson 1993, Edquist 1997, Braczyk, Cooke and Heienreich 1998, Simmie 2001, OECD 2001). In his theory of economic development, Schumpeter introduces the concept of the entrepreneur as an agent of change, and he defines entrepreneurial innovation as the introduction of a new combination. He also points to the role of entrepreneurship as 'breaking the circular flow' and disturbing current equilibrium. Furthermore, Schumpeter characterises the capitalist economic system as a system or method of organising change. One of the most well-known of his concepts, is the concept of creative destruction, i.e. that evolution takes place through the destruction, either direct or indirect, of the current industrial structure, and resources are reallocated from old to new modes of production.

In the literature, basic principles or mechanisms of evolution in a system are commonly referred to using the concepts 1) reproduction or preservation, 2) variation and 3) selection. Andersen puts it this way (1994:14):

- (1) a mechanism of preservation and transmission
- (2) a mechanism of variety-creation
- (3) a mechanism of selection.

Similarly, Edquist, in his analysis of approaches to innovation systems, maintains that an evolutionary theory of technical change often contains the following components (1997:6):

1. The point of departure is the existence of reproduction of entities like genotypes in biology or a certain set-up of technologies and organisational forms in innovation studies.
2. There are mechanisms that introduce novelties in the system (i.e. mechanisms that create diversity). These include significant random elements, but may also produce predictable novelties (e.g. purpose-oriented development work). In biology novelties are mutations; in our context they are innovations.
3. There are mechanisms that select among the entities present in the system. This increases the relative importance of some and diminishes that of others. The selection process reduces diversity, and the mechanisms operation may be the 'natural selection' of biology or the 'market selection' of competition as regards technical change. Together the selection mechanisms constitute a filtering system that functions in several stages and leads to a new set-up of, for example technologies and organisational forms. There might also be feedback from the selection to the generation of new innovations.

Similar approaches have been suggested, among others, by Nelson (1995), McKelvey (1997) and Aldrich (1999). According to McKelvey (1997), the three principles should not be seen as three different phases but instead as continuing processes which interact. In some definitions, selection is further assumed to occur in relation to an environment, leading to the proposition of local rather than universal optimality.

In line with this, evolutionary approaches are careful about analysing economic activity in a systemic context in which history and routines are important, and in which influences of environments and institutions are emphasised (Cooke 1998). Furthermore, emphasis on system approaches naturally leads to the understanding of processes of evolution as having an important collective dimension, i.e. to some extent processes in a cluster are the result of some form of collective action. For instance, the concept of collective learning is commonly focused on in the literature (e.g. Capello 1999, Longhi 1999, Keeble and Wilkinson 1999). Firms belonging to a cluster may also be regarded as part of a collective organisation (Cooke 1998).

Evolutionary processes are characterised, to some extent, by their unpredictability. Chance effects occur (Cooke 1998). Lundwall (1992) argues that processes of innovation are neither totally accidental nor totally predeter-

mined by the economic structure and the institutional set-up, but a strong element of randomness will always remain (Lundwall 1992:12).

There is no theory that can explain why a cluster or system develops in a particular area (Pouder and StJohn 1996), but when the system has started to evolve, its different stages of development may be analysed in a retrospective approach, and a rise-and fall pattern may be identified.

In her analysis of high-tech milieus, Garnsey (1998) says that the most common way of explaining why high-tech districts arise in certain places, has been based on a simple 'growth formula' designed to help promote the expansion of such systems. Factors commonly identified as providing conditions for a growing high-technology locality are (Garnsey 1998:3):

- 'A leading scientific university and associated research complex
- A prestigious industrial or science park
- A desirable social environment to attract and retain high calibre personnel
- Provision of venture capital
- Public support for innovative technology
- A facilitating labour market providing the requisite skills.'

Furthermore, Garnsey (1998), in her analysis of high-tech milieu, argues that the milieu is something more than just a clustering of specialised industry. It is a system with emergent properties. The system is animated by key agents, i.e. entrepreneurs, who form enterprises which develop in interaction with other actors in the system. She points out that the system evolves through the following processes (1998:9):

- 'resource exchange occurs across permeable boundaries
- coordination is through information flows, through which learning occurs
- there are linkages between key components, the agents and units of the system.'

Important processes of evolution are related to technology, the diffusion of knowledge and processes of learning organised around this. Eliasson (2000) suggests that diffusion of new technology may occur along five distinct channels, i.e. (1) when people with competence move over the labour market; (2) through the entry of new firms when people with competence leave established firms; (3) through mutual learning among subcontractors and the systems of coordinators; (4) when a firm strategically acquires other firms to integrate their particular knowledge with its own competence base; (5) when competitors *imitate* the products of successful and leading firms; and (6) through organic growth of, and learning in incumbent firms (Eliasson 2000:16).

The concept of collective learning is related to similar processes. Keeble et al (1999) point to three processes of collective learning: i.e. spin-off of (embodied) technological and managerial expertise in the form of entrepreneurs; inter-firm networking and interaction; and finally, the flow of professional and research staff between firms in the milieu.

Given that unpredictability and processes of chance represent important aspects of the evolutionary mechanism, it is necessary to include this dimension clearly in the system analysis. For instance, Metcalfe (2000) characterises the capitalist system as restless, and the economy as experimental. He regards the economy as a system for testing out new technologies and new business ideas, in which the market represents an important mechanism of selection.

The concept of the experimental economy has also been discussed by other authors, like Eliasson (2000) and Bahrami and Evans (1995). In their analysis of Silicon Valley, Bahrami and Evans point to the 'recycling' of business ideas and other resources as an important mechanism of evolution. Another aspect of this may be termed 're-starts', i.e. a new business that started out based on one business idea may turn out not to work, and will thus have to 're-calibrate' the business model, for instance, by organising a new management team (p71). Bahrami and Evans go on to describe how different resources, in particular human capital, 'float' around in the system continuously forming new constellations and new business units, and in this way contribute to a continuous process of re-cycling.

In analyses of cluster evolution, and in particular in formulating strategies for stimulating the further development of such systems, awareness of these effects are of great importance.

In the following sections we will analyse some of these aspects in three different cases, i.e. Cambridge, Dublin and Sophia Antipolis.

3.2 Cambridge and the Cambridge Phenomenon

Introduction³

The evolution and performance of the high-technology cluster in Cambridge is widely recognised as one of the most interesting in Europe. Often characterised as the Cambridge Phenomenon, the high-tech cluster in Cambridge has been given substantial attention over the last 20 years.

³ This section is an edited summary of Steinsli, J. 2003: The Cambridge Phenomenon. Norwegian School of Management, working paper.

Cambridge is often used as an example of successful university-led industrial development. This has resulted in several reports and articles. Segal Quince Wicksteed undertook the first study in 1985, which they followed up in 2000, and several researchers at Cambridge have published articles and books on high-tech businesses in the area.⁴

Cambridge's main strength is its world-renowned University. Since 1904, Cambridge University scientists have received 60 Nobel Prizes for their scientific discoveries. The high quality of the university, and its interest in interacting with companies, has been a main driving force. Development started during the late 1960s. From 1974 to 1984 the number of high-tech firms increased from around 100 to more than 300 (Garnsey and Lawton-Smith 1998). In 1999 more than 40 000 people were employed in high-tech firms in the Cambridge region.

Evolution of the Cambridge high-technology cluster

Although the basis for the evolution of high-tech industries in Cambridge may be traced back to previous centuries, the history of the Cambridge Phenomenon often starts with the situation during the 1960s, when the city was characterised by strict planning policies which aimed at restricting industrial development in the area around the city.

This resulted in considerable local controversy, the most famous of which was the refusal of IBM to establish its European research and development laboratories in Cambridge. At the same time, however, new companies were formed. Cambridge Consultants was established in 1960, and several new research institutes were established later on. The strength of computing at the University was also the background for the central government's decision to set up a new national CAD-centre (Computer Aided Design centre) in Cambridge in the late 1960s.

During this period, there was growing awareness within Cambridge University of the potential benefits to itself if the city became a prosperous regional centre. At the national level there was increasing awareness of the importance of industry-university links, and the Government urged universities to increase contacts with high-technology industry. As a result, Cambridge University set up the Mott Committee⁵ in 1967.

It took the Committee two years to complete the report, which involved a long process of consultations, as well as many rounds of debate and lobbying,

⁴ See for instance Garnsey 1993, 1994 and 1998, Keeble 1989, Keeble et al 1999, Keeble and Wilkinson 2001.

⁵ Sir Nevil Mott was head of the prestigious Cavendish Laboratory (physics department).

both inside and outside the University, with the result that a degree of consensus was reached between representatives from the University and local planning authorities. The Mott Report is widely regarded as constituting a significant shift in the University's official attitude to industrial development and collaboration with local authorities (Segal Quince Wicksteed 1985).

When the Mott Report was completed in 1969, it recommended a moderate expansion of 'science-based industry' close to the city, in mutual benefit to industry and university. One of its main recommendations was to establish a science park.

Cambridge Science Park was established in 1975 by Trinity College, which is wealthy due to its role as owner of huge land areas close to Cambridge city centre. No public funding was involved in the development of the park. The park was regarded as a commercial investment, but the College has been lenient towards firms with financial difficulties and did not earn a profit the first ten years. The first tenant moved in already in 1973, Cambridge Consultants, and they are still situated in the park.

In 1987, St. Johns College decided to build an innovation centre on the college's property north of Cambridge. Parallel to this, other events contributed to development in the area. In the late 1970s Barclays Bank became aware of the possibilities of high-tech ventures, and enabled a number of start-ups, including Acorn Computers. In 1978, the bank decided to work with spinouts from the University. In addition to providing loans, they helped businesses with advisory services, like assistance in writing business plans and help with budgets.⁶

To give the group of business managers a sense of identity, a club was formed and key speakers invited to improve business knowledge. The purpose of the club was also to encourage networking and learning among the firms, and to encourage sharing of expensive resources such as photocopiers (which were very expensive in the 1970s). In effect, Barclays set up a virtual incubator.

In order to make individuals feel important and to encourage others, the local paper was persuaded to write a business column on a weekly basis focusing on the sector. These initial conditions were the bases of a series of interdependent and reinforcing processes.

The importance of Cambridge University

The positive attitude of Cambridge University towards industrial development played an important role in developing a high-tech cluster, and a number of

⁶ St Johns Innovation Centre strategy 2001

firms in the region originate from the University. The first report on the Cambridge Phenomenon (Segal Quince Wicksteed 1985) indicated that the University either directly or indirectly gave birth to nearly all the high-tech firms in the area at that time. This is in part due to spin-offs either directly from the University, or from companies that were previously University spin-offs. Many leading companies have also been attracted to the area because of the reputation of the University and opportunities for interacting with University staff or taking advantage of the high quality labour market in the area (Segal Quince Wicksteed 1985). A survey undertaken by Cambridgeshire County Council points to the fact that one third of companies reported recruitment of graduates from the University as an important consideration in their decision to settle in the area.

The University's liberal attitude towards staff members who develop new products and earn extra income from their scientific research, seems to be another important reason for the region's success. An additional factor is the high average age of first appointment in permanent positions at Cambridge University. This has given experienced researchers on temporary contracts extra incentive to experiment with entrepreneurship (Keeble 1989). Many Cambridge researchers are only employed on three-month contracts, and therefore do not have much to lose if they do not succeed in starting a new venture. Finally, the University's scientific credibility, reputation and prestige provide clout to companies in the region which are seeking global markets.

High-tech industries in Cambridge

High-tech industries in Cambridge now account for about 40 000 employees (Table 3.1). What characterises the structure of these industries, is the strong position of the R&D sector with around 22 per cent of total high-tech employment. Obviously, this reflects the strong position of R&D activities at the University, and the influence of these activities on industrial development in the area.

A second characteristic of the Cambridge Phenomenon is the fairly low share of ICT-related activities. In total these sectors do not account for more than one third of all activity, which is considerably below other the cities referred to in this analysis. A third characteristic is the fairly strong role of high-tech based manufacturing industries, which accounted for about 42 per cent of activity in 1999, and even 50 per cent back in 1991.

There was also significant growth in employment during the 1990s; the numbers employed in high-tech grew by around 13 000 from 1991 to 1999, i.e. about 50 per cent. In terms of absolute employment growth, the most

significant contributions have come from R&D-activities, telecommunications and technical consultancy.

The data referred to here, summarise the industries in the whole of the Cambridgeshire region. As shown in Table 3.2, different areas of the region have their local specialisations, with for instance R&D activities concentrated in Cambridge City and South Cambridgeshire.

There has been a high rate of new firm formation in Cambridge and South Cambridgeshire. In the period 1997-99, 225 new firms were identified (Table 3.3). Cambridge City was home to 61 start-ups while South Cambridgeshire had 42. In Cambridge City, this was accompanied by a large number of businesses moving elsewhere. South Cambridgeshire attracted more firms that relocated within the county; 22 compared with Cambridge city's five. Lack of areas for new business development within Cambridge City and soaring property prices have forced start-ups to locate outside the city.

Table 3.1 High-tech employment in Cambridge

	1991		1999		Change
		%		%	91-99
24 Chemicals incl. Pharmaceuticals	2 970	11.3	2 600	6.5	-12.5
30 Data and office machines	1 850	7.0	2 210	5.5	19.5
31 Electro technical	0	0.0	1 300	3.3	-
32 Radio, tv and other comm. equipment	5 410	20.5	5 730	14.3	5.9
33 Medical and optical instruments	3 100	11.7	2 890	7.2	-6.8
35 Aircraft and spacecraft	0	0.0	2 130	5.3	-
51 Wholesale of PCs, data and telecom equipment	940	3.6	1 670	4.2	77.7
52 Retailing of PCs, data and telecom equipment	200	0.8	560	1.4	180.0
64 Telecommunication	1 250	4.7	2 610	6.5	108.8
72 Data processing, data bases, software development	3 680	13.9	6 340	15.9	72.3
73 Technical, science based R&D	5 820	22.1	8 720	21.8	49.8
74 Other technical consultancy work	1 170	4.4	3 240	8.1	176.9
Total	26 390	100.0	40 000	100.0	51.6
ICT	7 920	30.0	13 390	33.5	69.1
Other high-tech	18 470	70.0	26 610	66.5	44.1

Source: Research Group, Cambridgeshire County Council. Data are regrouped in accordance with the nace-standard as applied elsewhere in this report. Some data included in the original statistics, are omitted here for reasons of comparison.

Table 3.2 Top high-tech sectors in Cambridgeshire districts, 1999

District	Top sector	Second sector	Third sector
Cambridge City	R&D 3870 jobs, 22% of all	Computer services, 2800 jobs, 22% of all	Electronic engineering, 1760 jobs, 14% of all
East Cambridgeshire	Electronic Engineering 430 jobs, 30% of all	Specialist mechanical engineering, 200 jobs, 14% of all	R&D 170 jobs, 12% of all
Fenland	Specialist wholesale 200 jobs 32% of all	Specialist mechanical engineering, 160 jobs, 25% of all	Technical services, 90 jobs, 14% of all
Huntingdonshire	Electronic Engineering 1840 jobs, 29% of all	R&D, 960 jobs, 15% of all	Computer services, 840 jobs, 13% of all
South Cambridgeshire	R&D 3700 jobs, 22% of all	Chemicals manufacture, 2250 jobs, 22% of all	Aero engineering, 2060 jobs, 12% of all
Peterborough	Computer services, 1040 jobs, 34% of all	Electronic engineering 470 jobs, 15% of all	Specialist mechanical engineering 410 jobs, 13% of all
Cambridgeshire	R&D 8720 jobs, 21% of all	Computer services, 6340 jobs, 16% of all	Electronic engineering 5730 jobs, 14% of all

Source: Cambridgeshire County Council

Table 3.3 New firms and closures 1997- 1999, Cambridgeshire Districts

District	New firms			Lost firms			
	New	Spin-offs Buy-out etc.	Moved in	Total new	Closed/ moved out	Take overs, mergers, internal movers	Total lost
Cambridge City	61	6	8	75	49	24	73
East Cambridgeshire	9	1	6	16	16	3	19
Fenland	6	0	4	10	7	2	9
Huntingdonshire	26	5	11	42	29	6	35
Peterborough City	16	3	8	27	22	0	22
South Cambridgeshire	42	6	27	75	45	22	77
Cambridgeshire	160	21	64	245	168	57	225

Source: Cambridgeshire County Council

The high-tech industries of Cambridgeshire are characterised by a large number of small firms. 41 per cent of the firms employ between 1 and 5 people, and 19 per cent employ between 6 and 10. Only 2.5 per cent of high-tech

businesses employ 200 people or more, yet these employ 39 per cent of the total work force. Industries with high concentrations of small companies include computer services and technical services. Manufacturing sectors tend to have medium-sized and larger firms, and the same applies to the service sectors, including research and development and telecommunications.

In spite of the large number of small firms, the share of small firms is considerably below the national size distribution. Figures from 1996 show that the share of firms with less than 10 employees was 95 per cent for the whole of the UK (as compared to 60 per cent for high-tech in Cambridge), and these firms employed 31 per cent of the workforce (European Observatory for SMEs 1997).

The main characteristics of the high-tech community in Cambridgeshire are:

- *High share of businesses within research and development.* This sector employs over 8700, or more than 21 per cent of the total. The growing computer services sector provides over 6300 jobs (almost 16 per cent) and electronics engineering over 5700, or 14 per cent.
- *Geographical concentration of high-tech businesses.* High-tech employment is concentrated in two neighbouring districts—South Cambridgeshire (including Cambridge Science Park) and Cambridge City. In total 29 350 jobs, or near 75 per cent of all high-tech employment in Cambridgeshire is concentrated in these two districts.
- *High growth rates.* The longer term analysis of employment changes since 1991 shows that high-tech businesses have been very successful and have generally increased employment at rates well above those of the economy overall.
- *A large number of very small firms.* 60 per cent of all firms employ less than ten people, only 2.5 per cent employ more than 200 people.

Institutional factors

There are two universities in Cambridge, i.e. the Cambridge University and the Anglia Polytechnic University (APU). The latter was founded in 1992, and is a merger of two major colleges, the Cambridge College of Arts and Technology and the Essex Institute of Higher Education. There are approximately 23 000 students at APU. Cambridge University consists in total of 31 colleges.⁷ The oldest, Peterhouse College, was established in the 12th

⁷ The colleges are privately endowed autonomous institutions, which provide accommodation and teaching to groups of about 300 students from all faculties, and are administered by their fellows. In Cambridge college academic fellowships are not salaried for university employees.

century. At present, the University has more than 16 500 full-time students and a staff of around 7 000.

About 17 per cent of the students at Cambridge University are from overseas. Because of its excellent academic reputation, admission is highly competitive. Only about a third of applicants are admitted. The student body is fairly evenly split between arts and science subjects. Cambridge University consists of 62 different faculties and departments, among which 29 are science based and 33 are arts based. The university is struggling to keep the art:science ratio on a 50:50 balance to maintain the university's stronghold in science. In comparison, the University of Oxford has an art:science ratio of 1:4. This reflects a long-standing contrast of emphasis in the two places (Garnsey and Lawton Smith 1998). Each college forms a community with people from different disciplines. The collegiate structure of the university creates networks of researchers supplementary to those of the departments and facilitates interaction of knowledge between academics from different disciplines.

Cambridge University has an open and non-bureaucratic approach to the exploitation of research. Collaborative research programmes with industry are encouraged, and companies get easy access to skills and expertise. The University ensures companies' rights to exploit any result from research they sponsor, on terms that reflect the contributions made from both parts. Some increased formalisation of ground rules on the sharing of financial returns from successful commercialisations has recently been adopted by the university, but without fundamentally altering its traditionally benign attitude to entrepreneurial and collaborative initiatives by its own researchers.

The University's Industrial Liaison and Technology Office (ILTO) exists to promote and reinforce contacts between the University and industry. ILTO fulfils a number of tasks; it acts as a central clearing house for external enquires; it provides advice on research contracts, consultancy agreements and other forms of collaborative activities. In this way ILTO acts as a portal to promote contacts between the University and industry. They also operate CUTS, the University's technology exploitation company. Cambridge Research and Innovation LTD and Quantum Fund, in both of which the University is involved, are small local investment funds for university scientists seeking to commercialise their research.

In 1989 the Cambridge Foundation was established with an aim of raising £250 million over 10 years to research and development. Furthermore, new initiatives to encourage entrepreneurship and commercial exploitation by university staff, students and local firms have been initiated;

- Cambridge Entrepreneurship Centre, funded by central government as a part of a national investment competition
- Cambridge University for Manufacturing
- The Cambridge-MIT Institute to promote joint US-British research and innovation
- Business outreach programmes such as Government Challenge Fund (university spin-offs) and HEROBAC (Higher Education Reach Out to Business and the Community) funding.

Total research and development (R&D) activity in the UK is slightly below the EU average; 1.79 per cent of GDP was spent on R&D in 1999, while the EU average was 1.85 per cent. UK Government spending on R&D is below the EU average, while business expenditure is on the average level. According to the EU, the UK is falling behind compared to the development of most other European countries (European Commission 2001).

In the Cambridge region, however, R&D activities are way ahead of all other regions in the UK. In 1999, with 0.56 per cent of the UK's population, the region had 5 per cent of the national industrial research budget (Garnsey and Cannon Brookes 1993). A large portion of the firms in the area have undertaken some form of innovative activity over the last few years, and a significant share of firms have research links with Cambridge region universities or regional government research bodies (Keeble and Moore 1997).

Box 3.1 Institutions in Cambridge

Programs in Advanced Technology (PAT)

High-technology business-led initiative to raise global profile through increased local networking by Cambridge IT Companies.

Greater Cambridge Partnership

- Operating since 1998 to develop consensus between local businesses, government (county and district) and university on future economic strategy for Cambridge region.

Cambridge Futures

- Academic and business alliance investigating, alternative 50-year scenarios for accommodating anticipated growth. Report was published May 1999; work on local transport problems and infrastructure provision ongoing. Private sector funding.

Science parks and innovation centres

- There are four science parks:
- Cambridge Science Park
- St Johns's Innovation Park
- Melbourne Science Park

- Granta Park.

A new biotechnology park is being planned, total area 26,000 m².

Innovation centres:

- St John's Innovation Centre, established 1987 to house new high-technology start-ups, 50 current firms plus 100 'graduates' who have moved to larger premises.
- a new Bioscience Innovation Centre is planned.

Private Venture Capital Funds

- Prelude Technology Investments
- Amadeus Capital (includes Microsoft venture capital fund)
- Cambridge Research and Innovation (CRIL)
- Gateway Fund
- Avlar bioscience seed fund
- QTP high-technology seed fund
- 3i plc Cambridge Office

New Cambridge University Initiatives

- Establishment of new Cambridge Entrepreneurship Centre
- Cambridge University Institute for Manufacturing
- Cambridge-MIT Institute (CMI)
- New business outreach programmes with government Challenge Fund (university spin-offs)
- HEROBAC (Higher Education Reach Out to Business and the Community)

All initiatives have been taken since 1999.

New Cambridge based Eastern Region and European Initiatives

Two major new government-funded regional development organisations, the East of England Investment Agency and the East of England Development Agency, have established their headquarters in Cambridge since 1998. The former is promoting inward foreign investment to the region, while the latter is developing a new Regional Innovation and Technology Transfer Strategy, with co-funding from the European Commission. The latter has also established a European Innovation Relay Centre in Cambridge, based at St John's Innovation Centre.

Source: Keeble 2001.

Many different institutions have been set up in Cambridge in order to facilitate high-technology development and industry-university contacts (Box 3.1). Mainly, these are located in or in the vicinity of Cambridge City. There are four science parks, among which Cambridge Science Park and St John's Innovation Park are the most important. They host 10 per cent of the area's high-tech businesses. Cambridge Science Park is a prestigious address, which creates important legitimacy to risky and innovative ventures. Tenants are, however, frustrated by difficulties of expansion within the Science Park and also the costs of being located there (Segal Quince Wicksteed 1998).

St John's Innovation Centre is the home of several start-ups, and its managing director, Walter Herriot, is highly valued as a source of advice, inspiration and business contacts (Segal Quince Wicksteed 1998).

The UK venture capital market is one of the most well developed in Europe. UK scores highest among the European Union countries in high-tech venture capital investments measured as percentage of GDP (European Commission 2001). Venture capital and the seed capital industry in Cambridge have increased over the last few years, and are attracted to the area by the growth of companies in the region.

The increasing scale and visibility of the seed and venture community in Cambridge will, according to Segal Quince Wicksteed (2000), have a number of important spillover effects;

- The venture capital community is publicity hungry and will help sustain the Cambridge image as a high-tech community.
- With co-location the potential for syndication of investments is enhanced.
- Competition among venture capitalists may improve offers to the companies.
- An active community of external investors forces companies to focus on management.
- They add a further dimension to national and international networking, since most of the funds are both active outside Cambridge and have shareholders from the US and the rest of Europe.

In addition to these formal sources of finance, there has been growth in direct investments by corporate bodies as well as individuals. Previous entrepreneurs have played a role as financiers of start-ups. For instance, a previous Cambridge entrepreneur, Herman Hauser, started the venture capital fund Amadeus. However, Saxenian (1989) argues that development in Cambridge has been hindered due to venture capitalists' lack of knowledge of high-tech industries. Since institutional investors largely finance UK venture capital firms, venture capital firms tend to maintain an arm's-length relationship to entrepreneurs, in contrast to Silicon Valley, where venture capitalists typically have business experience and can provide access to networks and intervene directly in the development of the firms, based on first hand knowledge of the kinds of difficulties young entrepreneurs face. Future involvement in venture capital by former Cambridge entrepreneurs might improve this situation.

The role of entrepreneurial activity and larger firms

Evolution of an area occurs as a result of action taken by a number of different actors, and by the interaction between these actors. Previous sections of this report looked mainly at institutional actors; we will now turn to the primary business actors, i.e. the entrepreneurs and the firms.

Entrepreneurial activity has been one of the main forces of economic growth and dynamism in Cambridge (Segal Quince Wicksteed 2000). The development of the high-tech cluster reflects primarily a process of creation and growth of new independent firms by individual entrepreneurs (Keeble 1988). Successful entrepreneurs have encouraged others and contributed to the emergence of an entrepreneurial culture. The relatively high degree of start-ups and spinouts imply a considerable diffusion of knowledge from the 'incubating' firms or institutions. 70 per cent of new firms have been founded by entrepreneurs formerly working for another company, while 25 per cent of the chief founders were employed either by a university or a research institution prior to start-up (Keeble et al 1998).

As commented on earlier, there are a large number of small firms in the region. The question why many high-tech firms have failed to grow, is often raised. According to Garnsey and Lawton Smith (1998) there are many causes at work, but in their view the main explanation can be attributed to the lack of managerial or business experience among the bulk of scientific entrepreneurs.

Cambridge has several serial entrepreneurs. Gordon Edge, for example, left Cambridge Consultants in 1972 to set up PA Technology, and then in 1986 established Scientific Generics. A number of firms have since spun out of Generics. Generic has access to risk funds, and through its senior directors and major clients, the company has excellent links to potential development partners. As leading individuals have made money, they have demonstrated their confidence in Cambridge by investing locally in new opportunities. One example is Herman Hauser, the Acorn entrepreneur, who started the venture capital company Amadeus.

A study undertaken by Segal Quince Wicksteed (2000) of the entrepreneurial culture among students at the two universities of Cambridge showed that mostly, opportunities for starting their own businesses after their studies were perceived as very low⁸. The entrepreneurial culture at Cambridge University was lower than at Anglia Polytechnic University (APU). At APU the entrepreneurial intent is higher than in any of the other universities compared,

⁸ The results are based on a survey among 168 Cambridge University students and 148 Anglia Polytechnic University students.

including Stanford University, California. It is also important to be aware that Cambridge University primarily recruits students interested in research, and a significant share are recruited from all over the world. One would not expect to find influence from the entrepreneurial culture present in the area in the students' attitudes; on the other hand, it is possible that the high share of potential future entrepreneurs at APU reflects the entrepreneurial culture in the region. Still, the large size of the Cambridge University makes it an important engine of entrepreneurial spin-offs, even if this engine appears to be running at low intensity (Segal Quince Wicksteed 2000).

Several initiatives have been taken to support the entrepreneurial culture of the area, like the Cambridge Europe and Technology Club, Cambridge High-Tech Association and Cambridge Network.

The small size of the city seems to enable the development of a close network of informal linkages and to strengthen synergy within a high-technology complex, significantly more than in large cities (Keeble 1988). Key entrepreneurial role models are far more visible in cities like Cambridge than for instance in London.

According to Segal Quince Wicksteed (2000), large firms played an important role in the early days of the Cambridge Phenomenon. Companies such as Cambridge Instruments and the Pye Group served as seedbeds for spin-offs. Later, large R&D consultancies, notably Cambridge Consultants, PA Technology, Scientific Generics and the Technology partnership, played a very significant role in generating and fostering local research-intensive spin-offs.

Large R&D consultancies have also been important in creating a regional culture for trust and collaborative research. Being mainly spinouts from the university and employing University graduates, their internal organisational cultures were shaped by university research values. In 1998, Segal Quince Wicksteed estimated that Cambridge-based technology consultancy firms employed approximately 1500 people.

Cambridge Consultants have exerted a distinctive influence on the development. They have been important not only through spinouts, but also through enhancing Cambridge's international visibility. On average, 60 per cent of the company's revenue is generated outside the UK, and only a limited share of their customers are located in Cambridge.

Large firms have also played a significant role in providing trained staff to growing SMEs. Segal Quince Wicksteed showed that as many as 23 per cent of technical support staff had previously worked for one of the traditional large firms; in addition, nine per cent of administrators, consultants or researchers previously had done so. Large firms often run training programs for technical support staff and have therefore been very important in providing qualified staff to SMEs.

The role of public policy

Unlike the other two cases analysed in this chapter, public policy has not been a major driving force in the development of high-technology industry in Cambridge. However, public policy has been important as a 'background' factor, especially during particular stages of development.

The most important policy influence, is through financing of the University, even though it may be argued that it was the reduction in government funding that actually forced the University to take a more active approach to increasing their links with industry. The Government also played a role through location of the CAD centre in Cambridge.

Furthermore, regional government has also played a role in Cambridge by actively using planning regulations to shield the city's historic architectural environment, which has contributed to a high quality residential environment. Cambridge is an attractive place to live and work. Segal Quince Wicksteed (1985) have emphasised the importance of a strict planning regime which has prevented any large-scale development from taking place, which would have put enormous pressure on the labour market and on the area's physical capacity. This made it easier for small firms to establish and grow, and allowed the region to take advantage of new opportunities.

There are few financial schemes available for high-tech firms in Cambridge. However, government policies towards university-business technology transfer and links are far more supportive than in the past, although these policy initiatives are too recent to assess their effectiveness (Keeble 2001) or impact development.

UK firms invest less in R&D than firms in many other major industrial countries, and UK government R&D expenditure is historically heavily biased towards the defence industry. During the 1980s and 1990s UK science and technology policies were weak, and government expenditure on R&D and on university research was significantly reduced (Keeble 2001). This put, however, considerable pressure on universities to increase their links with industry, by seeking research funding, providing consultancy and promoting university-owned technology spin-offs and science parks. Private sector venture capital provision has also grown substantially in line with government encouragement.

The present Labour government has launched several initiatives to upgrade innovation, science and technology policies in the UK. Over the last few years three Government White Papers have introduced policy initiatives of relevance;

- *Our Competitive Future: Building the Knowledge Driven Economy*, Department of Trade and Industry 1998.

- *Excellence and Opportunity: A Science and Innovation Policy for the 21st Century*, Department of Trade and Industry, 2000.
- *Opportunity for All in a World of Change: a White Paper on Enterprise, Skills and Innovation*, Department of Trade and Industry, 2001.

The policy emphasis is now on;

- Strengthening and enhancing university basic science infrastructure and research capacity, for example by a £1 billion partnership with the Wellcome Trust to renew university science buildings and equipment.
- Further encouraging and stimulating university-business links and collaboration, for example via a new Higher Education Innovation Fund to strengthen university links with especially small firms, and the establishment of a new national network of 'university innovation centres'.
- Supporting development of local clusters of small technology based firms, for example via a new £50 million national 'innovative' cluster fund and new Regional Innovation Funds of £50 million a year to enable Regional Development agencies to support clusters and incubators and new clubs of scientists, entrepreneurs, managers and financiers.
- Supporting business formation and growth, for example by a £75 million incubator fund.

Summary

The high-tech cluster in Cambridgeshire has shown rapid growth since the first high-tech companies were established there in the early 1970s. More than 40 000 people are currently employed in high-tech firms. In this development, Cambridge has enjoyed a unique combination of advantageous conditions for growth. These include among others; the outstanding scientific achievements and reputation of Cambridge University, an attractive living environment and successful entrepreneurs.

It is widely acknowledged that Cambridge University has played a pivotal role in this development, although the role of the University has changed over the years. The Cambridge region has built an entrepreneurial culture in a 'self-ignited' way, i.e. processes of spin-offs and growth of technology based new firms started without policy intervention. The region's stronghold in science made Cambridge capable of utilising macroeconomic and technological changes, which have created new markets and product

opportunities in many areas, such as microcomputers, software and microelectronic appliances.

Despite a large number of local firms, it is not possible to argue that proximity to customers or competitors are central driving forces. Most companies serve worldwide markets. The same applies to their main competitors; most of their competitors are located abroad or elsewhere in the UK.

Still, businesses in the region have a mutual interest in being located in the same area, even if they operate within different sectors. In fact, the wish to locate close to other high-tech businesses and not least be identified as part of the 'Cambridge Phenomenon', has been important to location decisions.

There is evidence of mechanisms of regional collective learning in the region; it seems like a common set of rules of behaviour and collaboration have been established, which has enabled development of the trust essential to innovative collaboration. There are two key agents for developing such regional codes of behaviour, namely the University of Cambridge and a small group of large local R&D consultancies. The University's liberal attitude towards research collaboration has spread to the businesses community through spin-offs, recruitment of researchers and direct research collaboration (Keeble et al 1998).

The growth of institutions in Cambridge has been striking, and, according to Keeble 2001), helped to 'thicken' the local institutional environment and to encourage the continued growth of the high-technology cluster.

High-tech enterprise in Cambridge has also become a showpiece, receiving disproportionate media attention. The vast publicity about the Cambridge Phenomenon has been among the most important initiatives attracting further businesses to the area (Lawton Smith and Garnsey 1998).

Industrial policy seems to have played a marginal role, even if it seems like governmental policies have had some influence on the University and also through the location of the CAD centre to Cambridge.

Venture Capital has followed rather than led development in Cambridge. Creative local financiers were, however, identified as an important element in stimulating high-tech growth in the first report on the 'Cambridge Phenomenon' (Segal Quince Wicksteed 1985). In the late 1970s and the early 1980s Barclays Bank played an important role in financing and supporting new high-tech companies. Today successful entrepreneurs operate as venture capitalists or business angels.

3.4 Dublin – the software capital of Europe

Introduction⁹

Economic development in Ireland has been remarkable. Over the last few decades, Ireland has experienced one of the highest growth rates in Europe. A number of factors have contributed to the strong performance of the economy, among the most important are favourable tax incentives and the supply of a young and well-educated labour force which have attracted multinational companies (MNCs). Macroeconomic policies have generated confidence, and combined with high levels of public investment in physical and human capital based on substantial EU funding, business activities and productivity have escalated.

Ireland is now widely recognised as one of the leading European countries in the field of ICT. With its small population of 3.6 million people, and with about a third of this population concentrated in Dublin and its conurbation, the city has served as a main centre and driving force in this development. Although regional strategies have been implemented to support other areas of the country, Dublin plays a dominant role. In fact, the share of urban residents has risen from 46 per cent in 1991 to 58 per cent in 1996, and continues to rise.

Dublin is regarded as the software capital of Europe. Global IT giants such as Intel, Microsoft, IBM and Gateway 2000 are located in Dublin, and there has also been a significant expansion in the internationally traded service sector, which includes software production, financial services and other customer services linked to ICT. Of critical importance has been the provision of dedicated space for business development in the inner city landscape (Dublin City Development Board 2001).

Evolution of the Dublin high-tech cluster

Ireland first gained independence in 1922. Compared to other European countries Irish industrial policy has a relatively short history. The focus of Ireland's economic policy after 1922 was to build a strong agriculture sector and to secure a self-provided economy. High unemployment and emigration rates in the 1950s led to the development of a more outward looking policy, with an increased focus on industrialisation.

⁹ This section is a summary of Steinsli J. (2003): Dublin – Rise of the Celtic Tiger. Working paper. Norwegian School of Management.

The Irish Government developed a strategy based on attracting multinational companies (MNCs) to Ireland. The objective was to generate cash and employment through export-led development. This policy of 'industrialisation by invitation' included substantial incentives to MNCs to locate in the country. The Industrial Development Authority (IDA) was established in 1969 to help attract MNCs as well as develop Irish-owned industry.

The first major companies arrived in the late 1960s. The first was Digital, followed by companies such as Microsoft, Oracle and Dell. These companies received generous grants and financial support; the most attractive was a 15-year full tax exemption on export sales which applied to companies moving in between 1960 and 1981. In 1981 this was replaced by a 10 per cent corporation tax, guaranteed until 2010, for all manufacturing companies and many export oriented service companies (O'Riain 1997a). However, the EU Commission has decided that the tax scheme was not in compliance with EEA legislation, and the Irish Government now has determined that all companies must pay 12.5 per cent tax from 2003.

In addition to low tax rates, companies were offered other financial incentives such as rent subsidies and offsets against capital investments. The Irish entry into the European Economic Community in 1973, further strengthened Ireland's position as an attractive location, in particular for US companies. Low wage rates, a young, well-educated and English-speaking workforce also made Ireland attractive. Later, social partnership agreements, which were instituted in 1987, helped stimulate growth by keeping wage levels down, contributing to a stable macroeconomic environment and reducing the number of labour market conflicts.

A survey among senior executives in ten US firms identified Ireland's low rate of corporation tax as the key factor influencing the location decisions of inward investments (Gunnigle and McGuire 2001).

In the late 1970s, the Government identified the electronics industry as an industry with major growth potential (Grimes 1999, Travers 1999), and a number of initiatives were taken:

- IDA (The Industrial Development Authority) established a world-wide intelligence gathering system on key developments in the electronics industry.
- A systematic, consistent and professional promotional programme was organised and continually updated in response to the changing needs of businesses to attract investments from the best and most advanced electronics companies in the world.
- The capacity to provide graduates in electronic engineering and computer science was increased in third level education institutions.

- New research programmes in electronics were organised at the third level education institutions.
- The telecommunications system was radically upgraded in the early 1980s, and Ireland was among the first countries in Europe to achieve a largely digitalised telecommunication system.

By 1980, Ireland had attracted a number of producers of mainframe minicomputers, integrated circuit makers and data processing bureaus. MNCs also had positive impacts on other industrial sectors in Ireland, such as the printing industry, since few of the software companies printed their manuals in-house.

However, the success of this policy was questioned. The multinationals mainly created low-skilled jobs, they developed few linkages to the local economy, and often companies left once their tax breaks ended. On this background, the influential Telesis report¹⁰ in 1982 pointed to the need of a more strategic approach to industrial policy. The report recommended attracting companies that to a larger extent would be positive for Irish industry. As a result, industrial policy was changed to attract MNCs of importance for Irish firms, combined with an increased focus on developing indigenous industry. Efforts were made to improve linkages between multinationals and local companies and to stimulate the growth of indigenous firms through several policy initiatives. However, attracting foreign investments remains the most important objective of industrial policy.

The recession during the early 1990s hit Ireland particularly hard. In 1992, 280 000 people were registered as unemployed, and Ireland had a public debt/GDP ratio of more than 90 per cent. Although conditions improved again, the vulnerability of Ireland's strategy of industrialisation 'by invitation' and the dependencies of multinationals became more and more evident (Grimes 1999, O'Riain 1997a). Public authorities started to show increasing concern for the limited contribution MNCs had to the local economy. When the Culliten report was published in 1992 (Industrial Policy Review Group 1992), the main recommendations from the Telesis report were repeated. The report pointed to the need for further strengthening indigenous industries, and new approaches to industrial policy were suggested.

As a result, focus was directed towards foreign direct investment projects which required a high-skilled workforce, which would in turn generate supply activities from indigenous firms. This strategy was combined with

¹⁰ A Review of Industrial policy, by the Telesis Consulting group at the request of the National Economic and Social Council

public support to firms' training and education costs. Various initiatives were taken to encourage cooperation between firms and between firms and R&D institutions, and indigenous start-ups were stimulated through the provision of business parks and incubators (see discussion below).

These policy changes implied a shift from sector and firm specific subsidies towards a broader cluster or system oriented approach, in which the main focus was on developing synergies between industries, firms and other actors within wide resource areas. The Industrial Development Agency Ireland (IDA) was established in 1994 and given the sole responsibility for attracting inward investments. Enterprise Ireland was established in 1998 in order to provide support to indigenous industry.

High-tech industries

High-tech industries in Ireland comprised some 6800 firms and employed almost 123 000 people in 1999. Total turnover was estimated at around 47 billion IR£.¹¹ It has not been possible to obtain region data, but based on the dominant role of Dublin in the Irish economy, it is estimated that about 70 per cent of all high-technology activity is located in the city. (O'Gorman 2001, Dublin City Development Board 2001, Grimes 1999), i.e. high-tech employment in the Dublin area should be around 86 000 people, accounting for 16 per cent of the total workforce in the region.

¹¹ It has been very difficult to obtain good data for high-tech industries in Ireland. The best data we could get access to, was Eurostat, but some data were confidential.

Table 3.4: High-technology industries in Ireland 1999.

Nace Industry	Firms	Employment	Turnover		Empl	
		%	mIR£	%	per firm	
24 Chemical industries incl pharmaceuticals	99	13 718	11.2	16 709	35.4	139
30 Office machinery and computers	83	20 154	16.4	14 628	31.0	243
31 Electric control apparatus and equipment	89	7 091	5.8	822	1.7	80
32 Telecommunication equipment	23	13 388	10.9	5 221	11.1	582
33 Medical and optical instruments	117	13 441	10.9	2 180	4.6	115
35 Aircraft and spacecraft	12	na		na		
51 Wholesale office machinery and equipment	306	7 490	6.1	1 884	4.0	24
52 Retail sale computers, telecom equipm	3 959	16 631	13.5	1 609	3.4	4
64 Telecommunications	53	13 229	10.8	1 989	4.2	250
72 Computer and related activities	1 785	16 850	13.7	2 136	4.5	9
73 Technical and science based R&D	108	374	0.3	40	0.1	3
74 Technical testing, technical consultancy	37	394	0.3	28	0.1	11
Total	6 671	122 760	100.0	47 247	100.0	18
ICT	6 209	87 742	71.5	27 468	58.1	14
Other high-tech	462	35 018	28.5	19 779	41.9	76

Source: Eurostat, confidential data not included.

Generally, ICT-industries are the most important high-technology industries in Ireland, with more than 70 per cent of total employment and almost 60 per cent of turnover. Within the ICT-industries, the most important sectors are the production of office machinery and computers, accounting for approximately 16 per cent, while the second and third largest sectors in terms of employment are wholesale of office machinery and equipment and computer and related activities (Nace 72). This reflects the importance of the software sector.¹²

¹² The software sector includes the electronics and hardware industry, computer software industry, teleservice or call centre industry associated with PCs and software. These sectors can be found in NACE 30-32, NACE 72 and NACE 64 (OECD, 2001).

However, within high-technology industries chemicals are also important, with more than 16 000 employees and turnover exceeding 16 billion IR£ in 1999.

Growth in high-tech industries was particularly high in the second half of the 1990s. In fact, from 1995 to 1999 total employment increased by 44 per cent. Industries like office machinery and computers and computer and related activities contributed most to this development. Generally the growth of high-technology industries was significantly above the growth rate of the rest of the economy.

The role of MNCs in the local economy

As follows from the previous discussion, foreign-owned companies have played an important role in the economic development of Ireland. In 1987 foreign-owned manufacturing companies accounted for 42 per cent of all employment and 52 per cent of gross outputs. Twelve years later these shares increased to 49 per cent and 76 per cent respectively, indicating that the role of foreign-owned companies is even more important today than previously.

With 49 per cent of manufacturing employment and 76 per cent of gross output, the foreign-owned sector had a much higher output per employee than the Irish-owned sector. The figures for net output are even more striking, in particular when taking into consideration that wages are higher in the foreign-owned sector than in Irish-owned industry. In 1996, the average wage in the foreign-owned high-tech manufacturing industry was IR£ 18 800 per year, while the similar figure for Irish-owned industry was IR£ 15 100 per year.

Foreign-owned companies dominate high-tech sectors, such as chemicals and metals and engineering, while Irish-owned companies dominate sectors such as food, wood and paper. Therefore, a dual manufacturing structure has emerged; high-tech, high value added industries are owned by foreign interests, while low-tech, low productivity industries, to a large extent, are owned by Irish owners (Ministry of Finance 1999). The high output figures in the foreign-owned sector can be misleading, since the sector is dominated by US transnational corporations with low-end software development and language translation.

Table 3.5: Distribution of activities between Irish and foreign firms in manufacturing.

	1987	1996	1999
<u>Irish firms:</u>			
Firms	3 935	3 871	4 105
Employees (000s)	106.6	120.2	1268
Gross outputs (m IR£)	7 364	12 188	14 152
Exports (m IR£)	31.9	34	na
<u>Foreign firms</u>			
Firms	795	728	689
Employees (000s)	78.4	106.4	122.1
Gross outputs (m IR£)	8 028	24 108	44 641
Exports (m IR£)	84.7	89.3	na
<u>Foreign firms in per cent of total</u>			
Firms	16.8	15.8	14.4
Employees	42.4	47.0	49.1
Gross outputs	52.2	66.4	75.9
Exports	72.6	72.4	

Source: National development plan

Large firms dominate the enterprise structure in Ireland. On average, each enterprise employs 11 people, but the majority of employees are employed by large scale enterprises (European Observatory for SMEs 1997). In comparison, the average number employed per enterprise in Europe is 6. However, in Europe as a whole the majority of people are also employed by large-scale enterprises. As Table 3.5 shows, on average foreign-owned firms employed 177 people, while the similar figure for Irish-owned firms was 31 (FORFAS 1999).

In the past, the dominance of foreign companies generated few linkages to the local economy. They were important for generating employment and added value, but had less impact on economic development beyond that. Today, there is evidence of an increasing interdependency between the multinationals and the local economy, as the multinationals have contributed to the development of an indigenous software industry.

According to a survey of software firms,¹³ a majority of the founding entrepreneurs worked in a MNC either immediately, or at some stage, prior to

¹³ Interview with 36 managers or owners of indigenous companies in the software sector, summer 1996. The results from the survey are presented in a report by L. Stevansson (pending publication).

the start-up. About half of them had also worked abroad in software firms, or in a related sector, at some time before starting their company. About half of the group had at some time worked in a sector which now constitutes a major customer for their company. The pool of labour with working experience from MNCs represents a valuable resource for the indigenous software industry. On the other hand, higher wages in the foreign-owned sector has made it increasingly difficult for Irish-owned firms to attract qualified labour, in particular in periods with low unemployment rates.

MNCs also play a role through business relationship with indigenous firms. In some cases business relationships with MNCs lead to referrals to customers abroad (Stevensson, pending publication). Still, it is more likely that Irish firms are in dialogue with Microsoft in Seattle than in contact with Microsoft's company in Dublin.

MNCs contributed to the development of an Irish supplier base, even if this effect did not occur before the software manufacturing and localisation investments of the 1980s and 1990s. It seems like this was mainly due to two reasons: One mechanism was stimulated by changes in organisational structures within companies, with outsourcing as a strategy for taking advantage of external economies of scale. This led to opportunities for a number of spin-offs, which based their business development on the basis of MNC contracts. Second, government policy strengthened the development of an indigenous industry through several initiatives supporting development of an indigenous suppliers base (see next section). Support to R&D, marketing consultancy, management development and business networking were given priority. Today, networks of local suppliers have emerged around the multinationals.

Institutional factors

As a strategy for developing into the knowledge economy, education has been the focus of investments by successive governments over many years. According to the European 2001 Innovation Scoreboard (European Commission 2001), the share of people with third level qualifications was 22 per cent in 2000. Compared to other Northern European countries, this is not a particularly high share, but it is slightly above the average figure of 21 per cent for the European Union as a whole. In countries like Sweden and Finland 32 per cent of the population have third level qualifications, compared to 28 per cent in the UK.

There are three universities located in the Dublin area, Trinity College, University College Dublin and Dublin City University. These, along with the Dublin Institute of Technology and a number of other state and privately run

third level colleges, make Dublin City the main centre of Ireland's third level education system. In total, there were 42 000 students enrolled in higher education institutes in Dublin in 1999/2000, 5000 more than in 1996.

These institutions have produced graduates from a wide range of disciplines. Their IT graduates are among the most qualified in the world, and are perceived to be one of the reasons for Ireland's growth in the ICT industry (Dublin City Enterprise Board 1996, Travers 1999). Also in terms of having an education system that meets the needs of a competitive economy, Ireland scores high. In a survey conducted by IMD, Ireland is ranked one of the top three countries in the world, along with Finland and Singapore.¹⁴ According to Travers (1999), there is a strong tradition of collaboration between higher education institutions and companies in Ireland.

Another aspect of the knowledge economy, is resources allocated for R&D activities. In this respect, Irish performance is significantly below the OECD average. While total R&D spending accounted for 1.38 per cent of GDP in 1999, the similar figure for OECD was 1.69. In particular, public spending on R&D is low.

Given Ireland's relatively high share of high-tech industries, one would expect that the share of expenditure measured as a percentage of GDP would have been higher. One reasonable explanation may be that a large share of the high-tech industries are integrated in multinationals with their R&D and headquarter functions located outside Ireland, emphasising the role of foreign affiliates and international sourcing.

Although Ireland is on the low end of European R&D expenditure, the situation improved considerably in the 1990s with a growth rate of 30-50 per cent in the period 1989 to 1997. This was primarily due to increased efforts by the business sector (Waagø et al. 2001), however, R&D expenditure has also become a priority for the Irish authorities.

According to Waagø et al., Dublin gets 60–70 per cent of all the competitive funding for research in Ireland. Investments in R&D are directed towards areas supposed to be driving forces of future economic and industrial development. A Technology Foresight Fund was recently established in order to support research, technological development and innovation in the fields of biotechnology, information and communications technology and associated areas. In total, EURO 711 million will be invested in basic research in the period 2001 to 2007. Other initiatives have also been taken in order to stimulate R&D (Box 3.2).

¹⁴ According to World Competitiveness Yearbook 2001.

Box 3.2 Examples of measures to increase private sector R&D

Programs in Advanced Technology (PAT)

Developed to fill the gap between state of the art research and the universities and applied consultancy work. The program is organised as a partnership between Enterprise Ireland, industry and third level colleges, and helps industry to:

- Access new technology
- Improve competitiveness and existing production
- Move into new higher value areas
- Provide and train people for industry

PAT assists industry in attracting overseas and domestic investment in high-technology areas that may lead to the establishment of new technology based start-up companies. There are seven PATs which consists of more than thirty centres located at Ireland's Universities and Institutes of Technology. The seven programs are: Advanced manufacturing expertise and technology, bio-research, material technology, power electronics, optronics, software, and telecommunication. Each of the seven PATs has a core management group located at Enterprise Ireland which deals with IP-rights, marketing, business development etc. The total budget is roughly EUR 25 million a year with 2/3 from industry and 1/3 from public sources.

Technology Foresight Fund

Established in order to support research, technological development and innovation, funded by the Irish council for Science. The fund finances projects in key technologies strategic to long-term sectoral and national development. The objectives of these projects will be to provide internationally competitive RTDI, and to promote Ireland as an attractive location in which to perform RTDI. Projects are implemented on a public/private partnership basis. Funding: EURO 711 million over a period of seven years.

University Industry Programs

Started to promote co-operation between universities and industry to facilitate innovation, technology transfer, enterprise development, continuing professional development and all other forms of university/industry co-operation. There are such activities at all the Universities in the Dublin region. Actors such as Regional Authorities, Enterprise Ireland, Universities and industry, finance the various activities.

Several industrial parks and innovation centres have been developed in and around Dublin city, such as the Financial Services Centre in the former docklands, The National Digital Park at City West, Dublin Business Innovation centre, the Guinness Enterprise centre and the more recently proposed Digital District in the vicinity of the Guinness Brewery (Dublin City Enterprise Board 2001). Of critical importance for these centres has been an

attractive and central location and provision of telecommunications infrastructure. Some of them also provide various services to businesses located within their vicinity. In addition to these developments, a number of organisations provide incubation units and workspace for new start-ups. Community Enterprise Centres seem to be the most important provider of incubation units in Dublin. They are controlled by the local community and are 'not for profit' organisations. In addition to cheap rent, they offer a wide range of support facilities at a reasonable cost. In total there are more than 30 such units in the Dublin region¹⁵. Despite an extensive range of organisations providing incubation space, lack of space for further industrial expansion is a critical factor for future growth in Dublin (Fitzpatrick Associates 1999).

Box 3.3. Examples of technology parks, industrial parks and innovation centres

Docklands Innovation Park

Docklands Innovation Park is an enterprise hub housing a range of SMEs in a former dockland area now undergoing major regeneration. Docklands Innovation Park is under the joint direction of The Bolton Trust (an enterprise Trust owned and managed by DIT Staff) and the Project Development Centre (PDC). PDC is the largest incubator centre in Ireland for start-ups and fast growth technology companies. The Centre concentrates on knowledge-based and innovative firms.

National Digital Park at Citywest

The National Digital Park which covers an area of 40 hectares, is a joint venture between IDA Ireland and Citywest Business Campus, opened in 1999. The Park has been specifically designed to meet the needs of companies with broadband telecommunications requirements. There are now more than 50 companies employing 1700 people

Ireland's International Financial Service Centre

Ireland's International Financial Service Centre (IFSC) is located in the centre of Dublin, and is the most concentrated cluster of ICT-dependent companies in Ireland. In 1999 approximately 6500 people were employed directly in the IFSC. The primary objective of the IFSC was to promote the development of a well-regulated, financial services industry that would provide quality, sustainable jobs. A secondary objective was to assist the urban renewal programme at the Custom House Docks side. Half of the new FDI projects in recent years are located in the IFSC in Dublin (Grimes, 1999).

Leopardstown Business Park

Located in Clonskeagh, in proximity to major universities and the south city service sector. There are a number of large indigenous and overseas companies

¹⁵ According to the Dublin Enterprise support directory

located in Clonskeagh and in the nearby Leopardstown Business Park.

Arklow Technology Park Wicklow

A 30-hectare services, business and technology park, and hosts a major ceramics industry.

The Dublin Business Innovation Centre (Dublin BIC)

Established in 1987 with the support of the EU, private and public sectors. Has assisted the creation of a development and enterprise culture in the Dublin region. Its main purpose is to increase the level of entrepreneurial activity and improve survival rates and growth prospects.

The Centre is a joint initiative with the University Campus Programme, which aims to provide a mix of practical training and consultancy support in assisting participants in developing their business ideas. It is a link between the University and the business community in Ireland and overseas.

The Guinness-enterprise Centre

A Public Private Partnership providing incubator space to new and established small businesses primarily in software and international & technological services. Media Lab Europe, a subsidiary of MIT's Media Lab, is already in place on the Guinness site as part of the new Digital District designed to help speed Ireland's economy into the Internet age. The Digital District will comprise state of the art museums, leading edge telecommunications infrastructure and hundreds of high-tech start-ups. It also facilitates a wide range of Enterprise development related support services.

Source www.startingabusinessinireland.com

Venture capital provision has developed over the recent years, and is now one of the largest in Europe on a per capita basis, but still below the EU average when measured as percent of GDP.

The rapid increase in venture capital funding is shown in Table 3.6. In 1997, total VC funding was IR£ 30 million, while in 1999 this had increased to IR£ 140 million. This increase can be identified as an indicator of the recent growth in high-tech industries in Ireland. It is also interesting to note that the share of funding to early stage projects has increased. In 1999, 41 per cent of venture capital investment was in early stage projects.

Irish Venture Capital funds invest almost three times as much in computer related technology and biotechnology as the rest of Europe (Malinen 2001). Substantial funding from the EU's structural fund has been of importance in the expansion of the Venture Capital market. EURO 90 million was allocated to Venture Capital funds in the Operational Programme 1994-99.

Table 3.6 Venture Capital Investments in Ireland

	1997	1998	1999
Total amount invested (IR£m)	31	41	140
Number of companies financed	58	72	128
Financing stage			
Early stage (incl start-ups)	16	27	52
<i>Share of total</i>	28%	38%	41%
Expansion	39	38	66
<i>Share of total</i>	67%	53%	52%
Other	3	7	10
<i>Share of total</i>	5%	10%	8%

Source Report on Venture Capital Investment activity 1999, IVCA

Approximately 73 per cent of venture capital invested has been invested in the Leinster region (Dublin and Mid East region). Approximately 70 per cent of these investments have been in the software sector. The most important sources were pension funds and banks which represented two thirds of total funds raised in 1999. Corporate investors raised 24 per cent of total funds in 1999. Approximately 60 per cent of these investors were Irish.

In order to increase the number of start-ups and stimulate investment in venture capital, the Government initiated two tax deduction schemes; the Business Expansion Scheme, and the Seed Capital Scheme (Box 3.4).

Enterprise Ireland (EI) and Enterprise Boards provide grants and loans to companies. EI provides support for larger companies and companies with high potential for growth, while Enterprise Boards provides support to companies with less than 10 employees. There are in total four Enterprise Boards in Dublin. In addition to its main offices, EI has a regional office located in Dublin. Dublin has the status of regional aid region. Since 2000 it has been possible to support investments in companies with up to 17.5 per cent in Dublin. Business angels are hard to find. Enterprise Ireland and Dublin Business Innovation centre have developed registers of such investors, and can, after evaluating projects, arrange access to potential investors.

Box 3. 4: Tax Deduction Schemes

Business Expansion Scheme

The Business expansion scheme gives income tax relief to those who invest capital in qualifying Irish companies. Fund-raising companies must be incorporated and resident in Ireland, must not be quoted on the Stock Exchange (except for the new Developing Companies Market), and must be engaged in a 'qualifying trade'. It is up to the business to find potential investors and, when it does, to obtain approval of the arrangement from the Revenue Commissioners. The scheme has been in operation since 1984. The scheme has been important for small companies or start-ups to provide early stage development capital.

Seed Capital Scheme

The Seed Capital Scheme repays income tax to people leaving employment to start their own businesses (only companies qualify, not sole traders or partnerships). In the year of starting their business, qualifying individuals may claim back the tax paid in respect of up to IR£ 25 000 of income in each of the previous five tax years. This scheme has been in operation since 1993.

The role of Public policy

The Dublin case illustrates that government can play a significant role in the development of high-tech industries, even in the case of a small and peripheral country. The main strategy has been based on attracting foreign direct investment, and although the sustainability of the current Irish economy may be questioned, there is no doubt that the strategy has been successful. Ireland has the largest market of foreign direct investment (FDI) in Europe, with 55 per cent of the total, more than twice the share of the second most successful country, France, which has 21 per cent (OECD 2001). Furthermore, Ireland has attracted 23 per cent of all new US investments in Europe.

The Irish government has in four distinct ways contributed to the growth of high-tech industry:

- By offering favourable conditions for multinational companies
- By investment in education and infrastructure
- By contributing to the development of an industrial cluster by 'strategic' invitation
- By strengthening innovation and entrepreneurship.

IDA identified the potential of the ICT sector at an early stage (Travers 1999). In the early years focus was on companies in electronics, later focus was shifted to personal computer manufacturers and finally call centres (Grimes 1999). While the main focus for a long time has been on attracting multinational companies, during the 1990s there was a shift towards indige-

nous development with an emphasis on setting up institutions to support this development. The main reason for growth in the indigenous software industry seems to be the structure of the software industry. The software industry had, in general, lower entry barriers and offered opportunities for new or small Irish firms to develop. This was in contrast to the electronics industry's large-scale production plants, with high barriers to entry that offered few opportunities to start-up companies.

Irish industrial policy and enterprise support is largely based on an effective organisation at the ministry and agency level. At the highest political level, the Ministry of Enterprise, Trade and Employment has a leading role and a wide mandate in industrial development matters. FORFAS, the high-level policy advisory and coordination board, provides strategic level recommendations to the Ministry. The Irish system is rather centralised, which provides effective decision making at the policy and implementation level. Such capability coupled with sufficient resources provides a basis for a well functioning industrial policy (Kuusisto 2000). National policy has been formulated to make effective use of EU programmes, and EU funding has played a crucial role for Ireland. IR£ 3.3 billion has been invested in road infrastructure by EU funds, and EU contributed to 40 per cent of Enterprise Ireland funding in the period 1994-99.

Summary and Conclusions

The attraction of FDI has been a key element of Irish industrial policy for more than 40 years, but there is now evidence that the Government has succeeded in their attempts to strengthen indigenous industrial development, and has made the Irish economy less dependent on the multinationals. The growth in the indigenous software sector is one promising development, along with the increased 'embeddedness' of multinationals. Most of the new economic development has taken place within the greater Dublin region, and Dublin has increasingly strengthened its position as a favourable city to establish businesses.

However, the ICT industry in Ireland is concentrated at a relatively low point in the value chain, and deals with relatively mature technology that has been developed elsewhere (Grimes 1999). In accordance with globalisation theorists the 'footloose' character of these investments, implies that MNCs will soon move to cheaper locations. Therefore, the success of Ireland's strategy of 'industrialisation by invitation' is vulnerable to changes in Ireland's attractiveness relative to for instance emerging economies in Eastern Europe.

In recent years Irish public policies have been redefined in line with an increased focus on the importance of knowledge as a major factor for

stimulating innovation capabilities. Dynamic local networks seem important and are often the basis for self-reinforcing growth in regions (Porter 1998, Lundvall 1992, Camagni and Capello 2000, OECD 2001). The fact that MNCs in Ireland have developed tighter links to the regional economy supports this theory, and may indicate companies will choose to stay in a location even if they can find cheaper locations elsewhere. However, the Irish case shows that global penetration of local networks is inevitable (O'Riain, 1997b). While networks formed by corporate organisations do offer opportunities to developing countries, the developmental impact of local networks is severely constrained unless specific policies exist to guide the evolution of networks.

Further development of a world-class competitive software industry in Ireland depends on the firms' ability to remain competitive despite their location far from their main markets. Also, because of their scale and limited market size, Irish indigenous companies can succeed only by addressing specific market niches in which they have specialised knowledge (Grimes 1999).

In order to succeed, many Irish firms have been forced to set up offices abroad, and the success of the Irish software industry has attracted international capital. Growth of venture capital interests in Irish firms would mean an influx of resources combined with a loss of autonomy, as venture capital firms tend to manage their investment closely (O'Riain 1997b). The provision of venture capital is therefore important for future development, as well as continued investments in telecommunications infrastructure in particular. The low level of R&D in higher education has precluded any significant technology transfer from this source. Current investment in science and technology is designed to rectify this situation.

3.3 Sophia Antipolis – evolution of a Greenfield Cluster

Introduction¹⁶

Sophia Antipolis, located on the Côte d'Azur close to Nice in Southern France, represents an interesting case of the evolution of a high-technology

¹⁶ Mostly, the information presented in this chapter is based on two sources: 1) presentations, working documents by Michel Bernasconi, CERAM, and 2) Strategic Management Institute (2001) 'Sophia Antipolis – Creation of a Greenfield Cluster.'. The evolution of high-tech industries in Sophia Antipolis has also been discussed by Mønsted (2000), Longhi (2001), Tamasy and Sternberg (2002), Longhi and Keeble (2002) and Keeble (2002).

cluster. Starting from an area of ‘virtually nothing’, this cluster may be regarded as a greenfield cluster (Strategic Management Institute 2001). In the beginning of the 1960s an area which today is a flourishing industrial park with a number of dynamic actors present, was hills with undeveloped land – a piece of ‘vacant space’ (Longhi 1999). The region definitely had no industry and university tradition (Longhi and Keeble 2000).

Much of the development in the area is often attributed to one person, Pierre Laffitte, regarded as a community entrepreneur who has played a pivotal role as initiator, facilitator and organiser of the development. As early as 1960 Laffitte, who is from the area, wrote an article in which he raised the idea of decentralising R&D and engineering activities to green places outside Paris in order to establish alternatives to the ‘the grey matter in Paris’ (Strategic Management Institute 2001:7). Arguing that Parisian life was not conducive to research and ‘cross fertilisation’ between scientists working in different fields, he suggested decentralisation to areas like Fontainebleau and Orléans. He also indicated the area around Nice as a suitable place for developing this activity.

In 1962, the two companies IBM and Texas Instruments happened to establish activities in the area, largely owing to attractive living conditions on the French Riviera. IBM set up a research centre, and Texas Instruments established its European centre, demonstrating the potential for developing high-technology activities in the area. In 1964, a plan was launched to industrialise the Alpes Maritimes¹⁷ by allocating 120 hectares of land for an industrial park. Five years later, in 1969, Laffitte presented his vision of creating a city of 20 000 researchers, and gave the city the name Sophia Antipolis.¹⁸

This marked the beginning of a dynamic pattern of development, which according to Bernasconi (2002) may be divided in three stages (Figure 3.1). At the turn of the millennium the region included somewhere between 25 000 and 30 000 high-tech employees, among these around 14 000 in the science park of Sophia Antipolis.

¹⁷ Alpes Maritimes is the region in which Nice is the main city, Sophia Antipolis is located approximately 15 km west of Nice.

¹⁸ Pierre Laffitte explained in a speech on September 2002 that Sophia means wisdom, and Antipolis is Greek for Antibes (a small city close to Sophia Antipolis). Sophia is also the name of Pierre Laffitte’s first wife.

The start-up period

It took about a decade to develop the vision of Sophia Antipolis and to prepare and implement the plans that would open up for development. A very important stimulating factor was Texas Instruments and IBM's decision to locate in the region. The presence of these companies signalled and demonstrated opportunities related to high-technology development.

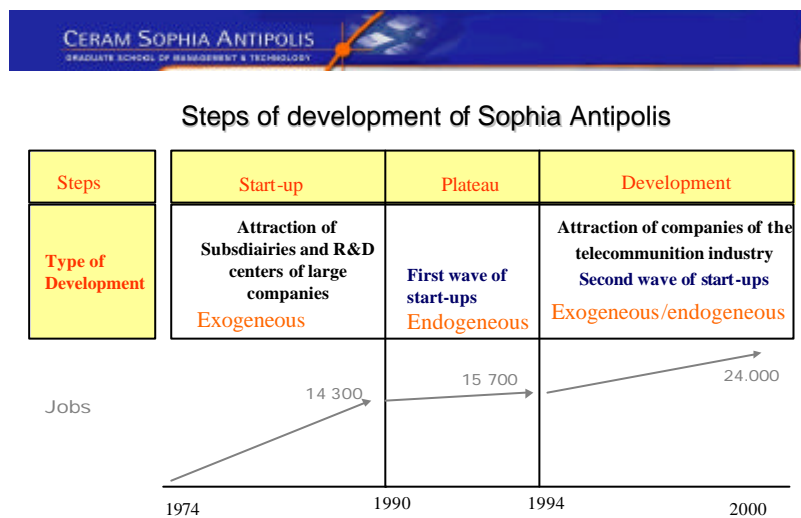


Figure 3.1: Steps of development of Sophia Antipolis. (Source: Bernasconi 2002)

In the beginning, it was the persistent promotion of the area by Lafitte and his team that convinced companies to establish in the new science park (SMI 2001). The area has the advantage of being located in a very attractive region with a good climate and living conditions, and with infrastructures linked to the tourism industry. In addition to this, the specific planning of the science park is extraordinary, and unlike many other science parks. The park is located in an area with many small hills and valleys. Of the total area of 2300 hectares, 800 hectares are allocated for industrial facilities, and 150 hectares for housing, sports and recreation. The remaining land is kept as 'green' areas. Furthermore, the road system as well as the buildings fit in nicely with the landscape. When in the park, one hardly gets the impression of being in such a large science park. Furthermore, design and architecture have been given high priority, with agreeable results.

The start-up period was characterised by entries to the science park by, mostly, R&D centres of international groups and national public research institutes. Towards the late 1980s large numbers of new companies followed, on an annual basis more than a hundred companies were started. Many belonged to the telecom and IT sectors. The association to 'Telecom Valley' was made during this period (SMI 2001:9).

Development during this period may be characterised as exogenous. Mostly, expansion came about because international and national companies and institutions set up their divisions or departments in the area and in this way implanted their own resources. In spite of dynamics at the local level, these dynamics were based on resources and actors from outside the region. The system that evolved was directed from outside, with a lot of external contact, but with fewer local linkages. There were also problems of developing local processes of collective learning (Longhi 1999).

An important mechanism in the evolution of high-technology clusters, is spin-off from existing larger firms (Dahlstrand 2000). However, in the case of Sophia Antipolis, this mechanism was lacking for a long time. In fact, a reverse spin-off effect could be detected; highly qualified personnel employed by small and medium-sized firms established in the park, were absorbed into larger firms (Longhi 1999).

The mechanisms of evolution were different in other ways as well. In other cases we have seen that universities have been important for early stage development, this was not the case in Sophia Antipolis. The University of Nice did not establish activities, i.e. engineering school, research institutes and doctoral training programs, in Sophia until 1986. These institutions are now of great importance.

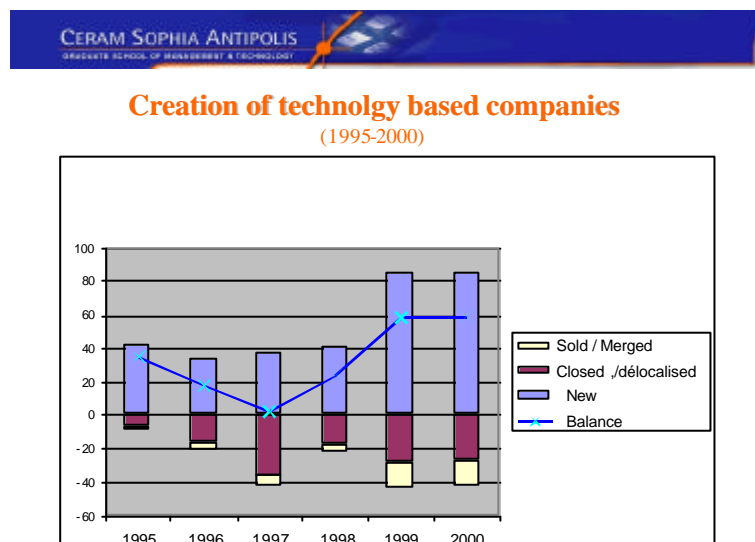
Longhi (1999:337) characterises the general pattern of development in the area as 'exactly the reverse image of the established model'. While the established model implies that development is based on local resources, for example, knowledge resources in a high quality university, Sophia started with 'empty space. Two large international companies moved in because of the attractiveness of the region, then more large companies and R&D activities followed, and finally, services and SMEs. Eventually, the university also established a presence. While reverse spin-off effects may be observed in the first stages of development, they were succeeded by ordinary spin-off effects, and processes of indigenous development started.

Consolidation and new growth

While there had been steady growth in high-tech industries up to 1990, this pattern suddenly changed in the early 1990s. There are different reasons for

this. Multinationals stopped establishing subsidiaries in Sophia Antipolis due to the recession in the US, and many companies were forced to downsize their activities due to the recession in Europe in 1992.

On the other hand, these developments represented change. Spin-off activities from larger firms resulted in start-ups of a number of new small firms, often based on subcontracting. Nevertheless, this was an important impetus to indigenous development. Later, there was a steady number of indigenous start-ups. Typically, the number of indigenous start-ups was around 40 during the second half of the 1990s, but by the end of the decade start-ups reached a level of more than 80 per year (cf. Figure 3.2). As shown in the figure, there have also been exits, but during the entire period there has been net growth, i.e. a positive number of new firms. In terms of employment growth, contributions from the new firms have been significant.



Source: Observatoire DYNAMIS - CERAM Sophia Antipolis

Figure 3.2: Start-ups of technology-based firms in Sophia Antipolis 1995-2000.

Source: Bernasconi 2002

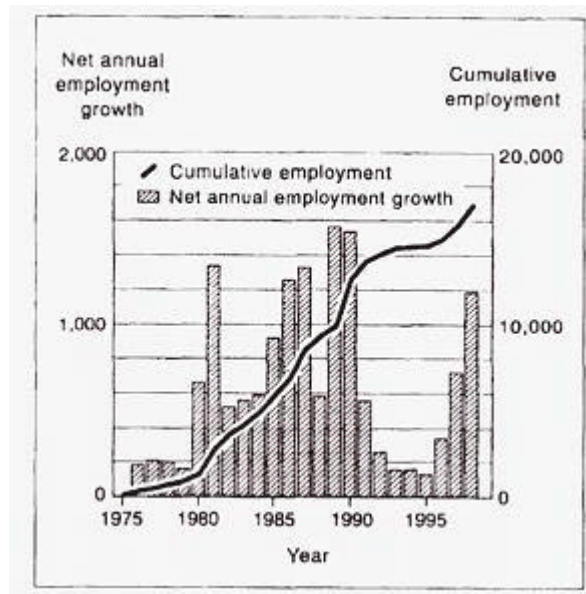


Figure 3.3: Employment growth in Sophia Antipolis 1975-1998. Source: Longhi 1999.

The current situation

There may be some confusion about the total extent of high-tech activity in Sophia Antipolis. Partly, one can look at the activities located inside the science park, i.e. the area designed to host high-tech development. In 2000 there were a total of 325 firms with some 13 000 employees in the park.

However, there are significant high-tech activities outside the park, including the two companies that originally triggered development. In comparison to Cambridge, for example, it suffices to include activities of the whole region, as the whole region is included in cases commented upon in the literature. Thus, when we include data for all relevant activities of the region of Côte d'Azur, there in total are 881 firms with more than 27 000 employees and a turnover of 41 billion Franc (Table 3.7, data for 2000).

Table 3.7: High-tech industries in Sophia Antipolis and Côte d'Azur 2000.

	Sophia Antipolis			Rest of region			Total Côte d'Azur		
	Firms	Empl.	Turn-over Bill. Fr	Firms	Empl.	Turn-over Bill. Fr	Firms	Empl.	Turn-over Bill. Fr
Information technology and related	282	11 120	11.6	353	7 355	16.8	635	18 475	28.4
Life/health science related	43	1 995	3.8	203	7 185	8.8	246	9 180	12.6
Total	325	13 115	15.4	556	14 540	25.6	881	27 655	41.0

Source: Sirius-Chambre de Commerce et d'Industrie Nice Côte d'Azur: Observatoire des Poles de Compétences Technologiques.

Information technology firms account for around two thirds of all activity. As seen from the table, IT industry is found in Sophia Antipolis, while life and health science related industries predominate in the rest of the region.

The industries present in the area are characterised by a mixture of small and large firms. In terms of number, smaller firms account for the majority; around 70 per cent have less than ten employees. There are only around 40 companies with more than 100 employees (SMI 2001). However, these large firms account for a significant share of total employment.

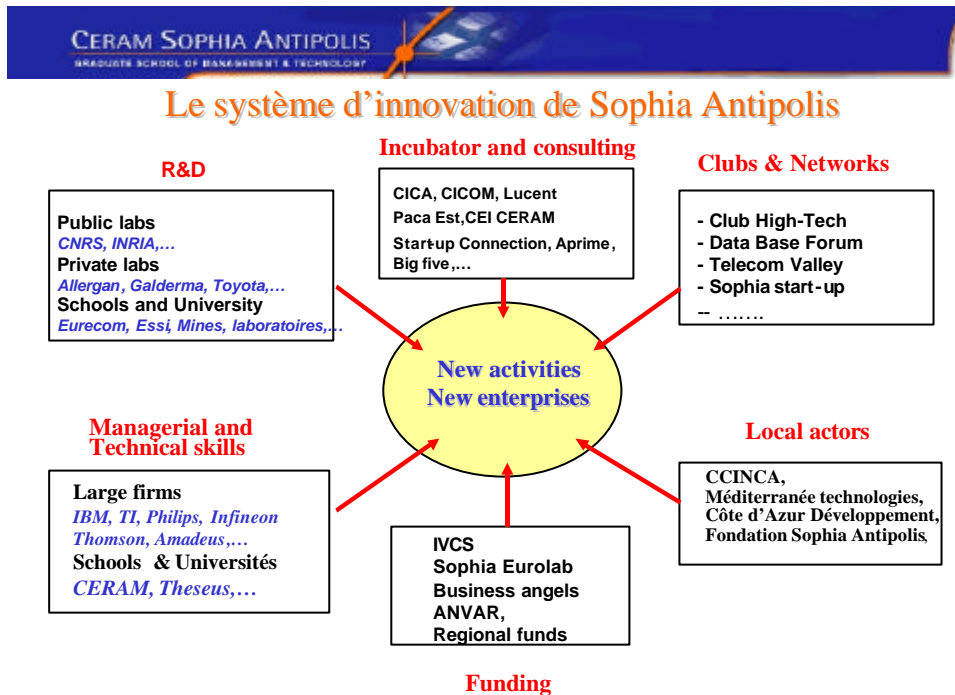


Figure 3.4: The innovation system of Sophia Antipolis. Source: Bernasconi 2002.

A large number of multinational companies are present in the area, approximately 110; it is claimed that 63 different nationalities are represented among their staff.

An important aspect of high-technology clusters is that they constitute a number of different types of actors who partly compete against and partly supplement each other. Together they constitute a kind of critical mass that creates synergies. According to Longhi (1999), Sophia Antipolis has now reached a stage of development which can be said to comply with the requirements of an innovative milieu. However, as Longhi as well as others point out, important cluster elements and mechanisms fell into place just recently. There are still significant challenges to be met for the future development of the area.

The system of innovation of Sophia Antipolis may be described in different ways; see, for instance, Bernasconi's illustration (2002, cf. Figure 3.4).

Research centres and higher education now play important roles in Sophia Antipolis. There are about 4000 people in public-sector R&D institutions, and different engineering and business schools are now established in

the area (See Box 3.5). It is estimated that R&D activities account for about 40 per cent of all activities provided by high-tech related firms and institutions (SMI 2001:26).

Box 3.5: R&D and Higher Education Institutions in Sophia Antipolis.

Most important teaching institutes:

- Ceram Group – CERAM Sophia Antipolis (graduate studies in management, finance and high-tech entrepreneurship) and EAI TECH (undergraduate studies)
- UNSA – University of Nice – Sophia Antipolis
- ESINSA – School of Engineering of Nice Sophia Antipolis
- ESSI – School of Computer Engineering
- ENSMP – The National School of Mines
- Eurécom Institute – Higher studies in communication systems (Corporate/ multimedia/ mobile communication)
- Theseus Institute – Management studies

Most important research institutions

- INRIA – National Institute for Research in Computer Science and Control
- CNRS – National Scientific Research Centre
- NRA – National Institute for Agronomic Research
- INSERM – National Institute for Health and Medical Research
- France Télécom R&D – European Telecommunications R&D Centre

Source: SMI 2001

Box 3.6: Incubators in Sophia Antipolis

- INRIA-Transfert, established in 1998 with support from the French Research Ministry. It is a subsidiary of the national research institute INRIA, and holds a capital of 86.5 million FF (approx. 15 mill Euro ??)
- Institute Eurécom, one of the leading European centres in advanced communications and networking research, also works as an incubator
- Incubator CERAM, started in 2000 as part of the High-Tech Entrepreneurship Chair
- PACA Est, started in 2001
- Incubator CICOM (Centre for International de Communication).

Source: SMI 2001

Recently, high-tech start-ups have become important for the evolution of the area, and incubators have been established to facilitate such start-ups, see Box 3.6 .

The organisation of venture capital activities at the regional level is a fairly recent phenomenon, and there are still just three funds organised locally (Box 3.7). In addition to these three, there are four national funds that are operating in the region.

According to an analysis performed at CERAM, 35 start-ups were funded by venture capital during the five years 1996-2001. Total funding was more than a billion FF. Most companies had only been through a first round of investment, but some had also been through the second and third rounds. VC funding has had a significant international profile, approximately fifty per cent was French capital, the rest was divided among ten countries, among them the most important were US capital with about 20 per cent of the funding, and UK capital with 6 per cent (Bernasconi 2002).

Box 3.7: Venture Capital Funds in Sophia Antipolis

Regional funds:

- Sophia Euro Lab, started 2000, is a mix between an incubator and fund for seed-money.
- I-Source Gestion, started 1999, main owner is INRIA-Transfert. Three funds with a total of 83 million Euro.
- FCPR Sud Capital No 1, started 2000, administered funds of 150 mill FF (23 mill Euro) in 2000.

National funds:

- CDC PME, owned by Caisse des Dépôts et Consignations (CDC), holds a capital of 1500 million FF (229 million Euro).
- FPCR, created in 2001, manages a fund of 150 million Euros.
- Sofinnova Partners, created in 1972, and is the oldest in France, manages 535 million Euros through four different funds.
- CDC – Innovation Partners, manages two different funds; CDC Innovation 1996 with 400 million FF (60 million Euro) and CDC-Innovation 2000 with 1 billion FF (150 million Euro).

Source: SMI 2001

To stimulate the role of venture capital, the first International Venture Capital Summit was organised in Sophia Antipolis in 1997 by the regional authorities and the Chamber of Commerce. Since then the event has been organised annually. Each year, a selection committee decides on 40 high

potential companies to participate. Participation is open to companies from all over the country, but the number from Sophia Antipolis has been around 30 per cent.

Another aspect of developing the innovative milieu, is to develop network mechanisms and organise professional organisations. In 1991, Telecom Valley was established as a non-profit organisation to gather actors important to the telecommunications and information technology sector. With around 60 members, this organisation aims at developing a unique pool of competencies based on members' expertise.

Other associations are also active, and to promote the development of the area, different governmental support institutions have been organised, see Box 3.8

Box 3.8: Government Support Institutions

- SYMISA, the Syndicate of Sophia Antipolis, is responsible for the general management, financial policy, international relations, promotion of and services to corporations in Sophia Antipolis.
- SAEM SACA, *Société Anonyme d'Economie Mixte Sophia Antipolis Cote d'Azur*, is in charge of planning, development and commercialisation of the Science Park under the auspices of SYMISA.
- CCI NCA, *Chambre de Commerce et d'Industrie Nice Cote d'Azur*, supports economic development in the region in various ways.
- *Maison de l'Entreprise de Sophia Antipolis*, is a department of the *Chambre de Commerce* in charge of stimulating economic environment in Sophia Antipolis.
- CAD, *Cote d'Azur Développement*, the official regional economic promotion and development agency.
- CICA, International Centre for Advanced Communications, provides the communication infrastructure of the region.

Source: SMI 2001

Summary

The story of Sophia Antipolis is extraordinary in the sense that the evolution of the area started with vacant space, a vision and plans for implementation. The result today is Europe's leading science park, at least according to local actors,¹⁹ with 13 000 high-tech employees in the park, and another 14 000 in the Côte d'Azur region.

Development has been carefully planned and administrated. One individual, Pierre Lafitte, has played a crucial role in the process of developing

¹⁹ 'Sophia Antipolis – Where Businesses and People Flourish'. Promotion brochure.

visions and coordinating different actions. He is still actively involved in the park.

Initially industrial development at Sophia was characterised by large international companies and national research institutions which established research units in the area. Development was mainly exogenously driven. In contrast to other areas, institutions of higher education were absent. In later stages of development, various university colleges and schools were set up, internal mechanisms started to work, and there was a significant shift towards more endogenously driven development.

However, important cluster factors did not fall into place until recently, including venture capital, business clubs, incubators and other institutions of importance to the facilitation of cluster evolution. Longhi (1999) claims that an innovative milieu in which processes of collective learning are at work clearly exists in Sophia, but that cluster dynamics created around the value-chains of the present industries are still missing, most likely due to their early stage development. Activities related to research and centres of excellence predominate, which so far has resulted in less manufacturing activity (SMI 2001).

Due to the early stage of local start-ups, Sophia strongly depends on a supply of venture capital from outside the area. As local firms grow larger and some go public, this will probably contribute to the financial dynamics of the area.

3.5 Diversity and similarity of cluster evolution

The cases discussed above clearly demonstrate the diversity of cluster evolution. Each story of evolution is unique and strongly dependent on the specific prerequisites of the region and the characteristics of its actors. However, there are similar groups of actors involved, and similar mechanisms at work. What varies, is the mix of factors and the extent to which the different mechanisms are at work. So it seems feasible to suggest a framework for analysing cluster evolution. In Table 3.7 we have summarised the factors we think are the most interesting for the three cases.

The initial conditions and prerequisites that characterise the three areas vary significantly. While a primary asset of Cambridge is its excellent university, which played a key role in facilitating development, the situation in Dublin and Sophia Antipolis was quite the opposite, with no local university tradition of importance in the early stages of development. While the university sector has been a primary driving force in the case of Cambridge, both by taking a number of initiatives to stimulate high-tech development and by attracting international companies, this has not been the role of the university sector in either Dublin or Sophia Antipolis. In Ireland, the universities have recently become involved in developing strategies which will support indigenous development. In the case of Sophia Antipolis, the university first moved into the science park recently, and is just now beginning to take an active role.

Table 3.7 Summary of factors of importance to cluster evolution in the cases of Cambridge, Dublin and Sophia Antipolis.

Factor	Cambridge	Dublin	Sophia Antipolis
Initial conditions	Strong university traditions Attractive living conditions	Less developed, agriculture dominance, cheap, qualified labour, EU membership, English speaking population	Attractive living conditions 'Vacant space'
Triggering factors	Cambridge University – the Mott Committee local planning	National policy for attracting multinational companies, tax incentives Dedicated space for industrial development	IBM and Texas Instruments established activity in the region, Pierre Laffitte – community entrepreneur, planning of Sophia Antipolis science park
Role of university	Cambridge University: scientific credibility, good industry contacts, spin-offs, attracting firms to the area	Not important in early stages, emphasised during the 1990s	Not present during the early stages, established in the area during the 1990s
R&D Institutions	Cambridge University R&D consultants and large companies with R&D departments located in Cambridge	Less developed	R&D centres of national research institutes and international groups important as driving factor
Science parks and innovation centres	Cambridge Science Park; St John Innovation Centre	Not important in early stages, important mechanism for development during the 1990s	Sophia Antipolis science park a key factor for development
Large firms, multinationals	Cambridge Consultants, PA Technology, Scientific Generics	Multinationals have dominated development, mostly US companies like Intel, IBM, Microsoft, Gateway 2000	Multinationals have dominated development
Local entrepreneurs	Strong entrepreneurial culture, many local entrepreneurs	Weak entrepreneurial culture	Weak entrepreneurial culture, improved during the 1990s
Small firms	Large number of small, indigenous firms	Weak indigenous and small firm sector	Weak indigenous sector, improved during the 1990s
Venture capital	Barclays Bank in the 1970s, fairly well developed VC sector, special funds for commercialising R&D results	Not present during the early stages, significant growth during the late 1990s	Not present during the early stages, improved significantly during the 1990s
Local policy	Restrictive local planning	Important in developing urban infrastructure	Important for developing the science park, collaboration between several local municipalities
National policy	Generally of less importance, mainly working indirectly through university funding, R&D policy etc.	Main driving force through tax incentives and programs for attracting foreign direct investments (FDI), recently more emphasis on indigenous development	National technopole strategy very important

Attractive living conditions have been important in both Cambridge and, in particular, Sophia Antipolis. The attraction of the French Riviera was the basis for Texas Instruments and IBM's decision to locate in Sophia Antipolis; large numbers of companies and people from many parts of the world followed. In the case of Cambridge, nice residential areas and the historic centre of the city, combined with its proximity to London, have made it an attractive place to live.

In the case of Dublin, attractive living conditions have not been a driving force, although the city has become an attractive place to live and visit in recent years. Nor have academic traditions and excellence been important. However, EU membership in combination with access to a qualified English speaking labour force at a low cost made Ireland attractive to, in particular, US multinational ICT companies. Based on these conditions, the Irish government developed a strategy for attracting multinational companies, and implemented different policy instruments to realise this development.

The role of research institutes has been strikingly different in the three cases. In Cambridge, research institutes have been an integrated part of Cambridge University, while in the case of Sophia Antipolis, national research institutes have set up departments in the area. In the case of Dublin, these kinds of institutions have been of less importance.

Science parks and innovation centres are generally regarded as important instruments for facilitating the development of high-tech industries. In the case of Sophia Antipolis, planning the science park was the key instrument for development, and the science park has played an extraordinary role. Unlike other regions, as many as half of all high-tech activities are concentrated inside the park. Innovation centres were established at a later stage. In the case of Cambridge, science parks have also been of great importance. The first science park was established during the early 1970s, and later, another three parks were opened. In Cambridge, the start of St. John's Innovation Centre is also regarded as significant to the dynamism in the area.

Dublin stands in contrast to Sophia Antipolis and Cambridge in that science parks and innovation centres were not important in the early stages. The Irish strategy has focused on other types of measures, and multinationals attracted to the country have been less R&D based. During the late 1990s, however, strategies changed significantly. Innovation centres opened, and the National Digital Park, which may be regarded as a science park, was opened in 1999.

One key mechanism in cluster evolution, is the local entrepreneurial culture and the propensity of local entrepreneurs to start new firms and in this way contribute to indigenous development. While Cambridge has had a strong entrepreneurial culture for a long time, and a number of companies have developed due to the role of local entrepreneurs, the situation in Sophia Antipolis and Dublin has been much more dependent on multinational companies and foreign direct investment. Particularly so in the case of Dublin, while in Sophia Antipolis national companies and national R&D institutions have also been important. So far neither Sophia Antipolis nor Dublin have succeeded in developing a strong entrepreneurial culture; in particular this seems to be a weak point in Dublin.

The role of venture capital has followed a similar pattern as the development of an entrepreneurial culture. The sector is fairly well developed in Cambridge, where it has played an active role since the late 1970s. In the case of Sophia Antipolis, the venture capital market first became active during the 1990s, and still has a way to go before a fully developed VC function is in place. Similarly, the venture capital market in Dublin saw significant expansion during the late 1990s.

The role of national and local policy has also varied between the three areas. In the case of Cambridge, national policy has been of less importance in terms of directly influencing development. In contrast, national planning may be regarded as the main driving force in the case of Dublin. Likewise, the national technopole strategy has been of great importance in Sophia Antipolis, although local authorities have also been important in the process of organising collaboration at the local level in order to open up for the science park.

4 Evolution of high-technology clusters in Oslo and Trondheim

4.1 High-tech industries in Norway

Having outlined the theoretical framework for analysing clusters, their structure and evolution in the earlier chapters of this report, we will now turn to empirical evidence for analysing high-technology industries in Oslo and Trondheim and their roles in the national context.

The main data analysed in this chapter is obtained from Statistics Norway. The data provide a comprehensive overview of all high-technology industrial activities in Norway and their distribution on the main urban areas. This gives an opportunity to reflect on the roles of Oslo and Trondheim in a national context. The data are supplemented by qualitative data on important institutions and firms, to further illustrate aspects of development and the current situation in the two cities.

Based on our definitions of high-technology (cf. chapter 2.4), data on high-technology industries in Norway in 1999 are summarized in Table 4.1. In total there were almost 18 000 firms with their most important activity in high-technology sectors. There were about 19 000 establishments, and total high-technology employment was about 106 000. Employment data are based on registrations at the establishment level, as this level is most appropriate for capturing relevant activity.²⁰

The most important sector, based on employment data, is the data processing industry with around 31 000 employees. Two sectors follow, i.e. technical testing and consultancy, and wholesale and retail sale of ICT products and software, both with almost 16 000 employees. Telecommunications ranks fourth, with slightly less than 11 000 employees.

A significant share of all high-tech activities belong to the ICT sectors. As shown in Table 4.1, about 60 per cent of all high-tech employment and two thirds of total turnover are in the ICT sectors.

²⁰ Statistics Norway collects data on firms as well as establishments. While a firm is a legal unit which may comprise several establishments with activities in different sectors, an establishment is a more homogenous unit which includes functional activity within a specific area. In the statistics, firms as well as establishments are classified by industrial sector. While firms are classified according to the sector which is most important for the company, establishments are classified according to the specific sector in which activities are organized. Thus, data on firms and establishments may differ. As the data on firms represent the lowest level, these data are the most reliable when analysing activities in different industrial sectors.

Table 4.1: High-technology sectors in Norway, 1999.

Industrial sectors*)	Estab-		Employment		Turnover	
	Firms	lishm.		%	mNOK	%
24 Chemical industries	90	136	8 241	7.8	24 043	11.6
30 Office machinery and computers	63	67	701	0.7	1 679	0.8
31 Electric control app. and equipm.	420	453	4 725	4.4	6 329	3.1
32 Telecommunication equipment	184	191	4 732	4.5	8 211	4.0
33 Medical and optical instruments	606	654	4 594	4.3	6 406	3.1
35 Aircraft and spacecraft	27	31	1 451	1.4	1 715	0.8
51 Wholesale office machinery and equipment	2 129	2 466	15 898	15.0	49 054	23.7
52 Retail sale computers, telecom equipment	1 063	1 114	1 912	1.8	2 624	1.3
64 Telecommunications	392	596	10 942	10.3	48 185	23.3
72 Computer and related activities	7 963	8 284	31 269	29.4	35 323	17.1
73 Technical and science based R&D	171	230	5 837	5.5	4 370	2.1
74 Technical testing, tech. consultancy	4 885	5 086	15 955	15.0	18 961	9.2
Total	17 993	19 308	106 257	100.0	206 900	100.0
ICT	11 794	12 718	65 454	61.6	145 076	70.1
Other high-tech	6 199	6 590	40 803	38.4	61 824	29.9

Source: Statistics Norway, data from the Central Register for Firms and Establishments, own

calculations. Data for employment and turnover are related to establishments.

*) The industries included in each sector are the following (cf. also Table 2.3):

Nace	Detailed classification
24	24.13 Manufacture of other inorganic basic chemicals
	24.14 Manufacture of other organic basic chemicals
	24.16 Manufacture of plastics in primary forms
	24.4 Manufacture of pharmaceuticals, medicinal chemicals and botanical products
30	30 Manufacture of office machinery and computers (whole group)
31	31.2 Manufacture of electricity distribution and control apparatus
	31.6 Manufacture of electrical equipment n.e.c.
32	32 Manufacture of radio, television and communication equipment and apparatus
33	33.1 Manufacture of medical and surgical equipment and orthopaedic appliances
	33.2 Manufacture of instruments and appliances for measuring, checking etc
	33.4 Manufacture of optical instruments and photographic equipment
35	35.3 Manufacture of aircraft and spacecraft
51	51.64 Wholesale of office machinery and equipment
52	52.485 Retail sale of computers, office equipment and telecommunication equipment
64	64.2 Telecommunications, except 64.201 'chat lines'
72	72 Computer and related activities (whole group)
73	73.1 Research and experimental development on natural sciences and engineering
74	74.209 Other technical consultancy work
	74.3 Technical testing and analysis

Table 4.2. Size structure and employment distribution of high-technology firms by industrial sectors in Norway 1999. Firms as statistical unit.

Industrial sector	Firms in size groups (%)									Total employm.	Employment in size groups (%)						
	Firms	1-4	5-9	10-19	20-49	50-99	100-499	500+	1-4		5-9	10-19	20-49	50-99	100-499	500+	
24 Chemical industries	57	28.1	1.8	10.5	22.8	7.0	17.5	12.3		8 848	0.3	0.1	0.9	4.1	3.2	20.1	71.3
30 Office machinery and computers	51	80.4	11.8	3.9	2.0	0.0	2.0	0.0		629	8.7	6.2	4.8	6.4	0.0	73.9	0.0
31 Electric control apparatus and equipment	307	71.3	12.7	6.8	5.9	2.6	0.7	0.0		2 311	15.2	11.4	11.5	23.4	21.9	16.6	0.0
32 Telecommunication equipment	127	64.6	9.4	3.9	11.0	7.1	3.1	0.8		3 330	3.9	2.4	2.5	14.3	19.2	25.8	31.9
33 Medical and optical instrument	217	59.0	9.7	14.7	8.8	3.2	4.1	0.5		3 995	5.5	3.6	10.7	13.9	11.8	41.7	12.8
35 Aircraft and spacecraft	21	71.4	9.5	14.3	0.0	0.0	0.0	4.8		579	4.0	1.9	6.7	0.0	0.0	0.0	87.4
51 Wholesale office machinery and equipment	1 533	64.2	17.5	10.6	4.9	1.6	1.0	0.1		14 095	12.5	12.7	15.4	15.4	11.0	20.7	12.3
52 Retail sale computers, telecom equipment	625	87.8	10.2	1.6	0.2	0.0	0.2	0.0		1 870	49.1	20.6	6.9	1.3	0.0	22.1	0.0
64 Telecommunications	240	69.2	10.8	5.4	4.6	2.9	4.6	2.5		10 871	2.4	1.5	1.6	3.6	4.3	20.7	65.9
72 Computer and related activities	4 332	83.5	6.9	4.8	2.8	1.0	0.8	0.2		30 324	16.7	6.3	9.2	11.8	10.1	24.7	21.2
73 Technical and science based R&D	113	49.6	8.8	9.7	10.6	9.7	9.7	1.8		5 176	1.7	1.4	2.8	7.6	15.2	35.7	35.5
74 Technical testing, technical consultancy	2 917	73.6	8.8	8.8	4.9	2.7	0.7	0.4		14 511	17.4	6.1	11.3	13.1	15.8	10.1	26.3
Total	10 540	67.9	10.6	9.5	5.9	3.5	1.3	1.3		96 539	8.7	4.0	6.7	8.5	11.2	9.6	51.2

Table 4.3. Size structure and employment distribution of high-technology firms by industrial sectors in Norway 1999. Establishments as statistical unit.

Industrial sector	Est. ments	Establishments in size groups (%)								Total employm	Employment in size groups (%)						
		1-4	5-9	10-19	20-49	50-99	100-499	500+	1-4		5-9	10-19	20-49	50-99	100-499	500+	
24 Chemical industries	100	20.0	4.0	12.0	20.0	11.0	32.0	1.0		8 241	0.4	0.4	2.0	7.4	9.0	73.3	7.6
30 Office machinery and computers	54	77.8	11.1	3.7	3.7	1.9	1.9	0.0		701	8.3	5.6	3.9	8.8	7.1	66.3	0.0
31 Electric control apparatus and equipment	345	66.1	12.8	7.5	7.2	2.9	3.5	0.0		4 725	7.9	6.2	7.1	16.4	13.7	48.7	0.0
32 Telecommunication equipment	139	59.0	10.1	4.3	12.2	5.0	8.6	0.7		4 732	2.7	2.0	2.0	11.5	10.7	58.0	13.0
33 Medical and optical instrument	264	54.9	11.0	15.9	11.7	3.0	3.0	0.4		4 594	5.4	4.2	12.2	19.5	11.2	36.4	11.1
35 Aircraft and spacecraft	24	62.5	8.3	12.5	4.2	4.2	0.0	8.3		1 451	1.6	0.8	2.7	2.5	5.5	0.0	87.0
51 Wholesale office machinery and equipment	1 830	59.3	20.1	11.8	6.2	1.6	0.9	0.0		15 898	12.6	15.5	18.0	21.1	12.2	20.6	0.0
52 Retail sale computers, telecom equipment	665	83.6	12.0	3.3	0.9	0.2	0.0	0.0		1 912	48.9	25.2	14.2	8.9	2.8	0.0	0.0
64 Telecommunications	347	53.9	13.5	8.9	11.8	4.9	6.1	0.9		10 942	2.9	2.9	3.9	13.3	11.2	40.9	25.0
72 Computer and related activities	4 568	79.8	8.1	6.3	3.7	1.2	0.8	0.1		31 269	16.6	7.6	12.2	16.8	12.2	22.2	12.5
73 Technical and science based R&D	156	41.0	10.3	11.5	14.7	9.6	12.8	0.0		5 837	1.9	1.9	4.2	12.1	19.4	60.5	0.0
74 Technical testing, technical consultancy	3 040	71.7	8.8	9.1	5.8	3.3	0.9	0.4		15 955	16.0	5.7	11.1	14.8	17.9	12.6	21.8
Total	11 532	63.2	10.7	10.9	7.3	4.8	1.6	1.6		106 257	8.1	4.0	7.7	10.6	15.7	12.0	41.9

This means that there is very little high-technology activity outside the ICT sectors. Most important outside the ICT sector we find other technical consultancy services with around 12 000 employees, and chemical industries, which employ around 8000. In the latter case pharmaceuticals are important. There is also some activity organised in sectors like electronics, radio- and communication equipment, and medical and optical instruments, but in total these sectors are fairly modest.

Tables 4.2 and 4.3 present statistics on the size structure; the first table is based on firms as statistical unit, the other on establishments.²¹ There is a general perception that high-tech firms are dominated by small firms more than other industries (Keeble 1989), but our data indicate that high-technology industries on average exceed the national average; 1.3 per cent of companies with a minimum of one employee have more than 100 employees. These firms employ more than 50 per cent of all employees in the high-tech sector. Comparable figures for all industries in Norway show that 0.7 per cent of all firms have more than 100 employees, accounting for 37.6 per cent of all employment (Spilling 2000:77, data for 1996).

Based on these statistics, high-technology industries may be characterised as large firm dominated. Although there are as many as 10 000 firms, a small share of them, i.e. 130 firms, account for more than fifty per cent of total employment. However, significant variation is found between sectors. While there is a strong concentration of activities in larger firms and establishments in the chemical and pharmaceutical industries as well as in electronics, telecommunications and R&D, the size structure tends towards the small business end in electro-technical, computer and software retailing, and particularly in technical consultancy services.

4.2 Oslo and Trondheim in the national context

The point of departure for our analysis was the assumption that Oslo and Trondheim are the two most important high-tech cities in Norway: Oslo due to its role as Norway's capital, where many of the leading companies and research institutes are located; Trondheim due to its role as the 'capital of technology' in Norway, with the University of Science and Technology as a key institution.

In Tables 4.4 and 4.5 data on the distribution of high-tech industries on the main urban areas are presented and provide a picture of the role of Oslo

²¹ See previous comments on the implications of using firms or establishments as statistical units.

and Trondheim in the national context. The data reveal a fairly clear hierarchical pattern with Oslo in first place; Bergen, Stavanger and Trondheim sharing second; and Tromsø trailing behind in third. This pattern is somewhat different from what one might expect.

Oslo is by far the most important city in terms of high-technology industries. Close to fifty per cent of all employment and more than sixty per cent of total turnover is located in the Oslo area. For ICT, the dominance of Oslo is even higher with 60 per cent of total employment. The cities of Bergen, Stavanger and Trondheim each have between 6 000 and 7 000 employees, each accounting for about 6 per cent of total high-tech employment.

Of primary interest is the significant difference between Oslo, on the one hand, and the three other cities, on the other. In fact, Oslo has more than twice the employment of the other three cities together.

Table 4.4: Total employment in high-technology industries in Norway 1999.

	ICT		Other high-tech		All high-tech	
	Employment	%	Employment	%	Employment	%
Oslo	38 567	58.9	12 229	30.0	50 796	47.8
Bergen	4 063	6.2	2 068	5.1	6 131	5.8
Trondheim	3 007	4.6	3 565	8.7	6 572	6.2
Stavanger	2 796	4.3	3 994	9.8	6 790	6.4
Tromsø	641	1.0	473	1.2	1 114	1.0
Rest of Norway	16 359	25.0	18 473	45.3	34 832	32.8
Norway	65 433	100.0	40 802	100.0	106 235	100.0

Source: Statistics Norway, the Central Register for Firms and Establishments, own calculations.

Table 4.5: Total turnover in high-technology industries in Norway 1999 (million NOK).

	ICT		Other high-tech		All high-tech	
	Turnover	%	Turnover	%	Turnover	%
Oslo	92 523	63.8	19 131	30.9	111 654	54.0
Bergen	7 999	5.5	2 051	3.3	10 050	4.9
Trondheim	6 149	4.2	3 259	5.3	9 408	4.5
Stavanger	4 467	3.1	3 944	6.4	8 411	4.1
Tromsø	1 014	0.7	318	0.5	1 332	0.6
Rest of Norway	32 812	22.6	33 120	53.6	65 932	31.9
Norway	136 865	100.0	70 035	100.0	206 787	100.0

Source: Statistics Norway, the Central Register for Firms and Establishments, own calculations.

Second, one would expect the ‘capital of technology’ Trondheim to have a more significant position in the field of high-technology, given its role as provider of higher technical education at the former Institute of Technology, now the University of Science and Technology. We would at least expect Trondheim to be closer to Oslo and significantly ahead of the competing cities Bergen and Stavanger. A poorer industrial environment in the Trondheim area, which has not provided synergies to the same extent as in the other cities may explain why this is not the case. We will discuss this in more detail later in the report.

When the data are split between ICT and other high-tech sectors, it is revealed that the hierarchical structure is even clearer in the case of ICT, while it is not so pronounced for the rest of the high-tech industries, which are more decentralized, with around fifty per cent of all activity located outside the main urban areas. In the ICT sector, Oslo plays a dominant role with about 60 per cent of all employment and two thirds of all turnover, leaving small shares for the other cities. The second level cities have in the range of 3-6 per cent of total national activity.

Out of curiosity, we have included the city of Tromsø in the list. Although the city is marginal in many regards, it is the fourth largest university city in Norway, and plays an important role as the ‘capital’ of Northern Norway. High-technology has been an important policy area, in particular related to ICT, medicine and marine biotechnology, so it is of interest to see the industrial impacts of these efforts. In spite of these efforts, only a small industrial high-tech sector has developed in Tromsø, accounting for about 1100 employees and one per cent of total high-tech employment. So, the data show that it is not easy to build new industries.

The data referred to above do not provide a complete picture of the regional distribution of high-technology industries. There are other interesting high-tech environments outside the main urban areas. A more comprehensive picture of the regional distribution of high-tech activities is obtained in Figure 4.1, which shows data for all counties.

Here, the same hierarchical picture is given, with the Oslo-region (including Akershus) far ahead of all other regions, and with the three regions of Stavanger (Rogaland), Bergen (Hordaland) and Trondheim (Sør-Trøndelag) occupying a clear second-level position. No other city or county challenges the position of these three cities.

At the next level follow the four most industrialised counties of Eastern Norway, i.e. Vestfold, Østfold, Buskerud and Telemark. Interestingly, we find Aust-Agder following close behind these four. Traditionally, Aust-Agder has ranked among the most peripheral counties, but in this case it seems to

have performed well over recent years, mostly due to developments in the ICT-sector.²²

As shown above, the position of Troms (with the city of Tromsø) is far down on the ranking. The county does not perform better than the traditionally peripheral counties of Hedmark and Oppland.

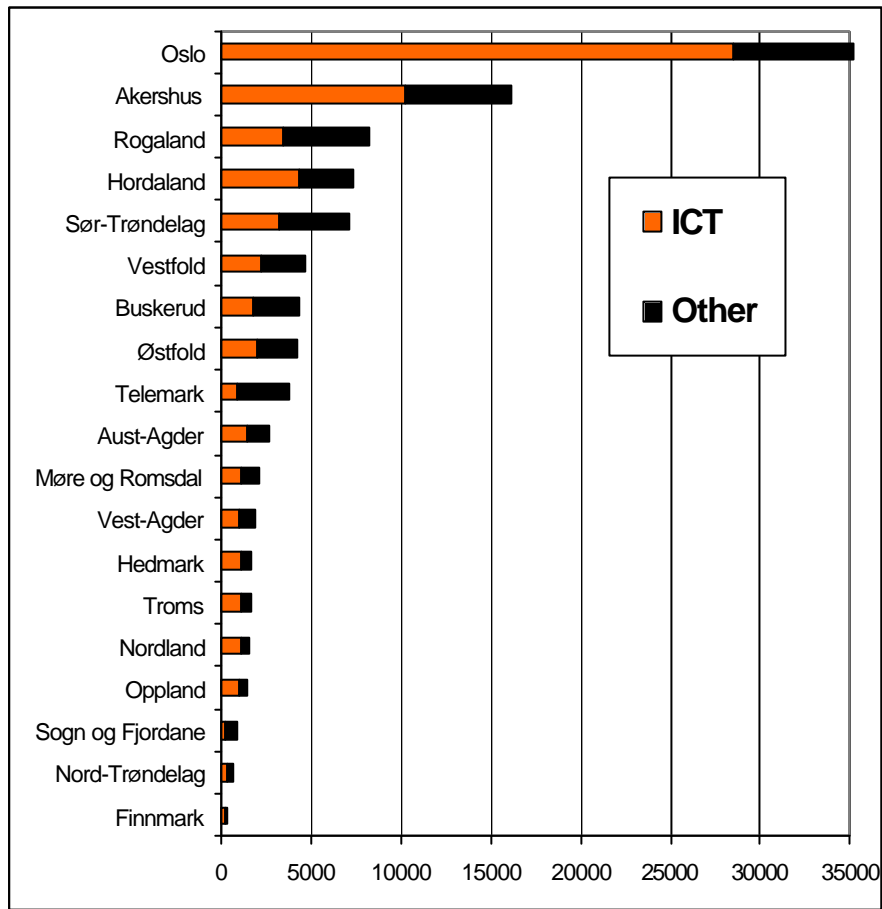


Figure 4.1: High-tech employment by counties, 1999. Source: Statistics Norway, own calculations.

²² An important actor in this development has been the Swedish company Ericsson. However, recently the company has experienced significant problems, and during 2002 it closed down significant parts of its activities in the area.

4.3 Evolution of high-tech industries in Oslo²³

The early stages

Oslo has always been important to industrial and technology-based development in Norway. Although Trondheim was formally ascribed the role as the 'capital of technology' after the National Institute of Technology (NTH) was established there in 1910, technology-based industrial activity in Oslo has been equally as important. As shown in the previous statistical overview, high-tech industries in the Oslo region outnumber those of Trondheim, and Oslo now accounts for close to fifty per cent of all high-tech activity in Norway.

When this development started historically, may be a question of definition. The University of Oslo was established in 1811 as the first university in Norway. In 1923, the University and the Government agreed to develop a new campus just outside the city centre. However, due to an economic recession, plans were delayed, and the first departments did not move to the new campus until 1931. Today, with nearly 36 000 students and 2300 scientific faculty, the University of Oslo is central to Norway's most important national knowledge community, located in the small area of Gaustadbekkdalen (see map in Figure 4.2).

After the Second World War, there was growing awareness of the importance of research for industrial development and economic growth in Norway. There was general political agreement on a program to stimulate R&D activities in order to develop technology based industries which would act as a motor for economic development. As a part of this program, the National Council for Scientific and Industrial Research (NTNF) was established in Oslo in 1946, and several state funded research centres were set up. The Norwegian Defence Research Institute (FFI) was established in 1946 at Kjeller, a few kilometres north of Oslo, and later The Central Institute for Research (SI) and the National Computing Centre were established close to the University campus in Gaustadbekkdalen. The new research institutes were intended to act as an interface between industry and academia.

The localisation of research institutions close to the university campus was deliberate. Politicians and industrialists saw possibilities for positive spill-over effects between the different institutions. Similar considerations underlie the decision to locate the new National Hospital (*Rikshospitalet*) in the same

²³ This section is a edited and restructured summary of Steinsli, J. 2003: Evolution of high-technology industries in Oslo. Working paper, Norwegian School of Management BI.

area. Although this was not realised until nearly 60 years later, it illustrates the strategic thinking at that time. Furthermore, the decision to locate the Norwegian Broadcasting Corporation (NRK) at Marienlyst in 1933, close to the University campus, was partly made because of the proximity to the university. Additional land close to the University was also reserved for future knowledge-based activities.

Industrial development

In the early 1970s, the Oslo region hosted most of the electronics industry in Norway. Companies like Tandberg and EB, and later Norsk Data, were all located in the region. At that time there were promising prospects for the development of a Norwegian electronics industry. However, none of the companies survived. Over a period of 12 years they all went bankrupt (Sogner 2002). According to Sogner, a combination of several factors contributed to their demise. First, growth in the oil sector created new opportunities for many businesses, but it also put very strong pressure on the Norwegian economy which resulted in high cost levels, and make many businesses less competitive in the international market.

Second, also due to growth in the oil sector, significant parts of the research community were focused on the oil industry, and consequently less attention was given towards other fields of interest, for instance electronics. Third, there was a lack of private strategic investors interested in the electronics sector, and the public sector was not able to establish financial systems to support long term and strategic investments. An oft-referred to example illustrates this situation, i.e. the development of the GSM system in Norway. The technology was developed during the 1980s in a collaboration between SINTEF and the R&D department of the Norwegian Telecom Company. Attempts were made to commercialise the technology, but the research departments did not succeed in finding investors. In 1986 the GSM standard was chosen as the European mobile communication standard. This technology was later the basic reason for Nokia's successful development (Moen 2002).

In Table 4.6 statistics are presented which show the development in high-tech sectors in Oslo from 1970 to 1999. In total, high-tech manufacturing remained stable until the mid 1980s, and has since declined considerably. During the second half of the 1990s, it stabilised on a level approximately fifty per cent of the previous level.

However, there has been significant growth in high-technology services, mainly related to ICT. Although our data do not reveal exactly when this expansion happened, there are important indications that significant growth

occurred during the 1990s. In particular, data processing and software has been an important sector of expansion.

Box 4.1 Time series data 1970-1999

The data in Table 4.6 are a combination of two different time series. The first series, 1970-94, is based on the previous system for industrial classification, while data from 1995 and later are based on the new NACE standard (SN94). This means that the two data set are not fully comparable. There are two implications of this: 1) the industrial classifications of the two series do not match. Although we have been careful in selecting industrial sectors based on the old classification that are as close as possible to the new classification, there may be some differences which imply that firms included in one series are not included in the other; 2) registrations by Statistics Norway have been through considerably expansion during the 1990s, and from 1995 the statistics include many sectors within the services that where not included in previous statistics, like telecommunications and technical, science based R&D. Thus the data from 1995 include more sectors than the first data set. However, coverage of some of the 'new' sectors was not complete until 1996 or 1997, so data earlier than 1998 should be handled with care, cf. in particular data for telecommunications.

Table 4.6: Evolution of high-tech industries in Oslo 1970–1999. Employment data based on establishments as statistical unit.

	1970	1975	1980	1985	1990	1994		1995	1996	1997	1998	1999
Chemicals incl. Pharmaceuticals	1527	1489	1874	1835	2170	2521	x	1616	2253	2131	2277	2061
Data and office machines	203	322	1001	2463	818	377	x	194	574	536	561	578
Electro technical	6579	5218	4647	4580	2040	1383	x	818	735	812	1006	767
Radio, tv and other comm. equipm.	6030	7164	5544	4744	2370	1675	x	1371	1323	1440	1295	1640
Medical and optical instruments	365	304	339	444	388	586	x	660	673	692	855	725
Aircraft and spacecraft	830	781	789	921	1161	996	x	998	1462	983	12	11
Wholesale of PCs, data and telecom equipment	2627	2949	3930	7330	8079	6468	x	7488	8301	8836	7827	8692
Retailing of PCs, data and telecom equipment							x	671	795	962	773	554
Telecommunication							x	143	2052	5838	4688	6971
Data processing, data bases, software development	702	1793	2630	4753	4817	7499	x	7592	9456	12178	16631	20132
Technical, science based R&D							x	1549	1426	2022	1810	2381
Other technical consultancy work	120	3172	4104	6675	5373	5987	x	5256	7837	7321	7620	6284
Total	18983	23192	24858	33745	27216	27492	x	28356	36887	43751	45355	50796
Manufacturing	15534	15278	14194	14987	8947	7538	x	5657	7020	6594	6006	5782
Services	3449	7914	10664	18758	18269	19954	x	22699	29867	37157	39349	45014
ICT	9562	12228	13105	19290	16084	16019	x	17459	22501	29790	31775	38567
Other high-tech	9421	10964	11753	14455	11132	11473	x	10897	14386	13961	13580	12229

Data source: Statistics Norway, Central Register for Firms and Establishments, own calculations.

See comments to data in Box 4.1.

There has been a high rate of start-ups in data-processing and software. This sector grew faster in the Oslo region than in the rest of the country (RITTS 2000). The high growth in business related services in the region is explained by the advantages of being located close to the headquarters of larger firms. Other important factors include well developed infrastructure, access to qualified labour and proximity to the central administration (Eikeland and Johansen 2000).

Institutions for higher education and R&D

Due to Oslo's role as capital, the region is well endowed with key institutions. Most major policy and technology transfer institutions have their headquarters in Oslo. Furthermore, the largest university is located in Oslo, as well as a number of other research institutions and institutions of higher education. Over the last decade, a number of institutions have been set up to support processes of commercialisation.



Figure 4.2: The three main locations of institutions for R&D and higher education in the Oslo region.

The institutional structure is concentrated in three different locations in the area; Gaustadbekkdalen, Ås and Kjeller. The University of Oslo campus is located at Gaustadbekkdalen, close to the city centre. The University of

Agriculture and related research facilities are found in Ås, 40 km south of Oslo, Kjeller, situated approximately 20 km north of Oslo, includes research institutes related to fields like mathematics, energy, the environment and information technology directed towards manufacturing and defence. In addition, the R&D department of Telenor was located at Kjeller until recently (2001). The research institutes at Ås are mainly centred on food, forestry, land and animal research, while the institutes close to the University are more technology and science oriented. For an overview of universities and research institutes, see Box 4.2 and 4.3.

Box 4.2: Universities and colleges in the Oslo region

University of Oslo

Employees: 4500, among them academic staff 2300

Students: 36 000; Arts 21%, Medicine, Mathematics and Natural Sciences 23%, Social Sciences 17 %

R&D: Medicine, mathematics and natural science get in total 63% of the total R&D budget, of total R&D budget in 1999, only 3% was funded by the business sector

Business development strategies:

- Main shareholder of Oslo Science Park
- Initiated Gründerskolen (entrepreneurship training program) in 1999
- Participates in Venture Cup and other entrepreneurship competitions

Oslo College

Employees: 570,

Students: 8 000, education of professional workers (teaching, nursing, engineering and economics/finance

Business development strategies:

Some research collaboration with industry, especially in computer science and biotechnology; student placements in industry

Norwegian School for Veterinary Science

Employees: 350, students: 320

Akershus College

Employees: 240, students: 2 000

Norwegian School of Management BI

Private business school, 19 500 students, staff 830

Business development strategies:

- Entrepreneurship programs
- Incubator on campus
- Participation in Venture Cup and Gründerskolen

Agricultural University of Norway

Students: 2500, staff 850 among them academic staff 400

Business development strategies:

- Entrepreneurship programs
- Ownership in Bioparken

Unik (Stiftelsen Universitetsstudiene på Kjeller)

Students 80. Courses within sciences and engineering. Doctoral and post-qualifying education

The University of Oslo is the largest University in Norway with more than 36 000 students. The university has a strong science base. Natural Sciences, with 23 per cent of the student population, receives 63 per cent of the budget. University faculty have won four Nobel prizes²⁴ in economics, physics and chemistry.

A large institute sector is characteristic of the Norwegian research system. Norway has developed an extensive network of institutes that constitute a source of knowledge for both industry and public administration. A large number are technical, industrial institutes, whose primary functions are to serve industry needs for research. This structure of separate research institutes is unique for Norway. These institutes provide R&D services which are taken care of by the private sector in most other nations.

Box 4.3: R&D institutions in the Oslo region

Location: Gaustadbekkdalen

SINTEF

Established in 1950, headquarters and main activities in Trondheim, employees in Oslo: 350.

Services: Applied research and consultancy.

Departments in Oslo: Applied mathematics, electronics and cybernetics, applied chemistry, materials technology, telecommunications and informatics, Sintef Unimed

Norwegian Computing Centre

Established in 1950. Private, independent, non-profit foundation. Employees: 50.

Services: Contract research and development in the areas of computing and quantitative methods for a broad range of industrial, commercial and

²⁴ In 1969, Ragnar Frisch and Odd Hassel were the first Norwegian researchers to receive the Nobel Prize. Frisch was awarded the very first Nobel Prize in economics, while Hassel received the prize in chemistry. Ivar Giæver won the Nobel Prize in physics in 1973. In 1989, Frisch's former student Trygve Haavelmo won the Nobel Prize in economics.

public service organisations in the national as well as the international market.

Norwegian Building Research Institute (NBI)

Established in 1953. Private foundation. Employees 172

Services : Leading national centre of technical and sociological research and development relating to buildings and the built environment.

Norwegian Geotechnical Institute (NGI)

Established in 1953 Private foundation. Employees 140

Services research and consulting in the geo-sciences, including soil, rock and snow. Center of excellence

Norwegian Institute of Wood technology (NTI)

Established in 1949. Private foundation. Employees 37

Services R&D centre for the sawmill and timber industry in Norway

Location: Kjeller

Norwegian Defence Research Institute (FFI)

Established in 1946, employees: 550, 100% funded by Government

Services: Competence within natural sciences and social sciences. Performs strategic-, operational- and cost analyses related to information systems, land and sea based weapons, and other issues related to long-term defence planning.

Institute of Energy Technology (IFE)

Established in 1948, employees 300, 60% funded by Norwegian Defence Research Institute, 40% by the Norwegian Research Council

Services: Nuclear physics, biochemistry and metallurgy
Long track record for spin-offs

Business development strategies:

Norwegian Institute of Air Research (NILU)

Established 1969, employees 140, from 1986 a private foundation. Funding: 12% from the Ministry of Environment and the Norwegian Research Council, the rest from national and international client based research

Services: Technical, economic, hygienic and other environmental issues related to air pollution and cleaning of polluted air.

Established NILU Products Ltd in 1996 to manage strategic owner interests in products and systems developed by NILU

Norwegian Seismic Array (NORSAR)

Established in 1970 as a part of a US/Norwegian agreement. Employees: 30, main funding from the Norwegian Research Council, also some US funding.

Services: Seismology and applied geophysics, including seismological problems relevant to the detection and identification of earthquakes and underground nuclear explosions.

Telenor Research

Established in 1967, 240 employees were located at Kjeller until the activity moved to Fornebu in 2001 together with the Telenor headquarters in order to contribute to the development of IT Fornebu.

Location: Ås

Norwegian Institute of forest research (NISK)

Established 1916, employees: 107 set up as an administrative institution under the Ministry of Agriculture.

Services: Provider of information for government, industry and the general public

related to sustainable management of forest resources. Working fields: forest resource management, wealth creation based on the forest and environmental initiatives in the forest

Institute of Aquaculture Research (Akvaforsk)

Established. 1971, employees 91. Funding by the Norwegian Research Council (30%), the rest from projects and industry.

Services: Research institutions for aquaculture, specialised in breeding and genetics, product quality and marine species.

Norwegian Food Research Institute (Matforsk)

Established 1971, employees: 151.

Services: Food research and development.

Business development strategies:

Centre for Soil and Environmental Research (Jordforsk)

Established in 1989, employees: 80

Services: Applied research and consulting on for solving soil-related problems.

Services are provided to industry, municipalities, national regulatory agencies, universities and homeowners.

The Norwegian Crop Research Institute

Established in 1995 as a tool for commercialisation of research. Employees: 100. 50% funding from public sources, the rest is client based R&D

Services: *Applied plant science research*

Institutions for commercialisation

During the early 1980s there was growing concern over insufficient commercial benefits obtained from the knowledge base in the region, and three schemes were launched (Hodgson and Lacave 1995):

- An Innovation Centre (ISAS - *Innovasjonssenteret AS*) was founded in 1984, with the objective to improve the commercial exploitation of research resources. The Centre was also responsible for

the industry liaison programme of the University. The main shareholders were the University of Oslo and the Municipality of Oslo, while companies and research institutes located in the region participated with smaller shares.

- In 1985 the research association *FOSFOR (Forskingsstiftelsen i Oslo regionen)* was established in order to improve links between industry and the University and the research institutes.
- An *incubator* project sponsored by the Municipality of Oslo was started in 1984.

These three initiatives were originally independent of each other, until they were merged into one organisation in 1990, and the Oslo Research Park was established. The Park was organised as a public company with the University of Oslo as the main shareholder with 34 per cent of stock. However, responsibility for industrial liaison activities was transferred back to the University (Hodgson and Lacave 1995). In addition to the University, a number of private companies and public agencies, including the Municipality of Oslo, are also shareholders.

The objective of the Oslo Research Park was to link the research resources at the research institutes in the area with the needs of the industry. In total, some 200 companies and institutions have been hosted in the office facilities of the Science Park. The number of resident firms is now about 100, among which 85 have been supported by the park's incubation and innovation services. In 2001 they started to use the name Oslo Innovation Centre.

Ås BioScience Park was established in 1991 and is situated in Ås near the site of the Agricultural University of Norway and the other research institutes located there (cf. Box 4.4). Approximately 10 new spin-off companies have been established annually since its inception, and 15 successful commercialisations have taken place.

Campus Kjeller was established in 1995, and is situated north of Oslo close to the research community at Kjeller. The park was set up in order to stimulate commercialisation based on activity at the research institutes in the area. During the period 1995-2001, the park boasted 37 commercialisations.

Box 4.4: Science Parks in the Oslo region

Oslo Innovation Centre

Established in 1990 based on a merger of three previously independent organisations, i.e. an innovation centre, a research foundation and an incubator. Main shareholder is the University of Oslo (34%), Oslo Municipality (13%) and SIVA (22%).

Characteristics: Total office space: 38,000 m². More than 100 companies with around 2000 employees are tenants, among which 85 companies have been supported by the incubation and innovation centre services.

Services: Rental of office space, rental at market price; incubator/innovation centre, support for new companies. Ideas from University of Oslo and research institutes (60%), from private sector (40%). Some 5-10 new businesses are started annually, and some 3-5 projects are commercialised through licensing.

Campus Kjeller

Established in 1995 by local and regional authorities and the research institutes located at Kjeller.

Objective: Commercialisation of research and technology from the Kjeller research institutes, and accommodating new technology based firms.

Services: Business incubator providing all types of support for business development. 37 commercialisations during the period 1995-2001.

Bioparken AS

Established at Ås in 1991. Shareholders are Akershus County Council, NLH, SIVA and 41 smaller shareholders. Main fields: Life science, aquaculture, nutrition and food science, environmental science.

Services: Short and long term rental contracts of office premises and laboratory facilities at market prices; technology transfer through patents and licensing, training, support to new businesses, licensing and patent protection activities, administrative services.

So far 15 commercialisations.

The current situation

In total, the high-tech sector of Oslo employs more than 50 000 people; the ICT sector is the most important with more than 38 000 people. Among these, the data processing and software industry employ the largest share, about 20 000 employees. Other large sectors include specialised whole sale, telecommunications and technical consultancy work.

In general, the high-tech services sector is the most important. High-tech manufacturing accounts for a minor part of all activity, and includes chemicals (including pharmaceuticals) and communication equipment with about 2 000 and 1 600 employees respectively. The relatively weak position of the manufacturing sector is further illustrated by turnover data. Of total

high-tech based turnover in the Oslo region, just about ten per cent is in the manufacture of high-tech products. This is an important consideration in our analysis of the high-tech structure discussed later in this report.

In the national context, the Oslo region has a significant role. As shown in the tables, approximately half of all high-tech activity in Norway is located in the region, slightly more in terms of turnover, slightly less when employment is considered. However, this varies by sectors. The situation of Oslo is generally rather strong in the ICT sectors, as on average 60 per cent of all national activity is concentrated in the region (Table 4.3), for some sectors the share in Oslo is even higher with more than 80 per cent of manufacturing of communication equipment, and more than 60 per cent for telecommunications and data processing and software.

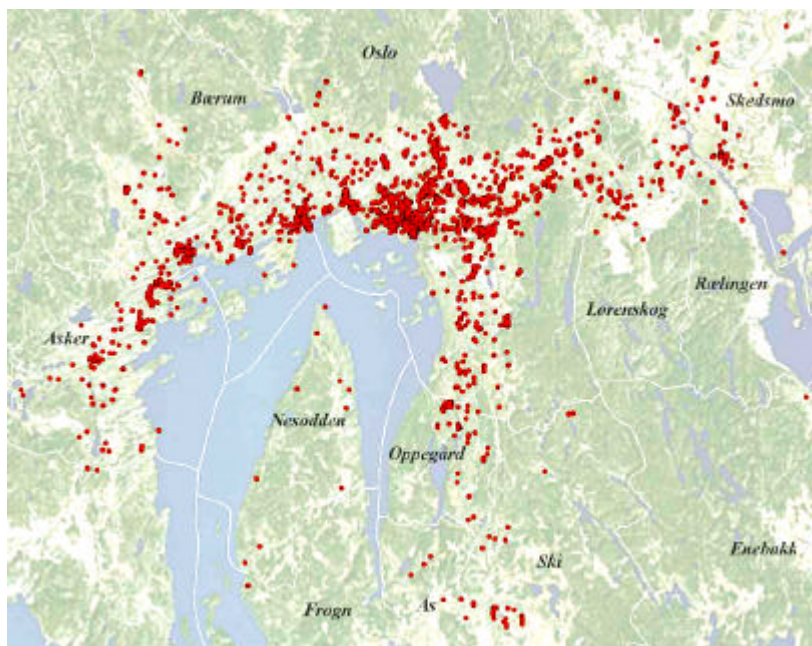


Figure 4.3: Location of ICT-firms in Oslo

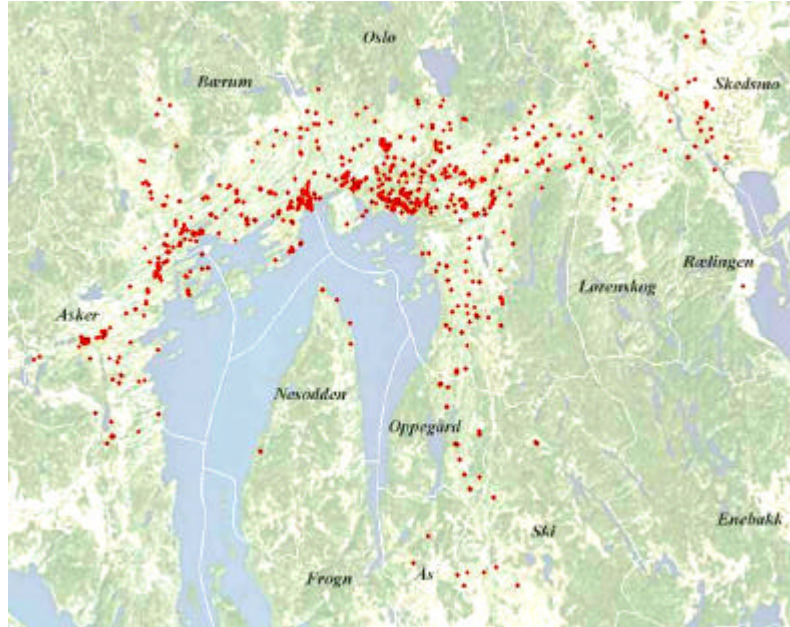


Figure 4.4: Location of other high-tech firms

On the other hand, Oslo has a smaller share of the national activity in R&D and retailing, and other manufacturing industries. If we look at figures for establishments the picture is more or less the same. There are (naturally) more establishments but with less employment, due to the location of the firm's headquarters in Oslo. This applies in particular to sectors such as chemicals and telecommunications.

Table 4.8 lists the larger high-tech firms based in Oslo. Out of expediency, only companies with more than 200 employees are included.²⁵

²⁵ Total employment listed for these firms adds up to more than 50 000, but may be corrected for activities located outside the Oslo region as well as non high-tech activities. As the data are on the firm level, they include all activities organised by the companies. This applies in particular to nace 24 and nace 64. *Sources:* Statistics Norway, Central Register for Firms and Establishments and CreditInform. In some cases also Amadeus. For some of the companies, data are obtained via their home pages. Mostly, data are from 1999 or 2000.

Table 4.7: High-tech industries in the Oslo-region

	Establishments in size groups					Employment in size groups				
	Total	1-4	5-19	20-99	100+	Total	1-4	5-19	20-99	100+
Chemicals incl. Pharmaceuticals	23	3	2	8	10	2 061	3	12	138	1 908
Data and office machines	22	16	2	2	2	578	17	8	38	515
Electro technical	77	48	18	8	3	767	56	90	196	425
Radio, tv and other comm. equipment	39	17	7	9	6	1 640	23	33	243	1 341
Medical and optical instruments	68	33	15	17	3	725	42	85	320	278
Aircraft and spacecraft	7	6	1	0	0	11	7	4	0	0
Wholesale of PCs, data and telecom equipment	699	315	211	139	34	8 692	399	1 122	2 906	4 265
Retailing of PCs, data and telecom equipment	163	93	63	6	1	554	112	288	101	53
Telecommunication	123	56	25	20	22	6 971	67	131	525	6 248
Data processing, data bases, software development	1 993	1 325	367	233	68	20 132	1 543	1 802	4 873	11 914
Technical, science based R&D	50	15	7	13	15	2 381	18	44	364	1 955
Other technical consultancy work	853	608	147	79	19	6 284	716	731	1 473	3 364
Total	4 117	2 535	865	534	183	50 796	3 003	4 350	11 177	32 266
Total (%)	100.0	61.6	21.0	13.0	4.4	100.0	5.9	8.6	22.0	63.5
ICT	3 039	1 822	675	409	133	38 567	2 161	3 384	8 686	24 336
Other high-tech	1 078	713	190	125	50	12 229	842	966	2 491	7 930

Table 4.8: High-tech companies with more than 200 employees, based in Oslo 1999/2000.

Industrial sector/Company name	Turn-over (mNOK)	Employment	Comments	Foreign ownership?
<u>24139: Manufacture of other inorganic basic chemicals</u>				
Elkem ASA	9 703	4 025		No
<u>24160: Manufacture of plastics in primary forms</u>				
Dyno ASA (Now registered as Dynea ASA)			Previous part of Dyno acquired by Neste (SF), and operates now under the name DyneaASA.	Yes
<u>24410: Manufacture of pharmaceutical products</u>				
Amersham Health AS	4 406	950	Previously Nycomed Imaging AS, acquired in 2000.	Yes
<u>24420: Manufacture of pharmaceutical preparations</u>				
Nycomed Pharma AS	1 236	691		Yes
Alpharam AS	904	544		Yes
<u>30020: Manufacture of office machinery and computers</u>				
Tandberg Data ASA	1 071	465		No
<u>31200: Manufacture of electrical machinery and apparatus</u>				
Elektrokontakt AS	350	229		No
<u>32200: Manufacture of radio, television and communication equipment</u>				
Ericsson AS	2 183	1 061		Yes
<u>33200: Manufacture of medical, precision and optical instruments</u>				
Air Park System	327	202	The previous Navia Aviation AS was acquired by Northrop Grumman Corp and is now registered as Air Park System	Yes

51640: Wholesale of office machinery and equipment

Merkantildata ASA	8 153	4 337		No
Getronics Norge (Now registered as Eterra AS)	1 675	1 084	Merkantildata established a strategic alliance with Getronics and integrated the Nordic part in 2000.	No
Wittusen & Jensen AS	519	283		No
Compaq Computer Norway AS	2 295	261		Yes
Canon Norge AS	860	254		Yes
Thrane Gruppen ASA	710	249		No
Hewlett-Packard Norge AS	155	240		Yes
EMO AS	550	204		No

52485: Retail sale office equipment and telecom equipment

Telenor Telehuset AS	881	413		No
----------------------	-----	-----	--	----

64200: Telecommunications

Netcom AS	2 914	502		No
United Pan-Europe Communicat Nor AS	376	340		Yes
Eltele Øst AS	182	217		No
Telenor ASA	37 644	20 150	Figures cover the whole corporation, incl.the daughters below.	No
Telenor Eiendom Holding AS	1 248	519		No
Telenor Nett AS	10 951	2 585		No
Telenor Mobil AS	6 706	1 294		No
Telenor Privat AS	8 399	1 202		No
Telenor Bedrift AS	6 994	1 065		No
Telenor Nextel AS	803	380	Previously Nextra	No
Telenor Satellite Services AS	1 727	276		No

Telenor Avidi AS	379	150		No
Telenor Multicom AS	578	118	From 2001 integrated in Telenor Business Solutions	No
<u>72200: Software consultancy and supply</u>				
Accenture AS	980	900	Previously Anderson Consulting	Yes
Cap Gemini Norge AS	604	625		Yes
Alcatel Norway AS	1 093	609		Yes
Tietoanator Consulting AS	328	425		No
Ementor Financial Systems AS (Previously Provida ASA)	224	259	Acquired by Merkantildata in 2000, changed name before it was acquired by Tieto Enator, February 2002	No
Ementor Norway AS (Prev. Avenir AS)	349	390	Avenir was acquired by Merkantildata in 2000	No
International Business Machines AS	3 427	1 520		Yes
Oracle Norge AS	294	293		Yes
Thomson-CSF Norcom AS (Now Hales Communications as)	339	271	Changed name in 2000.	Yes
IFS Norge AS	297	251		Yes
Hands AS	343	225	Previously Merkantildata applikasjon as which was separated from Merkantildata applikasjon AS	No
Bull AS (Now Steria as)	580	223	Bull AS changed name into Integris AS before it was acquired by Steria in 2001	Yes
CSC Computer Sciences Norge AS	207	210	Previously Computer Sciences International AS.	Yes
Ecosoft Norge AS	185	209		Yes
Siemens Business Services AS	402	202		Yes
WM Data Consulting AS	192	199		Yes
EDB Business Partner ASA	4 493	3 020		No
EDB Teamco	1 916	783	Telenor Dataservice AS and EDB's operating division was merged into EDB Teamco in 1999	No
EDB Fundator AS	253	313		No

72300: Data processing

Posten SDS AS	1 236	865	Changed name and was restructured in 2001	No
Fellesdata AS	72 300	1 178	Part of EDB Business partners bank finans from February 2000.	No

72400: Data base activities

Bankenes Betalingssentral BBS AS	754	634		No
----------------------------------	-----	-----	--	----

72500: Maintenance and repair of office, accounting and computing machinery

NCR Norge AS	754	168		Yes
--------------	-----	-----	--	-----

73100: Research and experimental development on natural sciences and humanities

Institutt for energiteknikk	321	532		No
-----------------------------	-----	-----	--	----

74209: Other Technical consultancy activities

Aker Engineering AS	512	631		No
Techpower AS	89	215		Yes

74300: Technical testing and analysis

Det Norske Veritas AS	2 256	2 600	Figures cover the whole business, including the daughter below.	No
Det Norske Veritas Certification AS	350	264		No

A significant share of the larger firms are controlled by foreign owners. In total, these companies employ more than 10 000 people. The share of foreign-owned companies is particularly high in sectors such as chemicals (nace 24) and the production of communication equipment (nace 32). Likewise, the share of foreign-owned companies is high in computers and related activities, representing more than 50 per cent of employment in foreign-owned companies.

In contrast, research sectors within the natural sciences and engineering (nace 73) and technical testing and analysing (nace 74), all relatively large institutions, are owned by Norwegian interests.

The largest Norwegian-owned company on the list is Telenor, the Norwegian Telecom Company, which is a telecommunications group with extensive and fast growing business operations in a number of countries in Europe and Southeast Asia. The company is Norway's leading distributor of voice, information, knowledge and entertainment through a broad range of modern communications services. Telenor was listed on the Oslo stock exchange in December 2000.

Another large Norwegian high-tech company is Merkantildata. It was founded in 1968, and listed on the Oslo stock exchange in 1985. In 2001 the company had 4 300 employees. With offices in all the Nordic countries, Merkantildata aims to be a leading consultant and integrator in the field of information and communication technology (ICT). However, Merkantildata does not provide technology or competence which is unique (Sogner 2002).

The ICT sector was one of the sectors included in a large cluster study in Norway in 1999/2000 (Fjeldstad, Andersen and Viken 2000). An important conclusion made in this study is that the ICT sector in Norway competes negligibly on international markets. Almost two thirds of the companies studied had activities directed towards international markets, but this activity accounted for less than 25 per cent of output. Sales offices for international companies and a few large companies dominate the Norwegian market. Out of 21 000 employed in computers and related activities in 1999, approximately 14 000 were employed by large companies, of which 16 of a total of 23 were foreign-owned or had a majority of foreign owners.

The high-tech industry in Oslo is dominated by companies which are located in the region due to Oslo's role as capital of Norway. Many of them are multinationals like IBM, Microsoft and Philips with only distributive functions. Both the distribution of cell phones and computer equipment are high in Norway compared to other countries. Thus, it is attractive for foreign companies to establish sales functions in Norway. The computer sector is dominated by imported technology, and Norwegian customers have little

impact on innovation and growth in these companies (Fjeldstad, Andersen and Viken 2000).

Venture Capital

Several venture capital companies are located in Oslo. Although they do not limit their activity to Oslo companies, information from the Norwegian Venture Capital Association (NVCA) indicates that a significant share of total venture capital investment is in companies located in the Oslo region.

In total, members of NVCA have invested about 2 billion NOK in 214 different companies (data for 2001). 84 per cent was invested in Norway, of which 57 per cent was invested in projects in the expansion phase while only one per cent was invested as seed capital (NVCA 2001).

According to a study of seed capital in the Nordic countries, the Norwegian venture capital industry is considered immature, with a majority of private investors concentrating on later stage venture capital and restructuring investments. Similarly, a relatively large share of investments targets traditional industries and primary sectors. A majority of both private and public based investors have historically been involved with investments in a broad spectrum of industries, including more conventional and less technology intensive industries. The characteristics of later stage investments and investments in conventional industries are in the literature symptomatic of an immature venture capital market (CEBR 2001).

Summary

The main explanation for the relatively good 'performance' of Oslo in the field of high-technology, at least in a national context, is its role as the national capital. This role may explain many aspects of the development of the region.

First, the region is well endowed with institutions of higher education and R&D. The oldest and largest Norwegian university is located there. The University of Oslo is supplemented with a number of other institutions of higher education, and a fairly large number of research institutes. A significant share of all national R&D resources are located in the Oslo-region, i.e. approximately 50 per cent, the bulk of which are concentrated in what is called the Oslo Science City, including Gaustad, Majorstuen, Lovisenberg. No less than one third of all national R&D resources are located within a few square kilometres, with the University of Oslo and Gaustadbekkdalen at the centre (Johnstad 2003).

Second, many companies locate their headquarters in the capital due to the advantages this location gives for accessing national markets. Being at the centre of the most populated part of the country, the location advantages

of Oslo are significant related to consumer markets. Similarly, Oslo is advantageous in relation to business markets, as many of the larger companies have their headquarters in the city.

Third, based on the same mechanisms, international high-tech companies present in Norway are located in Oslo. These companies account for a significant share of total high-tech employment.

Fourth, the high-tech service sector dominates in Oslo. Within this sector data processing and software dominate, while manufacturing plays a secondary role, with some activity in chemicals and pharmaceuticals. In ICT manufacturing only a couple of larger companies are present (Ericsson, Tandberg).

Fifth, in line with this, few companies provide unique products or services. To a significant extent companies are service providers with their main roles related to reproduction and distribution, while an emphasis on R&D based activities is weak in significant parts of the industry.

The venture capital market has started to evolve, but is mostly concentrated on later stages of firm development, and less oriented towards the early stages. In addition, venture capital actors are largely oriented towards traditional sectors, and less towards high-technology.

4.4 Evolution of high-tech industries in Trondheim

The early stages²⁶

Traditionally, Trondheim has been recognized as the capital of technology of Norway, and plays an important role in the national context mainly due to two institutions; the University of Science and Technology (NTNU) and the technological research centre SINTEF. These two institutions, which are closely related, have been of great importance to the technology-based development in the region as well as nationally, and may be regarded as important generators of the high-technology industries located in the city today.

However, as the data on high-technology industries in Norway shows (Table 4.4), Trondheim, with around 6500 high-tech employees, is far behind Oslo, and approximately on the same level as the cities of Bergen and Stavanger. Based on this, the reputation of Trondheim as the ‘capital of technology’ may be challenged. We will return to this issue later.

²⁶ The first part of this presentation is based on Bakkevig et al 2002, chapter 3.5.1.

The history of Trondheim's development in the field of technology, started during the early part of the twentieth century with the establishment of the Norwegian Institute of Technology (NTH) in 1910. The Institute, which at that time was organised as a college of engineering, offered degree programs in the fields of physics, chemistry, electro, construction and mechanical engineering, and also organised research activities in these disciplines. In addition to educating engineers primarily for the manufacturing and construction industries, the mission of the Institute was to be directly involved in industrial development by collaborating with companies. The professors had roles as consultants.

In 1946, after the Second World War, the National Research Council for Technology and Science was established (in Oslo). It had a strong influence on research policy and funding. When the Central Institute for Industrial Research (SI) was established in Oslo in 1949, it triggered a lot of activity in Trondheim. Due to Trondheim's peripheral location in the national industrial context, the threat of being trapped 'on the side-track' of national industrial development was very significant. Thanks to local mobilisation and collaboration between local industries, local authorities and NTH, the research organisation SINTEF was established in 1950.

Evolution of High-Technology Milieu in Trondheim

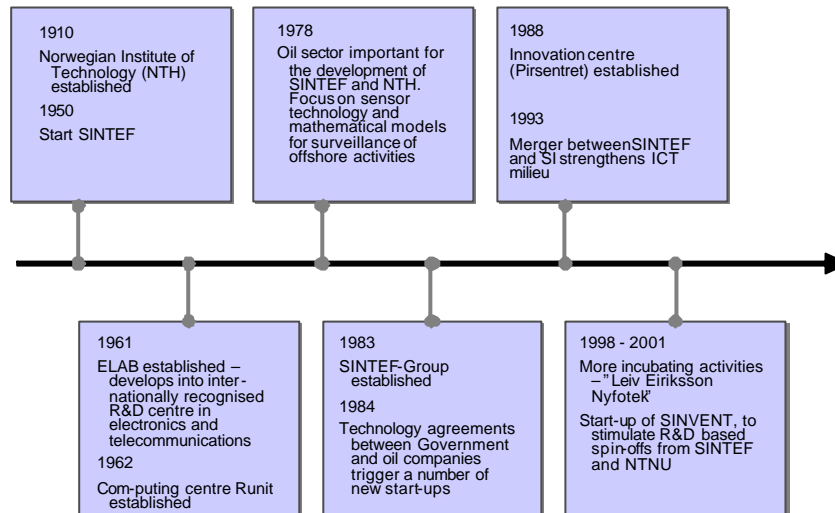


Figure 4.5: Evolution of High-technology Milieu in Trondheim (based on Bakkevig et al 2002:130).

The purpose of establishing SINTEF was to organise market-oriented research activities and support industrial development by linking academic resources to the business sector. SINTEF was organised as part of NTH, with the Professor Council as its highest body, but with an administration of its own. Later, SINTEF was organised as an independent company, but remained closely linked with the University. Its different departments are co-located on campus together with related university departments and with offices and laboratories in the same buildings.

The interaction between NTH and SINTEF has been instrumental to the development of high technology in Trondheim, and these two institutions may be regarded as motivating forces. One of the most successful developments was the establishment of Elab, the electronics based research laboratory, which was started in 1962 and operated in close collaboration with the National Research Council (NTNF), the national telecom company (at that time Telegrafverket, now Telenor) and some of the major national electronics companies, like EB, STK and Nera.

Vitalisation – the first stage

Until the early 1980s, the electronics-based industrial environment outside NTH and SINTEF was restricted to a few companies. NTH/SINTEF was not successful in creating spin-offs. In order to improve this situation a seed capital company called ASEV (*AS Etablerings- og Virksomhetsutvikling*) was started in 1984. The company was initiated by NTH and SINTEF, and supported by the local authorities, banks and some of the leading national manufacturing companies. The investment capital of the company was about 12 mNOK, and significant subsidies for operating the company were obtained from central government (i.e. *Industrifondet*).

The establishment of ASEV marks the implementation of a new strategy for stimulating the development of new technology-based firms. The first incubator in Norway was established the following year, in a collaboration between ASEV and the local authorities. From the mid- to late 1980s a number of new start-ups followed. Several gave rise to successful and leading companies in the national context.

During this period, an important mechanism at work was the expanding Norwegian economy, thanks to a growing oil sector and significant involvements from SINTEF in developing new technology for the oil industry. As a result of a coordinated national strategy for developing offshore activities, oil companies were obliged to organise significant parts of their R&D activity in Norway. SINTEF reaped the benefits. At this time SINTEF also developed a strategy towards more emphasis on research and less on commercialisation. Some of SINTEF's more commercially oriented groups left and started new companies, in total 40-45 over the span of a few years'. This development was also stimulated by an upturn in the economy during the mid- and late 1980s.

The establishment of the seed capital company ASEV and the incubator in 1984/85 may be regarded as a new type of infrastructure for supporting start-ups and technology-based firms in Norway. Further initiatives were taken in the late 1980s and throughout the 1990s to organise different 'centres' and set up new facilities to host technology-based firms and stimulate spin-offs and start-ups. To a large extent, this progress at the local level was supported by national programs like the FORNY-program²⁷, the national industrial development agencies SND²⁸ and SIVA²⁹. Today, a diversified

²⁷ FORNY: Research based commercialisation, in Norwegian: *Forskningsbasert nyskaping*.

²⁸ SND: The national and regional development agency, in Norwegian: *Statens nærings- og distriktsutviklingsfond*.

array of institutions and programs are at work to facilitate technology-based firms (see Box 4.5).

Vitalisation – the second stage

In spite of efforts to stimulate high-tech development, the overall performance of the Trondheim area in terms of spin-offs and start-ups has been fairly modest. During the 1990s, the number of technology-based new firms was typically just a few per year, cf. Figure 4.6, and significantly below the level of start-ups during the mid 1980s.

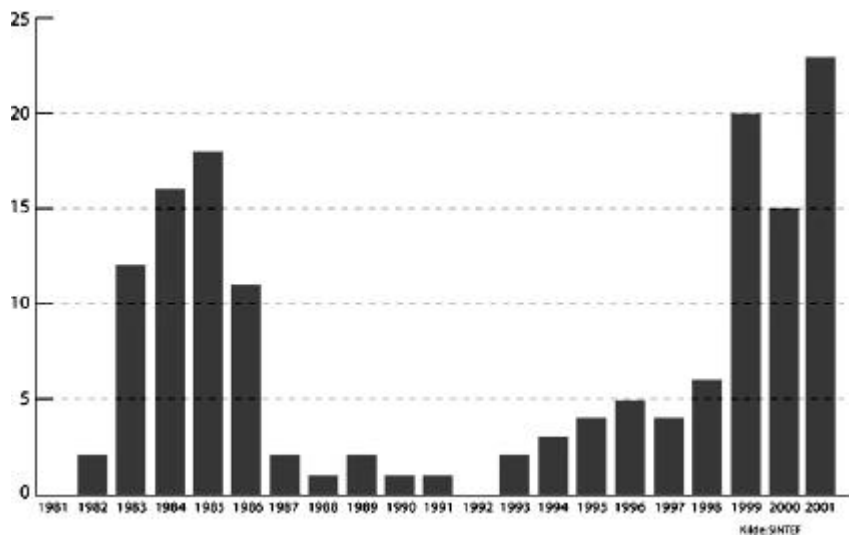


Figure 4.6: Start-ups from NTNU and SINTEF 1981-2002. Source: SINTEF.

²⁹ SIVA: Traditionally, this agencies has organised industrial parks, building and office facilities, more recently, there has been a shift towards innovation centres and incubators.

Box 4.4: Main institutions and networks facilitating technology-based start-ups and commercialisation in Trondheim

Leiv Eiriksson Nyfotek

Established in 1998 to facilitate commercialisation of research based ideas by providing:

- assistance throughout the process of developing a business idea
- financing through the regional seed fund
- incubators the first critical years

Funding is provided via Seed Funding Middle Norway (*Såkorninvest Midt-Norge*) with funds of more than 100 mNOK.

Shareholders: 12, among which SINTEF and NTNU are the largest.

Gløshaugen Innovation Center

Established 2001, the first on-campus incubator in Norway, a joint initiative taken by NTNU, SINTEF and SIVA.

START NTNU

Students' organisation started in 2000 to facilitate innovation and entrepreneurship among students and employees. Activities: Organising courses, competitions and meetings with a focus on setting up businesses. This organisation has served as model for starting similar organisations at other universities. A national network is underway.

Entrepreneurship and Innovation Group (GREI)

Based at the Department of Industrial Economics and Technology Management at NTNU, the Group has offered courses in innovation and entrepreneurship since 1978, and is responsible for teaching, research and business development programs within the field of innovation and entrepreneurship, among them a New Venture Acceleration Program.

SINVENT

Originally started in 1985 as a daughter company of SINTEF to work with innovations, but was mostly a non-active company until it was revitalised in 2000 and is now working actively as a development and investment company. Total turnover in 2001 was 215 mNOK.

Support and services are provided in four major areas:

- partnership development
- advisory services
- business development
- management and sales of technology.

SG Venture

Established in 2002 by SINTEF and SINVENT with purpose of investing in the seed and early venture stages of SINTEF based companies. SINVENT will be the management organisation of SG Venture.

Source: Reitan, B. (2002): Trondheim as a high-tech hot spot.

New initiatives were taken to improve the situation around the turn of the century. In 1998 two of the existing centres were merged into a more powerful unit named Leif Eiriksson Nyfotek. Nyfotek is backed by NTNU³⁰, SINTEF, SND and private investors. Their business idea is based on bringing together capital, academia and industry in order to stimulate technology-based industrial development. SINTEF also started a process of strategy development at this time, coinciding with the dot-com boom. Since the 1980s SINTEF had followed a research oriented strategy. Commercialisation had not been among the core activities of its institutions. In order to supplement its commercial activities, SINTEF's subsidiary SINVENT, which had been inactive for a decade, was restructured to work with innovation and the commercialisation of new technology. An investment fund of 100 mNOK was set up to fund new technology-based companies.

At SINTEF as well as the University, significant changes have been taking place in terms of attitudes towards commercialisation and a clearer focus on this role from academia. In fact, the University has re-formulated its strategy, and intends to become one of the leading European universities in knowledge-based innovation by the year 2005. Many of the University departments have a strong interest in commercialisation. Entrepreneurship courses have been offered for many years, and other types of activities supporting start-ups have been organised. Recently an innovation centre was established on campus, and with one thousand square meters space it currently (2002) hosts 16 firms. Mostly, the companies have been started by students, or previous students.

Other initiatives have been taken as well, among them the students' initiative, START NTNU, which has been an important model for similar activities at other universities and business schools in Norway.

In parallel with this is the growing venture capital industry in the region, SG Venture and the partially state-funded *Såkorninvest Midt-Norge*, being the most noteworthy (cf. Box 4.6). Private initiatives have also been taken, but so far the VC businesses in the region may be regarded as being at an early stage of development, and in general, with the exception of the two funds mentioned above, VC companies have been of less importance in developing high-tech industry in the region.

³⁰ The previous NTH (the National Institute of Technology) was in 1996 reorganised into NTNU (*Norges teknisk naturvitenskapelig universitet*) the National University of Science and Technology, which also includes institutions in the social sciences and humanities.

Box 4.6: Venture capital in Trondheim

The following 8 venture capital companies are active:

Gjensidige NOR Regional Invest

Part of the national bank- and insurance company Gjensidige NOR

R. Kjeldsberg

A family-owned company active in property development and operation. A total of 150 mNOK is managed, of which 40 million are allocated for venture investments.

Reitan Invest

A private investment company linked with the Reitan Group, have invested in four companies, but are currently not active in the VC market.

SG Venture

Recently established by SINTEF and SINVENT to invest in the early stages of SINTEF-based companies. Total capital of 100 mNOK, no investments so far.

Såkorninvest Midt-Norge

This investment fund is one of several national funds to facilitate high-risk investments in early stage start-ups. Total capital is 100 mNOK. The fund is managed by Leiv Eiriksson Nyfotek. Has taken part in developing more than 40 companies over the last three years.

Trondheim Næringsinvest

Founded in 1998 by some of the leading business executives of Trondheim. The group focus on early stage ventures, and emphasise cooperation with other investors. They are involved in four companies, and are also involved in Såkorninvest Midt-Norge.

Viking Venture

Focuses on investments in various technology-based fields. The capital base is 180 mNOK. So far the company is involved in four companies.

VI Partners

Founded in 2001, committed capital is aimed at 2-300 mNOK. Currently they manage *Trøndelag Vekst* which include a portfolio of some 20 companies, they also intend to take over the management of other portfolios.

Source: Reitan, B. (2002): Trondheim as a high-tech hot spot.

Status 2002³¹

The current situation in the high-technology sector of Trondheim may be characterised by a relatively strong university- and R&D-sector, and relatively weak private sector.

The core actor has been the NTNU-SINTEF constellation. In total, these two institutions employ around five thousand people, three to four thousand of whom may be regarded as belonging to the high-technology sector (see details in Box 4.7-4.8). But given the strong position of these two institutions, employing nearly fifty per cent of all high-tech personnel in the region, the strength of this constellation also reflects the weakness of the region. i.e. performance outside these two institutions has not been impressive, for instance in terms of spin-offs and other forms of synergies with the region.

Box 4.7: The Norwegian University of Science and Technology (NTNU)

Established: 1996

NTNU represented a reorganisation of the University of Trondheim which included:

- Norwegian Institute of Technology (NTH, originally established in 1910)
- College of Arts and Sciences
- Museum of Natural History and Archaeology.

Employees: 3159 (in 1998) including:

- professors: 453
- other academic staff: 522

Students: Approximately 20 000

Students at different faculties (in 1999):

- Architecture, Planning and Fine Art: 462
- Civil and Environmental Engineering: 939
- Electrical Engineering and Telecommunications: 1402
- Physics, Informatics and Mathematics: 2413
- Applied Earth Sciences: 624
- Arts: 2803
- Chemistry and Biology: 1724
- Mechanical Engineering: 1009
- Marine Technology: 596
- Medicine: 491
- Social Sciences and Technology Management: 5167

³¹ This section is mostly based on Reitan, B. (2002): Trondheim as a high-tech hot spot.

Research activities

Strategic areas:

- Energy and the Environment
- Medical Technology:
- Materials Technology
- Marine and Maritime Technology
- Information and Communications Technology

National research laboratories in Trondheim

There are several national research laboratories situated in Trondheim, closely linked to SINTEF and NTNU:

- Marine Science Laboratories (indoor ocean basin laboratory and towing tank)
- Hydrotechnical Laboratories (river hydraulics and harbour design)
- Laboratories for Materials and Construction Engineering
- Laboratories for Electronic Materials and Components
- Refrigeration and Air Conditioning Laboratory
- Ultrasound Laboratory
- Fire Research Laboratory
- Electrical Power Laboratory
- Multiphase Flow Laboratory

Source: Reitan, B. (2002): Trondheim as a high-tech hot spot.

Box 4.8: SINTEF

Established: 1950

SINTEF was initiated by the Norwegian Institute of Technology (NTH), and was initially a tool used by the professors at NTH to handle external cooperation and activities that did not fit into the activities of the university. Later on, SINTEF has been organised as an independent organisation that has grown larger than the 'old NTH'.

SINTEF works in close collaboration with NTNU, sharing laboratories and equipment.

Total staff: 1590 (2001)

Total turnover: 1700 mNOK

90% of turnover is generated by industry contracts

SINTEF consists of eight research institutes and four research companies:

- SINTEF Applied Mathematics
- SINTEF Applied Chemistry
- SINTEF Civil and Environmental Engineering
- SINTEF Electronics and Cybernetics
- SINTEF Industrial Management
- SINTEF Materials Technology
- SINTEF Telecom and Informatics
- SINTEF Unimed
- SINTEF Energy Research
- SINTEF Fisheries and Aquaculture
- SINTEF Petroleum Research
- MARINTEK (Norwegian Marine Technology Research Institute)

Source: Reitan, B. (2002): Trondheim as a high-tech hot spot.

An overview of the high-tech sectors in Trondheim is presented in Table 4.9. The data cohere with data presented earlier in this chapter (Table 4.3 and 4.4), i.e. the data only include establishments, in order to exclude activities located outside the area. The data do not include government-based activities like universities and colleges, while the activities of SINTEF (those located in Trondheim) are included. The table only includes establishments with recorded employment, i.e. there are some 560 establishments with a minimum of one employee, and a total employment of about 6500.

The important role of SINTEF is reflected in the data comprising technical, science-based R&D, which is by far the most important sector with more than 1800 employees. Technical consultancy is closely related with 950 employees. Other sectors of great importance are wholesales of data and telecom equipment, telecommunications and electronics.

Compared to Oslo, high-technology industries in Trondheim have greater shares of R&D-based activity and, in general, smaller shares of ICT. Size structure is similar, with close to 60 per cent of all employment in firms of more than a hundred employees.

Table 4.9: High-tech establishments and employment in Trondheim

	Establishments in size groups					Employment in size groups				
	Total	1-4	5-19	20-99	100+	Total	1-4	5-19	20-99	100+
Chemicals incl. pharmaceuticals	0	0	0	0	0	0	0	0	0	0
Data and office machines	2	0	2	0	0	9	0	9	0	0
Electro technical	21	8	8	1	4	468	11	42	15	400
Radio, tv and other comm. equipment	7	3	2	1	1	111	3	6	34	68
Medical and optical instruments	14	6	5	1	2	325	7	29	17	272
Aircraft and spacecraft	0	0	0	0	0	0	0	0	0	0
Wholesale of PCs, data and telecom equipment	96	40	33	21	2	712	48	164	324	176
Retailing of PCs, data and telecom equipment	20	9	9	2	0	87	9	33	45	0
Telecommunication	17	5	6	2	4	560	5	33	66	456
Data processing, data bases, software development	222	142	41	33	6	1528	171	208	629	520
Technical, science based R&D	29	6	6	6	11	1822	7	29	162	1624
Other technical consultancy work	138	91	24	20	3	950	102	101	379	368
Total	566	310	136	87	33	6572	363	654	1671	3884
Total (%)	100.0	54.8	24.0	15.4	5.8	100.0	5.5	10.0	25.4	59.1
ICT	364	199	93	59	13	3007	236	453	1098	1220
Other high-tech	202	111	43	28	20	3565	127	201	573	2664

Table 4.10: The most important high-tech firms in Trondheim*)

Company	Turnover (mNOK)	Em-ploy- ees	Products/business	International ownership?
<u>Nace 3162- Manufacture of other electrical equipment</u>				
Autronica Fire and Security AS	307.3	155	Systems for fire detection	Yes
<u>Nace 3210 Manufacture of electronic valves, tubes and other components</u>				
Nordic VLSI ASA	73.2	68	Components for wireless communi-cation, mixed signal, complex digital and analog integrated circuit design.	No
<u>Nace 5164 Wholesale of office machines and equipment</u>				
LindbakGruppen AS	272.2	154	Supplier of office equipment and computer systems to businesses and gov-ernment offices	No
<u>Nace 7220 Software consultancy and supply</u>				
EDB Gruppen NORGE AS	116.2	88	Administrative systems for private and public sector	No
Q-free ASA	161.4	74	Automatic vehicle identification systems	No
Powell ASA	70.7	66	Suppliers and partners to power companies, software systems for demand and load forecasting etc.	No
Maxware International AS	72.9	55	Software system solutions	No
<u>Nace 7310 Research and experimental development on natural sciences and engineering</u>				
Stiftelsen for industriell of tek-nisk forskning - SINTEF	997.4	1.308	Knowledge and related services based on research in technology, the natural and social sciences and medicine.	No
Norsk Marinteknisk Forskningsinstitutt	178.2	218	Marine technology research and development services	No
SINTEF Energiforskning AS	162.3	200	R&D activities on power production energy conversion, transmission and distribution	No
SINTEF Petroleumsforskning AS	63.6	92	R&D and consultancy services world wide within petroleum exploration and production technology.	No

This table only includes firms classified as high-tech firms, as defined earlier in this report, see Chapter 2.4. There may be important firms that locally are recognised as *technology-based* which are not included.

Summary³²

To summarise the situation, the university and research facilities are Trondheim's strongest dimension, as these are not only leading institutions in Norway, but also internationally renowned. SINTEF, NTNU and Statoil are important local actors; together they represent a unique pool of researchers and competence. Skilled people have been trained in Trondheim for many years, and NTNU and SINTEF, to some extent, have a history of spinning off new technology-based firms. Systematic efforts to bolster high technology were, however, not in place before 1994, and further strengthening took place just recently.

A weak dimension of the high-tech industries in Trondheim is the lack of dynamic, international, growth-oriented technology-based companies. Although there are many technology-based businesses in Trondheim, few are clear success stories, i.e. listed on the stock exchange or international. Moreover, those that have made it, experience large difficulties with economics and finance. In general, there are few large technology-based companies and multinationals in Trondheim.

The number of fast growing medium-sized firms is also rather low. There are several new companies, many of which are struggling due to lack of access to growth capital and market networks internationally. Customers and partners are for the most part outside the region or nation, and access to markets is difficult to obtain and time-consuming.

Another weak dimension is the availability of risk capital. Although the number of providers of risk capital in Trondheim has grown over the last 2-5 years, there is still need to further develop the capital base, raise new funds, and build close ties to national and international co-investors. There is still too little risk capital available, and, moreover, growth and development capital is lacking.

Few opportunities to exit may also hinder the future development of risk capital in Trondheim. Investors need to be able to exit from investments in order to have success. Exits provide new optimism, returns to investors and possible capital for new funds and new companies. As of today, the lack of good exit-opportunities has been a problem for local investors. This is also linked to the other weak dimension: too few large and multinational technology companies. With more large and multinational companies present in the region, more exit channels would exist through these companies and their networks.

³² This summary is based on Reitan, B. (2002): 'Trondheim as a high-tech hot spot', with some modifications.

4.5 Oslo and Trondheim in international comparison

So far we have discussed Oslo and Trondheim in a national context, but more interesting is how the two cities may be assessed in an international context. To facilitate this comparison we have obtained data for Dublin, Cambridge and Sophia Antipolis, as well as the Finnish cities Helsinki and Oulu and Swedish cities Stockholm and Jönköping.³³ This should provide a fairly differentiated basis of comparison.

An overview of the data is given in Figure 4.7. At first glance the data may give the impression that Oslo is performing fairly well. With 50 000 employees in high-tech sectors, Oslo matches Helsinki, and outperforms Cambridge. However, Oslo trails behind Stockholm, which has more than 122 000 high-tech employees, and is also significantly behind Dublin, which has an estimated 86 000 employees.

Trondheim, with 6500 employed in the high-tech sector, lags behind the other ‘number two’ cities, Oulu, Finland’s main high-tech city; Linköping, with three times as many people employed in high-tech; and Sophia Antipolis, with four times the high-tech employment of Trondheim.

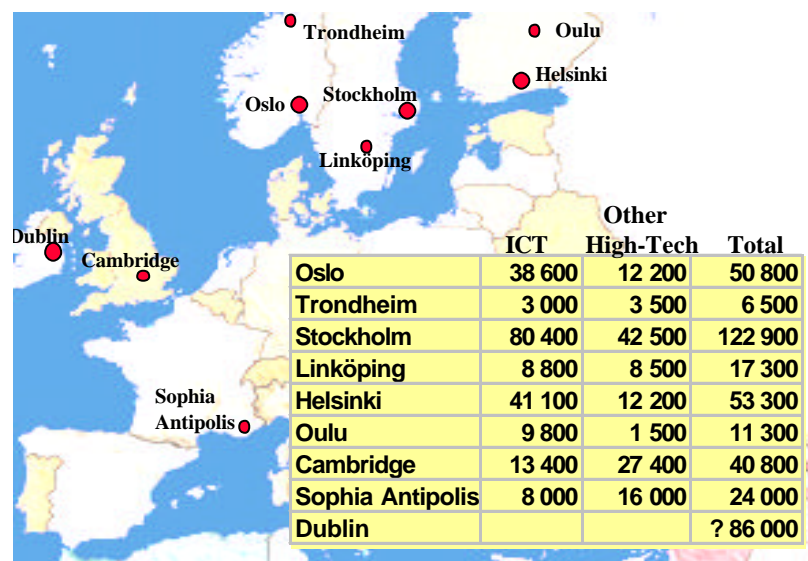


Figure 4.7: High-tech employment in European cities, 1999.

³³ Data for Finland are obtained from Statistics Finland. Data for Sweden are obtained from Jönköping International Business School.

But is this the whole story? To answer this question, we have to go into more detail and analyse the underlying composition of the high-tech sectors of the various cities.

Oslo in international comparison

To get a better impression of the strength and weaknesses of the high-tech structure of a city, it seems reasonable to compare similar cities. As we have commented on before, there seems to be a ‘capital function’ at work, i.e. businesses tend to locate in the capital of a country because of the feasibility of accessing national markets. Thus the total industrial structure of a capital does not necessarily indicate industrial dynamism. Also, to make data comparable, it seems reasonable to examine data in a national context, and to choose countries of similar size.

Oslo - Stockholm - Helsinki

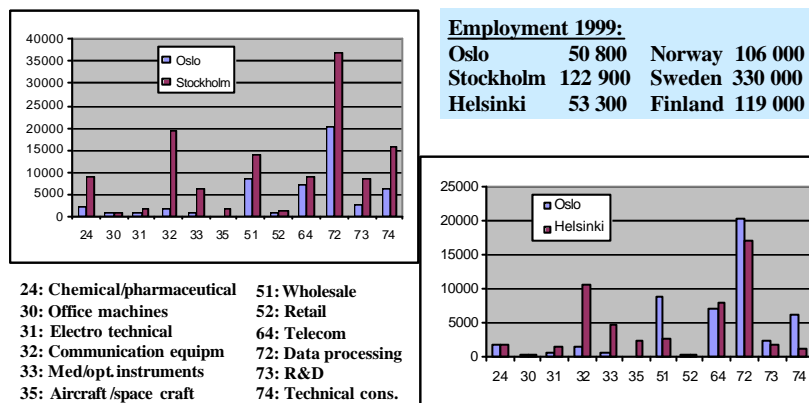


Figure 4.8: Oslo high-tech industrial structure compared to Stockholm and Helsinki

In Figure 4.8 the high-tech structure of Oslo is compared with the two other capitals Stockholm and Helsinki. From the data, it seems that Oslo matches Helsinki fairly well, also at the national level. In fact, when corrected for differences in size, the number of high-tech employees in per cent of total population is virtually the same.

However, data on the industrial structure of Oslo and Helsinki reveal an important difference related to the composition of the high-tech sector. While Helsinki has more than 21 000 (40%) employed in the manufacture of high-

technology products, the similar figure for Oslo is 5700 (11%). The manufacture of communication equipment accounts for the greatest difference in these figures, with more than 10 600 employed in this area in Helsinki, while Oslo has no more than 1600. Furthermore, Helsinki has around 5000 employed in the manufacture of technical instruments, while Oslo has just a few hundred.

On the other hand, Oslo has a stronger technical consultancy sector than Helsinki, at least as it is reflected in the statistics. The two cities are virtually identical regarding data processing, telecommunications and R&D. Although Oslo is much stronger in sales functions, this type of activity is related to the distribution of products and services, and is of less importance as a basis for dynamic development. This situation is also reflected in the export balance of high-tech products. While Finland has a very significant export of ICT products, Norway has a significant net import of such products.

Although a similar pattern is revealed in a comparison between Oslo and Stockholm, the relative share of high-tech employment in Sweden is significantly higher than in Norway. While the Swedish population is about twice that of Norway, their total high-tech employment is 2.7 times higher. Again, we find that the manufacturing sector is much weaker in Oslo. While Oslo has less than 6000 people in manufacturing, the figure for Stockholm is 38 000, accounting for more than 30 per cent of total high-tech employment. The most important manufacturing sectors are communication equipment and chemicals/pharmaceuticals. In the service sectors, Stockholm is also stronger, particularly in the areas of data processing and software, and R&D.

In Figure 4.9 Norway and Ireland are compared, as data for Ireland were only available on a national level. In spite of Ireland's smaller population (3.6 million), the country has significantly more people employed in the high-technology sectors, i.e. close to 123 000. Once again we find the same structure; high-tech manufacturing in Ireland is significantly stronger than in Norway. While Ireland has more than 67 000 people (55%) employed in high-tech manufacturing, Norway has around 24 000 (24%). Virtually all manufacturing sectors are strong in Ireland, in particular computers with more than 20 000 people; Norway has less than a thousand. This may explain why the two countries perform so differently in terms of export.

On the other hand, the diagram also provides an indication of the weakness of the Irish industrial structure, with very little R&D activity.

Norway - Ireland

Employment 1999:	
Norway	106 000
Ireland	122 800

24: Chemical/pharmaceutical
 30: Office machines
 31: Electro technical
 32: Communication equipment
 33: Medical/optical instruments
 35: Aircraft/space craft
 51: Wholesale
 52: Retail
 64: Telecom
 72: Data processing
 73: R&D
 74: Technical consultancy

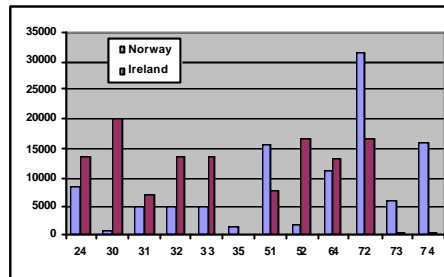


Figure 4.9: Comparison Norway – Ireland: high-tech industrial structure.

To further illustrate the important aspect of industrial structure, we include a comparison between Oslo and Cambridge. As mentioned above, Oslo has more people employed in the high-tech sector than Cambridge, but can in no way compete with the quality of the industrial structure in Cambridge. The reason for this is that Cambridge is highly specialised in specific R&D sectors and manufacturing related to these sectors, so that a high level of research-based manufacturing has been developed, cf. Figure 4.10.

Oslo - Cambridge

Employment 1999:	
Oslo	50 800
Cambridge	40 800

24: Chemical/pharmaceutical
 30: Office machines
 31: Electro technical
 32: Communication equipment
 33: Medical/optical instruments
 35: Aircraft/space craft
 51: Wholesale
 52: Retail
 64: Telecom
 72: Data processing
 73: R&D
 74: Technical consultancy

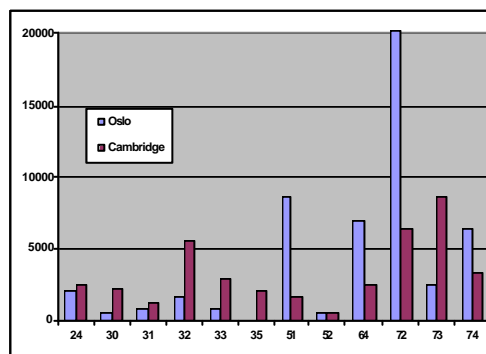


Figure 4.10: Oslo high-tech industrial structure compared with Cambridge

Of total high-tech employment in Cambridge (around 40 000), more than 16 000 (42%) are employed in manufacturing, and close to 9000 (22%) in R&D. This means that around two thirds are in research and research-based manufacturing, while the similar figure for Oslo is 7000 (15%). Oslo has greater activity in data processing and software, and telecom and sales. However, this structure provides significantly less opportunity for developing uniqueness and competitive advantage.

Trondheim in international comparison

Trondheim may be labelled a 'second level city' without the functions of a capital. It seems reasonable to compare it to cities that are in a similar position. Thus we have chosen Oulu, Finland and Linköping, Sweden for our comparative analysis.

Oulu saw rapid expansion in high-tech activities during the 1990s, largely attributed to the success of Nokia which has its headquarters in the city. In fact, employment in the city expanded by more than 130 per cent between 1993 and 1999, from 4800 to 11 300. Employment in Trondheim grew by 50 per cent in the same period.³⁴ Although this is significant, it is far below the performance of Oulu.

Trondheim - Oulu - Linköping

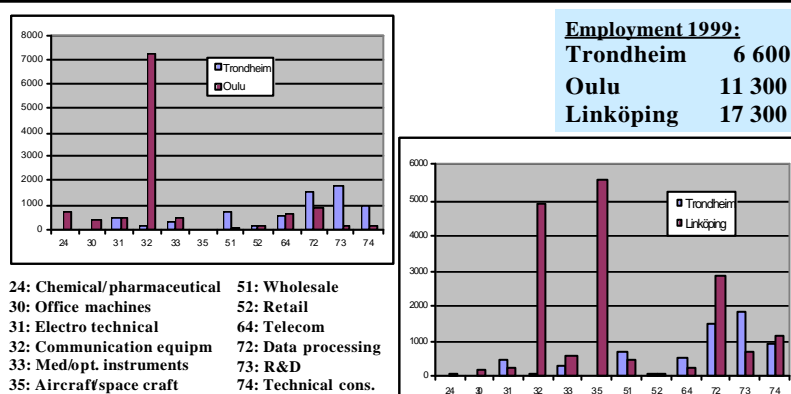


Figure 4.11: High-tech industrial structure of Trondheim, Oulu and Linköping

³⁴ This is just a rough estimate, due to missing statistics during the first half of the 1990s, it is not possible to provide an exact figure.

The difference between Oulu and Trondheim is clearly illustrated in Figure 4.11, which shows that more than 7000 people in Oulu are employed in the manufacture of communication equipment. The driving force behind these statistics is Nokia. In other sectors, particularly R&D and consultancies, Trondheim outperforms Oulu, however, important R&D activities are most likely taken care of by manufacturing companies in the case of Oulu.

The situation in Linköping resembles Oulu in many respects. Linköping also has a very strong base in manufacturing, but unlike Oulu, it is split between two industries, i.e. communication equipment and aircraft. In the first case, the most important company is Ericsson, in the latter the main company is SAAB. In addition, Linköping is also characterised by a strong data processing and software sector, which is about twice the size of Trondheim's. Trondheim, on the other hand, has a stronger R&D sector.

Summary

The general conclusion from these comparisons is that high-tech industries in Oslo and Trondheim are outperformed by their counterparts in leading European cities. There is no single factor that can explain these weaknesses. As illustrated earlier in this report, the evolution of high technology industries is the result of complicated processes based on interaction between different actors. However, certain factors seem more important than others.

The manufacturing sectors of Oslo and Trondheim are not well developed. Compared to other cities, larger companies that serve as drivers of industrialisation are missing in the Norwegian cities. In the case of Oslo, there are a few larger manufacturing companies, but the potential that seemed to exist in this field during the 1980s, has gradually fragmented. With a few exceptions, leading international companies that can serve as drivers, are also missing. In the case of Trondheim, the absence of larger firms, national as well as international, is striking.

This situation may partly reflect the inability of the two cities to attract international high-tech companies to the area, in contrast to Dublin, Cambridge and Sophia Antipolis. Although Oslo has attracted a few multinationals, it is not because of the attractiveness of the local area per se, but because of an interest in exploiting local market opportunities. As we have seen, most multinationals in Oslo are in reproductive and distributive functions, and do not contribute to developing uniqueness and competitive advantage.

Another explanation for the lack of larger manufacturing companies, may be related to less capacity for developing indigenous firms, i.e. as a result of spin-offs from universities or existing firms. However, reliable statistics on

spin-offs in Oslo and Trondheim are not available, making judgement difficult. As we have seen, the number of spin-offs has also been a constraint to development in Dublin and Sophia Antipolis. Whereas in the case of Cambridge, this mechanism has been very important. Clearly Oslo and Trondheim lag behind Cambridge in this sense.

It is widely recognised that the unavailability of risk capital, particularly in the early stages of development, may represent an important barrier to development. As commented on earlier, there are weak traditions in this field in Norway, and the Norwegian venture capital market is immature. Traditional venture capital companies have been late in developing compared to other countries. A number of factors may contribute to this situation. There are a limited number of highly profitable Norwegian firms and 'successful' entrepreneurs with capital resources available to invest in new firms. The situation may also be related to government policies which have allocated less money to the risk capital market. Furthermore, the situation may be explained on the background of limited growth in R&D funding. In particular, there has not been a clear focus on processes of commercialisation and how research institutions and intermediate institutions may be designed in order to improve these processes.

5 Evolution, technology and the role of small firms

5.1 Introduction

In the previous chapter we gave an overview of high-technology industries in Norway and their regional distribution, followed by a presentation and discussion of high-technology evolution in Oslo and Trondheim. In this chapter we will go into more detail by analysing empirical data obtained from Oslo and Trondheim. The data are based on two different approaches:³⁵

First, to illustrate key evolution mechanisms related to high-technology businesses and the commercialisation of specific technologies, we present details related to one particular case on the development of businesses based on Internet technology during the 1990s in Oslo. This case illustrates how complicated evolutionary processes can be, with a mixture of competing and collaborating actors related in many different ways.

Second, to give a more representative view of the role of small high-tech firms, we present data based on a survey of firms in Oslo and Trondheim. Although these data, to a large extent, are cross sectional, retrospective data on evolution is also included in order to reflect important aspects of evolutionary processes. These data also illustrate aspects of the firms' innovative behaviour.

5.2 Case: Evolution of Internet-based businesses in Oslo

When the company Oslonett started in 1991, it was the first Norwegian company to develop commercial activities based on Internet. Oslonett was started by a group of 16 partners, all with backgrounds in information technology from the University of Oslo (see Box 5.1). Their start-up triggered

³⁵ The following is based on two papers:

Steinsli, J. and O.R. Spilling 2002: On cluster evolution and the role of small firms: The case of Internet development in Norway. Paper prepared for the 12th Nordic Research Conference on Small Business, Kuopio, Finland, May.

Spilling, O.R. and J. Steinsli 2002: On the Role of High-Technology Small Firms in Cluster Evolution. Paper for the Tenth Annual High-technology Small Firms Conference, Enschede, The Netherlands, June.

diverse development, which may be characterised as a ‘chain reaction’. When the group met ten years later for the tenth anniversary of their start-up, the original company was no longer in existence. Their original business idea, which had turned out to be very successful, had been developed and restructured, split into different fields and transformed into different organisations. What was once the core of a small and growing company during the early 1990s, was now spread, diffused and merged with other ideas and concepts in many different businesses. The group was no longer working together; they had all moved into different organisations, working as entrepreneurs, employees in various companies, and professors and scientists at the University.

Box 5.1: The Pizza Gang

On the 12th of December in 1991 a group of 16 people met for a pizza meeting in seminar room 3B in the Informatics Building at the University of Oslo. The organiser of the meeting was Kjell Øystein Arisland, who had invited some of his colleagues - a graduate student, a few doctoral students and other technicians and researchers from the Department of Informatics, the Norwegian Computing Centre and the University IT Centre, all institutions located at the University of Oslo.

The meeting went on in an informal atmosphere; the colleagues enjoyed the pizza, although the important issue of starting up a new company was on the agenda. For a long time Kjell Øystein Arisland had been considering the idea of starting up a new firm which would exploit opportunities he thought would emerge in the field of Internet. In spite of his young age (around thirty years), he was already an experienced entrepreneur. He had carefully selected colleagues he knew well from his work as Assistant Professor at the Department of Informatics, and he was ready to present his vision for a new business opportunity. He asked his colleagues to participate as partners in the new company on the condition that they contributed a share of NOK 5000 (approximately Euro 620) in cash and committed themselves to a minimum of one month’s work during the coming year with no guarantee for payment. Everybody accepted the invitation, and they decided to establish the new company Oslonett.

From Steinsli and Spilling 2002

The start-up of Oslonett was based on knowledge of the emerging Internet technology and infrastructure. The business idea was to sell Internet access and provide services related to the net. Their innovations included the development of the search engine Kvasir, the establishment of market places on the net, and a system for the distribution of online result services for sports events.

The start-up of Oslonett was closely related to previous events. In addition to being based on the emerging Internet technology, it was also based on previous entrepreneurial experiences of the key founder, i.e. the person who invited the 16 partners to the start-up meeting. Employed as Assistant Professor at the University, he had one day per week at his disposal. Towards the end of the 1980s he had started two new companies within data technology and communication, both with colleagues from the University. The first company went bankrupt in 1988 due to market problems. However, the second company was started immediately afterwards and still exists. One of the partners took over the remains of the first company and started new companies based on these resources (Figure 5.1).

Oslonett – the Start

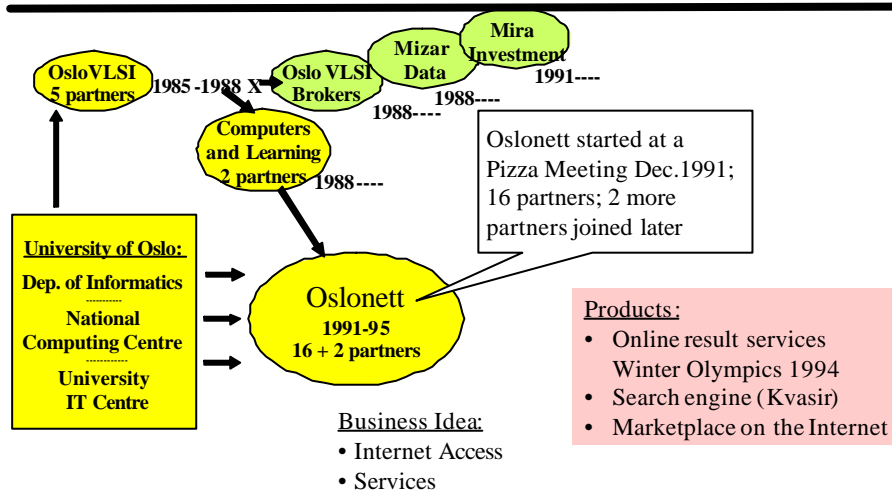


Figure 5.1: Start-up of Oslonett.

It soon became clear that the partners of Oslonett did not have the resources necessary to provide a direct link to Internet, so a strategic alliance was established in 1992 with the company TelePost, which had capital to invest in infrastructure, while Oslonett possessed the requisite expertise in Internet technology.

In 1994, Internet technology had a breakthrough in the market, and larger companies, in particular, started to show interest in the use of the technology. At the time, Oslonett had around one thousand access customers; they had

thirty full-time and twenty part-time employees; and their turnover had grown from around 500 000 NOK in 1992 to 4.3 million NOK in 1994.

However, being competitors in the same market, relationships between Oslonet and TelePost became tense, and the cooperation between the two companies disintegrated. Oslonett had great potential for growth, but competition was stiff, and they needed more 'muscle' to manage the necessary investments. First, they looked for a partner, but in 1995 the whole company was sold to Schibsted, a leading Norwegian private publishing house, which was considering utilising Internet technology.

Oslonett was restructured into Schibstednett. By buying Oslonett, Schibsted obtained important advantages. Firstly, they got a significant number of customers (7000 in 1995). Secondly, they acquired an established access net. Thirdly, they secured access to a group of people with unique competence in Internet technology (six of the entrepreneurs behind Oslonett remained in the company). But Schibsted also contributed with valuable knowledge and with its extensive publishing experience, was able to improve the quality and design of Oslonett's various web services. They also contributed to the further development of the market for using the Internet as a market place and as a new medium of communication.

At this time there were two large actors in the Norwegian market, i.e. Telenor Online (formerly Telepost) and Schibstednett. TelePost had changed its name to Telenor Online and was fully owned by Telenor, the leading Norwegian telecom company. Telenor Online created the web portal Scandinavian Online, inspired by American Online, and Schibstednett had SN-Horisont as their portal. Clearly, this situation could not last, and after a period of tough competition, they agreed first to merge the two companies, and then to split their activity into two separate companies: Scandinavia Online AS and Nextel (later Nextra). Scandinavia Online – or SOL - delivered Internet services, while Nextel provided Internet access. The name of their common web portal was Scandinavian Online.

Oslonett - Acquisition - Restructuring

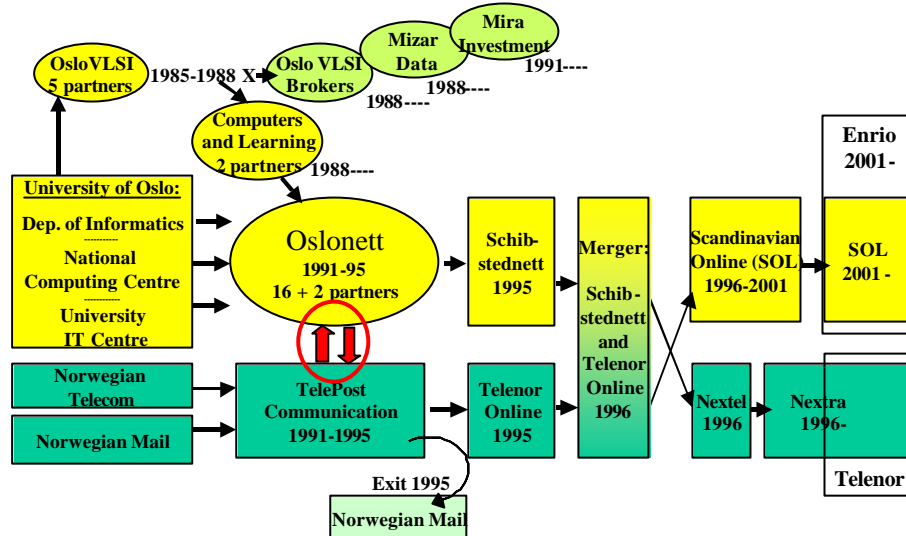


Figure 5.2: The main actors in the development of Internet technology.

Scandinavian Online had the ambition to become the largest Internet portal in Europe, and soon established companies in Sweden and Denmark, and later in Finland. The Internet market did not, however, grow as fast as expected, and after years with deficits, the company was forced to undergo significant processes of restructuring in 1998 and 1999, but still without being profitable. In 2000, after a new round of restructuring, SOL was listed on the Stockholm and Oslo stock exchanges. The following year, the Swedish company ENRIO bought SOL, including the rights to the Internet portal SOL and the former Oslonett product Kvasir (search engine). In 2001 SOL was the leading Internet media company in the Nordic region.

During the same period, NEXTRA developed to become Norway's main Internet access provider with 75 per cent of the private market and 35-40 per cent of the business market in 2001. NEXTRA is now integrated in Telenor (cf. Figure 5.2 and Box 5.1)

Box 5.1: The main direct or indirect actors in the development of Internet technology in Norway.

A. University based institutions.

The Norwegian Computing Centre (Norsk regnesentral)

A research and consultancy company owned by the University of Oslo. One of the first milieu in Norway with expertise in Internet technology.

Department of Informatics

Part of the University of Oslo. One of the very first milieu in Norway which got access to the Internet through the university's network.

University Centre for Information Technology

Part of the University of Oslo.

B. Private and public 'background players'

Telenor (The Norwegian Telecommunication Company, previously named Televerket).

A company 100% owned by the Government.

Telenor established TelePost Communication with Postverket in 1991. Telepost changed its name to Telenor Online in 1995, parts of Telenor Online's activities were transferred to NEXTEL, later NEXTRA.

Today Telenor is one of Norway's leading Internet companies.

Posten Norge AS (The Norwegian Mail Company, previously named Postverket.)

Posten Norge AS established TelePost Communication with Telenor in 1991 (see below). They sold their part of the company to Telenor in 1995 when it became clear that the company would focus on Internet. Posten had at that time just taken over *Statens Datasentral* (the Government's computing centre) and wanted to continue their e-mail business through this company.

Schibsted

Leading Norwegian private publishing house. Schibsted bought Oslonett in 1996 and gave the new company the name Schibstednett.

C. Companies directly involved in the development.

The companies are listed in order of 'appearance'.

Oslonett

Norway's first commercially based Internet company. Established in 1991. Bought by Schibsted in 1995.

Schibstednett

Oslonett was acquired by Schibsted in 1995 and renamed Schibstednett.

TelePost Communication

The company was started in 1991 by Telenor and Posten to deliver electronic

message services. The ambition was to become the dominating company offering electronic mail in Norway. Posten and Telenor owned 50% each in the new company. Telepost based their e-mail service on the X-400 technology.

- The management of TelePost was not satisfied with the X400 technology. After some resistance by their owners, the board of TelePost eventually accepted that TelePost started an Internet business. During the summer of 1993, TelePost became the first commercial company in Norway to offer direct Internet access through permanent lines to businesses. TelePost changed its name to Telenor Online in 1995, later NEXTRA.

Telenor Online

Owned by Telenor, started in 1995. The company provides Internet access as well as online services, such as the Internet portal Scandinavian Online. The company was restructured into NEXTRA.

Scandinavian Online AS (SOL)

Started in 1995.

The SOL group developed into the leading Internet media network company in the Nordic region. SOL was listed on the Stockholm stock exchange and on the Oslo stock exchange.

Enrio

Enrio is Northern Europe's leading provider of directory services online and offline, with operation in 23 countries. Enrio was listed on the Stockholm Exchange O-list in 2000 and has been expanding rapidly in the international market.

NEXTRA (former NEXTEL)

In 1996 Schibsted and Telenor agreed to merge the two companies Schibstednett and Telenor Online. The company was then split into two divisions, one was named NEXTEL and was based on providing Internet access. The company was renamed NEXTRA.

Oslonett and the companies that followed have led to a number of new spin-off companies. One group of spin-offs derived from Schibstednett and Scandinavian Online. The main companies in this group were Schibsted Interactive and SOL System. Schibsted Interactive later led to the establishment of Bokkilden, which is now one of the leading Internet based bookstores in Norway. SOL System, an operational unit outsourced from SOL in 1998, is based on Oslonett's technology; two of Oslonett's founders worked for this company. Sol System later became SOL ABB which developed 'Alt om København' and 'Alt om Stockholm'. Part of SOL System was acquired by Infostream, a company which had been merged with Intervett, a spin-out from Oslonett, at an earlier stage.

A second group of spin-offs was started by the Oslonett founders themselves, such as Intervett, Internet Service, Candleweb and Morell Software.

Nine of the co-founders established other companies after 1991, either alone, together with colleagues from Oslonett, or with others (Figure 5.3). Several of Oslonett's entrepreneurs became serial entrepreneurs. By 2002 Oslonett's 'family tree' had branched considerably. As shown in Box 5.2, In total, the 18 partners behind Oslonett have been involved in setting up a total of 14 companies. Many of these companies have merged with other companies, which in turn have spun-out new companies.

Spin-Offs from Oslonett Partners

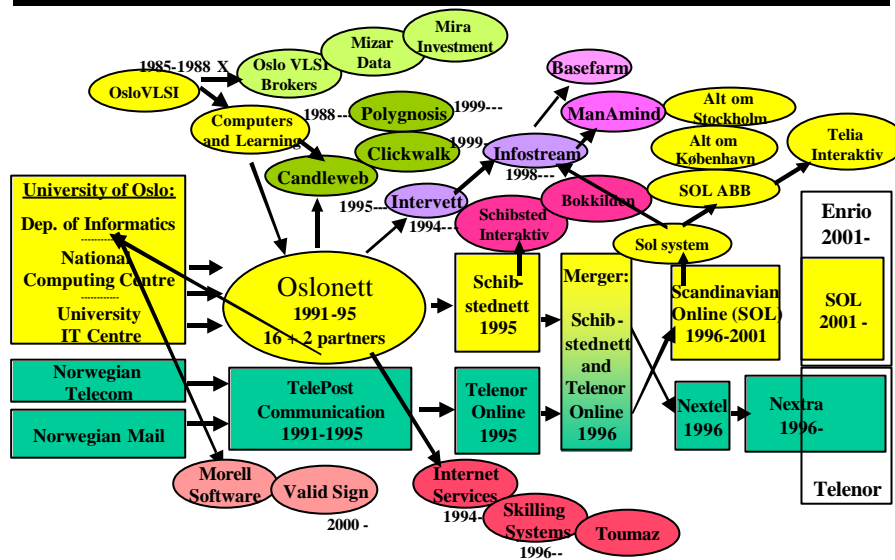


Figure 5.3: Spin-offs related to the process around Oslonett.

A significant number of the 18 original Oslonett partners point to the positive experience with Oslonett as an important source of inspiration for further participation in business development. The success of Oslonett demonstrated that it was possible to establish a business. Furthermore, selling Oslonett to Schibsted provided financial means that could be used as risk capital in new companies.

Box 5.2: Career pattern of the persons taking part in the start-up of Oslonett. (List to be completed.)

The following 16 persons participated in the ‘pizza meeting’ and became partners of Oslonett on the 12th of December, 1991. (Title in brackets indicate formal position at the time of start-up.) Listing in alphabetical order.

1. Arisland, Kjell Øystein (Assistant Professor at the Department of Informatics)

Initiator of the ‘pizza meeting’ and the main organiser of the start-up of Oslonett.

Previous start-ups:

Oslo VLSI AS, 1985-1988, together with Arne Kinnebergbråthen (se below) and two other people, the company went bankrupt in 1988.

Oslo VLSI Broker AS, 1988- ; was based on the remains of OSLO VLSI AS. The main founder was Arne Kinnebergbråthen, Arisland participated in a minority position.

Computers and Learning AS, 1988 –

Partner in Oslonett until 1994. When the firm was sold to Schibsted, he left the company and went to work at Computers and Learning. In 1994 he took a year’s sabbatical to Canada. Later start-ups:

Candle Web AS, 1995 –

Polygons AS, 1999 -

Click walk AS, 1999 -

2. Berg, Yngvar (Employed at the Department of Informatics)

Left Oslonett when it was sold in 1994, continued working at the University and is now Professor at the Department of Informatics.

3. Ellefsrud, Anders (Engineer at the Department of Informatics)

He never had a permanent job in Oslonett, but was employed by Scandinavian Online (SOL) when Schibstednett was reorganised to SOL in 1997. He later followed as an employee when SOL was restructured and activities transferred to the following firms:

SOL System (outsourcing of the operation unit of SOL) 1998 –

Infostream ASP (SOL System was acquired by Infostream) 1998 –

Basefarm, 2000 - (this company was set up by a group of partners who previously worked in SOL System

Since 1997, when Ellefsrud started as an employee at SOL, he has been working at the same desk in spite of being employed at four different companies.

4. Hannemyr, Gisle (Employed at the Norwegian Computing Centre)

When Oslonett was sold to Schibsted, he followed the company to Schibstednett and SOL; he became manager of SOL with special responsibility for development activities. After a few years, he left his job, and returned to the University to finish his PhD in Informatics, where he still works as a researcher at the Department of Informatics. Since he returned to the University, he has participated in other start-

ups:

Morell Software

Valid Sign 2000 -

He has also worked for Schibsted Interactive Studio, which was a 'think thank' for developing new business ideas. One well known company to result from this is Bokkilden, an Internet based bookshop.

5. Holen, Hans Petter (Employed at the University IT Service Centre)

He followed Oslonett to Schibstednett, for a short period he worked for Telenor Online before he returned to SOL, later to SOL System and Infostream ASP where he was central in the development of the Internet portals SOL in Sweden (SOL ABB), 'Alt om Stockholm' and 'Alt om København'. He is now head of the technical unit at Tiscali Norway, an International company providing operation of databases.

6. Karlsen, Tore Solvar (Employed at the Norwegian Computing Centre)

He was the first among the 16 partners of Oslonett to be employed by the company, and was manager of Oslonett from 1993 until the company was sold and converted to Schibstednett. He was also employed by Schibstednett for a short period of time, where he worked with internal systems development, before returning to the Department of Informatics, where he conducted research on the development of the next generation of Internet Services, before he was employed by Telenor, the main Norwegian telecommunication company. At Telenor he works with establishing Internet provision in Russia and other Eastern European countries.

7. Kinnebergbråten, Arne (Employed at the Department of Informatics).

Previous entrepreneurial experiences:

Oslo VLSI AS, 1985-1988, with Kjell Øystein Arisland (see above) and two other people. The company went bankrupt in 1988.

Oslo VLSI Broker AS, 1988- ; was based on the remains of OSLO VLSI AS.

Kinnebergbråthen was the main founder, while his previous partner Arisland participated in a minority position.

Computers and Learning AS, 1988 - , minority position, main partner: Arisland

Mizar Data, 1988 - investment company

Mira Investment Company 1991- investment company

He developed specialist competencies in financial issues, and assisted the partners in Oslonett in this field.

8. Kjærnsrud, Steinar Arne (Head of the operation unit at the Department of Informatics)

He had a special role in setting up most of the web services provided by Oslonett, including the Kvasir search engine and web services developed for the Winter Olympics at Lillehammer in 1994. He also developed Internet courses that were later was sold through Intervett, see below. He left Oslonett when the company was sold, and then started:

Intervett, 1994, which was started with a friend, Knut Jærstad. In 1998 Intervett

started to look around for a partner, and Intervett and the company Infostream (established in 1989) merged in 1998. Infostream later became Norway's first Internet company on the Norwegian stock exchange in 2000. Infostream was in 2000 bought by a French company, Integra, which again later was bought by the American company Genuity. Today the name of the former Infostream is Manamind:

9. Knudsen, Terje (PhD student at the Department of Informatics)

He left Oslonett when the company was sold in 1995, went back to the Department of Informatics, where he still works as a senior engineering officer in charge of the data systems of the Department.

10. Lande, Tor Sverre (Assistant Professor at the Department of Informatics)

When Oslonett was sold, he followed the new company and was a member of the board of Schibstednett until 1997. He returned to the Department of Informatics, where he is now a Professor. He has also been involved in other start-ups:

 Skillig Systemer AS 1996 – (specialised technical consultancy services)

 Internet Service AS 1994 – (with Otto Milvang, see below)

 Toumaz

11. Milvang, Otto (Engineer at the Department of Informatics)

When Oslonett was sold, he started a new company:

 Internet Service AS 1994 – (with Tor Sverre Lande, see above)

 Axicon 1991 – (with a colleague from the Norwegian Computing Centre).

12. Neset, Leif Arne (Engineer at the Department of Informatics)

After Oslonett was sold and converted to Schibstednett, he continued working in the new company until 1996. He then left and was employed by Bærum KabelTV, a local cable TV company which has recently restructured and now operates under the name alfaNETT.

13. Næss, Sigbjørn (PhD student at the Department of Informatics)

He finished his PhD after the sell out of Oslonett and continued at the Department of Informatics as an Assistant Professor, and he is still in this position. He also works part-time for NERA Satcom, a leading Norwegian electronics company.

14. Oslo, Kjetil Otter (employed at the University IT Service Centre)

He only participated in the start-up of Oslonett as a partner. He has worked at the University during the whole period, where he is responsible for the University's data- and telecom network.

15. Thomassen, Jens (Engineer at the Department of Informatics)

He followed Oslonett to Schibstednett and SOL. For a short period he went back to the University, before he started working for the company Metamerge (established in 1998). Metamerge is a consultancy service on systems and software.

16. Tvedten, Knut (Graduate Student at the Department of Informatics)

After the sell out of Oslonett, he was employed by the company Sysdeco Mapmill.

Recently, this company went bankrupt, and he is now considering starting a new related company with some of his former colleagues.

In addition to the above mentioned 16 partners that started Oslonett, two persons were invited and joined as partners in 1994:

17. Martmann-Moe, Erling (employed at the Norwegian Computing Centre)

He worked with Oslonett and Schibstednett until 1996. He then became CEO of New Media Science which later was merged and restructured into the new company Cell. Today he works as an independent consultant and is a partner in Alliance Venture. He also established Martmann-Moe Nye Medier in 1997, and consultancy services on systems and software.

18. Aas, Gisle (employed at the Norwegian Computing Centre)

He worked with Oslonett and Schibstednett and later SOL, but left SOL in order to start his own consultancy firm, and work towards the international Pearl development milieu. He is now working for ActiveState in Canada.

5.3 The role of different actors

The case of Oslonett serves as an illustration of how complex and diversified processes of evolution are, and how they are characterised by a complicated interplay between a large number of actors, whose roles vary over time. Even in this fairly narrow field of technology, a large number of actors have been involved.

Private actors in the form of entrepreneurs and established companies are found at the core of the cluster and serve as the main drivers of the evolutionary process. However, the presence of various institutions is also essential to the functioning of clusters and innovation systems.

In the case described here, the University of Oslo was the cradle for development. Competencies available at the Department of Informatics and the National Computing Centre, provided the knowledge base for the new Internet technology. Later, the knowledge resources of two other research institutions also were important. However, development could not have taken place without the presence of actors with entrepreneurial capacity, i.e. with the ability to see the commercial potential of the technology and to take steps to organise new ventures to exploit these opportunities. Entrepreneurs in the Schumpeterian sense played a crucial role as agents of change (Schumpeter 1934/1996, Eliasson 2000).

The first stage of development may be characterised as technology-based or technology-driven in the sense that it was the technologists that identified the opportunities. Although their motive was to exploit commercial

opportunities, their recognition of the potential of the technology was probably the main driving force. All the founders of Oslonett had basic knowledge in the field of information and communication technology.

Oslonett's business concept may be identified as a radical innovation – based on Autio's typology of technology-based companies as innovators (Autio 1995), the firm may be classified as 'paradigm innovator'.³⁶ Obviously the role of Oslonett was to explore an emerging technology as well as an emerging market. During the first stage of development, i.e. as long as Oslonett existed as a formal unit of operation, the main orientation of the firm was more towards technology than the market.

The assumption of technology driven development, is further supported by the absence of financial actors. The founders of Oslonett did not collaborate with financial actors, because they considered it unlikely that anyone in finance would be able to understand the business concept and the commercial opportunities. Basic funding for the initial development of Oslonett was provided by the partners' own financial resources, and supplemented by an investment of their spare time in the venture and by selling consultancy services.

The next stage of development serves as an example of the limited capacity of technology-based entrepreneurs. With limited financial resources, the founders of Oslonett faced problems in following up their venture. By the end of 1994, the activity of the company had expanded to the equivalent of forty full-time employees, and more financial resources were required both to manage growth in general, and, in particular, to make investments that would allow them to further exploit opportunities.

A new organisation was required; it was time for a shift from technology-driven development to finance-driven development; the technologists gradually left this particular business arena to continue with activities in other businesses or institutions, and more formally dressed businessmen took over. This also implied a shift from small, entrepreneurial firms to a dominance of larger firms in the evolution of this particular field of business.

This case also showcases the different roles that small and large firms may have in the development and application of new technology. One aspect of this is the role of small firms in creating variation and testing out new busi-

³⁶ The classification of Autio is based on a combination of two dichotomies; novelty of market (established-emerging) and novelty of technology (established-emerging). Based on these two dimensions, Autio suggested the following four categories of innovators 1) application innovators (established technology, established market), 2) market innovators (established technology, emerging market), 3) technology innovators (emerging technology, established market), and 4) paradigm innovators (emerging technology, emerging market).

ness ideas. In this way small firms contribute to the experimental economy (Metcalf 2000). Larger firms, then, acquire successful business concepts and provide for the further commercialisation and exploitation of the market. As demonstrated in this case, the larger players Schibsted and Telenor, and later other multinational companies, played an important role in taking development further when Oslonett no longer had the required resources.

The case also illustrates the extent to which new and small firms spin out, create variation and contribute to the continuity of processes of evolution. Typically, most new firms remain small; it is only in a minority of cases that high potential business concepts are developed.

5.4 The role of small firms in cluster evolution

As a next step in our analysis of the role of small high-technology firms, we will present data obtained through a survey based on representative samples of high-technology firms in Oslo and Trondheim.³⁷

As illustrated in the previous sections of this chapter, the best way to analyse cluster evolution, is through a longitudinal approach. By nature, a survey based on questionnaires is cross sectional and only provides information on specific actors at a certain point in time. However, longitudinal studies require a lot of resources. One is constrained to perform some kind of cross sectional analysis, and from this try to reconstruct what has happened. In doing so, we have drawn upon previous analyses of the Cambridge region (Keeble et al 1999).

The relevant populations of high-technology firms in Oslo and Trondheim were identified through the databases of Statistics Norway and CreditInform. All firms in the specified industrial and service sectors with more than two, and less than a hundred employees in 1999 were selected. A sample of these firms were contacted by telephone, and questionnaires were sent to those willing to participate. This resulted in a total of 117 acceptable responses, and a response rate of 39 per cent on average (see Table 5.1). Although we would have preferred a response rate of minimum fifty per cent, the actual response rate may be regarded as acceptable considering 'normal' rates for these kinds of surveys.

³⁷ The survey was organised in collaboration with the Centre for Value Creation at The Norwegian School of Management BI. The questionnaire (in Norwegian), is presented in the Appendix.

Table 5.1: Total population of firms, firms contacted and responses

	Oslo	Trondheim	Total
Total population	288	145	433
Contacted	200	103	303
Not willing to participate	23	6	29
Received responses	81	36	117
Non-responses	96	61	157
Response rate	41%	35%	39%

Based on the idea that companies tend to specialise in different fields and in different functions, the firms have been classified according to the main functions they cover cf. Table 5.2.. The classifications used are based on a value chain and production system perspective,

Table 5.2: Surveyed Firms classified according to their functional roles. (N=117).

Standard products to end user	19%
Specialised products to end user	23%
Subcontractors	12%
R&D-services	15%
Software and system development	24%
Data and information services	17%
Consultants	57%
Sales	27%

Comment: More than one answer possible, number of responses adds up to more than 100%.

The data show that many firms have more than one role in the production system. In fact, among the 117 firms that responded to the survey, only 52 (44%) reported one function; two functions were reported by 36 companies (31%); and the remaining 29 companies (25%) reported three or more functions. Thus, a significant share of small high-tech firms are based on what we may call multifunctional activities.

In this respect there is no significant difference between the companies in Trondheim and Oslo, and in general, there are strong similarities between firms in Oslo and Trondheim in terms of sectoral and size distribution. However, there is a significant difference in the market orientation of the firms, as a significantly higher share of firms based in Oslo are exporters (Table 5.3). In total, 53 per cent of these companies produce goods or services for export, while the similar share of Trondheim based companies is 30 per cent.

When comparing the cluster structure in terms of the location of the most important customers, suppliers and competitors, there are significant differ-

ences between Oslo and Trondheim. In Oslo, 70 per cent of companies surveyed report that their most important customers are in the local area, while only 28 per cent of the Trondheim companies claim the same. Similarly, the firms in Oslo report that 58 per cent of their most important suppliers and 62 per cent of their most important competitors are located in the local area, while, in contrast, the shares in Trondheim are 32 and 23 per cent respectively.

This clearly points to the conclusion that the Oslo cluster is much more complete than is the case of Trondheim. This is to be expected, considering the significant difference between Oslo and Trondheim in terms of cluster size and total activity in high-technology fields.

Table 5.3: Market orientation and location of customer, suppliers and competitors of firms in Oslo and Trondheim

	Oslo	Trondheim	Significant difference*)
Export companies (%):			*
Non-exporters	47	70	
Exporting less than 50%	45	18	
Exporting more than 50%	8	12	
Location of most important customers (%):			***
Regionally (in the cluster)	70	28	
Elsewhere in Norway	20	50	
Internationally	11	22	
Location of most important suppliers (%):			**
Regionally (in the cluster)	58	32	
Elsewhere in Norway	14	46	
Internationally	28	21	
Location of most important competitors (%):			***
Regionally (in the cluster)	62	23	
Elsewhere in Norway	20	53	
Internationally	18	23	

*) Level of significance indicated as: *: <.05; **: <.01; ***<.001

5.4 The role of small firms in cluster evolution – the dynamic view

The majority of firms included in this survey are of recent origin. Around sixty per cent were established during the 1990s, and around one third were established in 1996 or later. Mostly, the firms have been developed

independent of other organisations (Table 5.4); close to sixty per cent of the companies report that their business idea was developed independently, while a smaller share, 29 per cent, report that the idea was developed in other companies or institutions. Ten per cent of the firms were established in collaboration with other firms or organisations.

A significant share of the founders (75 per cent %) previously occupied positions in other firms, either as managers (33%) or in non-managerial positions (42%). Among the remaining founders, only twelve per cent were employed in the university and R&D sector, while the rest were either unemployed or students.

It is important to note that the founders were asked to provide information about what they were doing immediately prior to the start-up. When asked about their general background, the share of founders with a background in R&D increased to 26 per cent, while the most significant group in this case turned out to have a background in marketing (50 %); 29 per cent had a management background; and 28 per cent had a background in production. Since a team rather than an individual entrepreneur starts many of the companies, different backgrounds may be combined, and the percentages add up to significantly more than a hundred.

Table 5.4: Development of the business idea.

Development of the Business Idea	Oslo	Trondheim	Total
- Independent	57.5	54.3	56.5
- In another company or institution	28.8	11.4	23.5
- In collaboration with another company	10.0	31.4	16.5
- Other	3.8	2.9	3.5
Total	100.0	100.0	100.0
(N)	(80)	(35)	(115)

Table 5.5: The role of the main founder before start-up.

Role of the main founder before start-up	%
- Unemployed	7.7
- Student	3.4
- University/R&D	12.0
- Employed (not manager) in another company	41.9
- Manager of another company	33.3
- No information	6.0
Total	100.0
(N)	(117)

There are two aspects that need to be commented on. First, a fairly large number of the companies report that their business idea was developed independent of other organisations; thus just a small share of the start-ups may be regarded as spin-outs from existing organisations. Instances of spin-outs, in the sense that they grew out of an active incubator organisation, are fairly modest since less than a fourth of the companies report this kind of process.

Another issue of special interest, is the role of universities and R&D institutions as incubators of new firms, and the extent to which one can talk about direct spin-outs from these institutions. In the literature on cluster evolution, this is regarded as a very important mechanism (Keeble and Wilkinson 2000, Segal Quince Wicksteed 1990 and 2000). According to our data, links to these institutions are rather weak. Among those reporting that their business idea was developed in another organisation, the vast majority specify that the idea was developed in another firm, mostly larger companies, while only a few cases report that the incubator organisation was a university or R&D-institution. As a matter of fact, only eleven companies (9%) report being developed in the context of a university, a science park or research institute.

Based on these findings, one may question whether there is a relationship between Norwegian academic institutions and the business community; obviously, the findings do not indicate a very impressive link. However, it is important to have a differentiated perspective on this. One thing is a direct link in terms of direct spin-outs of new firms from academic institutions; another is the total influence or contact pattern, which may prove to be something much more substantial when one takes into account the total number of links between academic institutions and new firms. This may be discussed along two dimensions.

First, there may be indirect links. Founders may have a background from an academic institution, even though it has not directly served as an incubator organisation. In the survey, twelve per cent of the companies reported that their founders were employed in an academic institution prior to start-up. When asked about the general background of their founders, as many as 26 per cent reported that at least one of their founders had an R&D background.

Second, links to academic institutions may be even more indirect as the commercialisation of academic knowledge may go through several stages of firm formation and processes of sequential entrepreneurship, as is clearly demonstrated in the case of Oslonett (discussed in previous sections of this chapter).

Third, other links between academic institutions and the business community may be provided through the employment of former students, or by different forms of informal contact. Thus, it is not easy to make a total assessment of the interface between the academic institutions and the business community.

However, this should not be an excuse for not analysing the opportunities for improving relationships and taking more advantage of the potential for more spin-off firms (RITTS 2000).

To follow up on different aspects of evolutionary processes, the firms were asked to what extent they had been involved in, or contributed to, different types of processes. Data in Table 5.6 show that diverse processes have been at work. More than twenty per cent have been through a merger with another company; the same share have acquired another company partially or fully. As many as 32 per cent have contributed to the start-up a new firm, and in 27 per cent of the cases employees have left the firm to start a new business.

The phenomenon of licensing out production rights does not seem to be important to these firms, as only 11 per cent report having licensed *out* production rights. Five per cent have licensed *in* similar rights.

Altogether, however, the data indicate that patterns of development are complex. Evolution is diversified and constituted by a number of restructuring processes, including: forming new independent organisations, spinning out new businesses from existing ones, and restructuring through mergers and acquisitions.

Table 5.6: Share of firms reporting different types of evolutionary processes:

Merged with another company	23.9
Acquired other companies (partially or fully)	22.2
Licensed <i>in</i> the right to other production	5.1
Developed and licensed <i>out</i> production rights	11.1
Contributed to a new start-up	31.6
Employees have left to start new business	26.5
N	(117)

5.5 Small firms and innovation

According to our data, there is a high level of innovative activity amongst the firms surveyed. In total, close to 60 per cent of the companies reported having organised R&D-activities internally during the past year. A significant share of the firms also acquired R&D-services externally. When asked about innovative activity, virtually all the firms reported having performed some kind

of innovation during the last three years, only seven per cent did not report any kind of innovative activity (Table 5.7). Mostly, innovation activities are product- and service-oriented. 65 per cent of the firms developed new products or services; 70 per cent improved products and services. In total, close to 80 per cent of the companies were involved in some kind of product and service related innovation. Significant shares were also involved in other forms of innovation, among which the application of new software or system solutions were most frequently mentioned. Two thirds of the companies have applied new software or system solutions.

Table 5.7: Share of firms with R&D-activities and innovation activities (N=117).

<i>R&D activity last year:</i>	<i>(%)</i>
- Own R&D activity	58
- Acquired R&D-services	25
- New products or services	65
- Improved products or services	70
- Process innovation	41
- Innovation in marketing/sales	29
- New markets	45
- Applied new technology	44
- Applied new software or system solutions	67

When analysing the importance of different actors in the innovation process, a typical picture is revealed; firms report that key contacts for the innovation process are organised along the value chain, with customers and suppliers as the most important partners (Figure 5.4). Interestingly, competitors are also considered important to the innovation process, implying that there are significant contacts and flows of information between firms even though they compete in the same market.

Other groups of actors are considered less important; consultants, universities and research institutes, public agencies, banks and other capital providers get low scores. However, these scores are based on the averages for all firms, and there may be significant variations between different firms regarding which actors are important. We have two comments related to this.

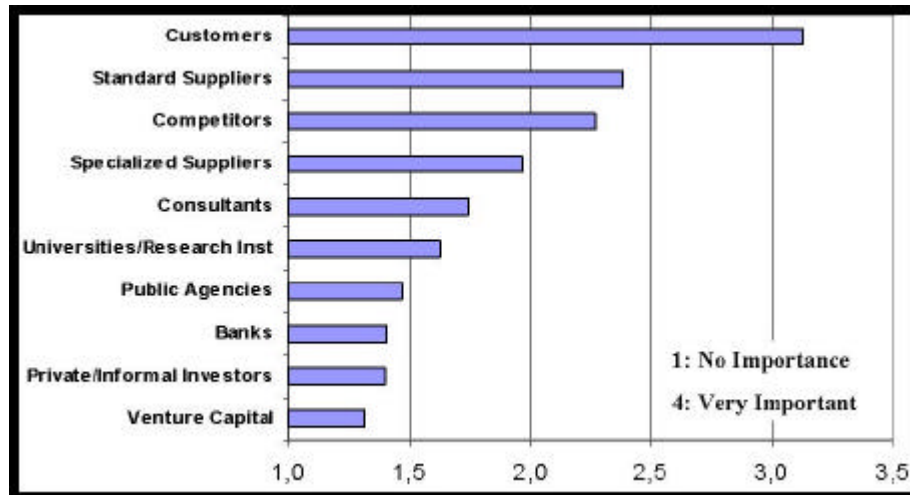


Figure 5.4: Importance of different actors in the innovation process.

First, it may be asked why universities and R&D institutions score so low. As discussed earlier, links between firms and institutions may be indirect, so many firms do not recognise them as being important to the innovation process. However, a small share of the firms, i.e. around 15 per cent, report that these institutions are of high or very high importance. Thus, for some firms there is close interaction.

Second, the role of capital providers needs to be addressed. It will be of no surprise that banks, in general, are of less importance to the innovation process. More interesting is the finding that venture capital as well as private investors also score very low. However, it should be kept in mind that these actors are generally less involved in start-ups. In fact, the data show that only seven and fourteen per cent, respectively, give high or very high importance to venture capital or private investors in the innovation process.

The general conclusion is that all types of actors present in the innovation system may be important to innovation processes, but the extent to which specific firms collaborate with different actors varies considerably.

To shed more light on processes of innovation and the role of small firms, a factor analysis has been carried out in order to identify a potential structure of innovative behaviour among small firms. Based on an analysis of the pattern of contacts with different actors in the innovation process, three factors were identified, which provides a basis for grouping the firms according to their role in the innovation system (Table 5.8). The three groups may be identified as 1) the R&D-based innovator, 2) the competition-based innovator and 3) the supplier-based innovator.

Table 5.8: Factors for identifying different types of innovators

	Component		
	1	2	3
Standard Suppliers			0.820
Specialised Suppliers			0.768
Customers		0.603	0.316
Consultants		0.793	
Competitors		0.769	0.241
Universities/R&D	0.658		
Venture Capital	0.803		
Private Investors	0.771		
Banks	0.389		0.346
Public Programs	0.650		

Extraction method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalisation.

In the case of R&D-based innovators, the innovating firms have strong links to R&D institutions and obviously work in close interaction with these institutions. Interestingly, this group also has close connections to providers of risk capital. i.e. venture capital and private investors as well as public agencies that provide financial resources. It is likely that this group is oriented towards radical innovations which require access to significant financial resources.

The second group comprises competition-oriented innovators, which has strong links towards their customers, competitors and consultants; other links are of less importance. The third group consists of supplier-based innovators, which has strong links towards their suppliers. Interestingly, standard suppliers score slightly higher than specialised suppliers.

In total these groups of innovators cover different and complementary parts of the innovation system. It would be of interest to conduct more research into this area, in order to further develop the typology and obtain more detailed insights into the characteristics of these different groups of innovators.

Comparing the data on innovation activities for firms located in Oslo and Trondheim, no significant differences are revealed, leading us to the conclusion that processes of innovation are similar in the two regions. Approximately the same number of firms are involved in the same types of innovation activities, and, on average, the importance of different actors turns out to be much the same.

When a factor analysis of the firms is performed separately on the two cities, virtually the same types of factors are identified, thus indicating that the

typology suggested here is fairly robust. However, this should be further investigated by a larger and preferably more detailed data set.

Although the process of innovation turns out to be virtually the same in the two cities, the data reveal significant differences between Trondheim and Oslo regarding whether actors of importance to the innovation process are located in the city or not. Not surprisingly, firms located in Oslo report that significantly higher shares of actors important to the innovation process are located in the region. Thus, firms in Oslo have the advantage of local competitors, suppliers, customers and different service providers compared to their colleagues in Trondheim. There is only one important exception, university and R&D institutions; the Trondheim firms report closer links to these local institutions than is the case for Oslo. This indicates that, in general, the Oslo cluster has a more developed local environment, with the exception of links to the university and R&D sector, which seems to be more developed in Trondheim.

5.6 Comparisons with Cambridge

In our survey of Oslo and Trondheim we applied questions similar to those in a study conducted in Cambridge. Comparative data is presented in Table 5.9.³⁸

In Cambridge, 88 per cent of high-technology SMEs were identified as spin-offs or new start-ups. In Oslo and Trondheim 80 per cent of the high-technology firms were either spin-offs or new start-ups. Compared to Cambridge, the share of spin-outs and new start-ups are slightly less in the Norwegian study. However, the relatively large number of new start-ups and spin-outs among the surveyed high-tech firms, both in Cambridge and in Norway, implies a considerable diffusion of embodied knowledge in the 'incubating' firms or institutions.

In Cambridge, 70 per cent of the high-tech firms were founded by entrepreneurs who had formerly worked for another company, while 25 per cent of the chief founders were employed either by a university or a research institution prior to start-up. In the Norwegian study 75 per cent of the founders had previously been employed by another firm, while 12 per cent had a background from a university or research institute. The role of the university as a generator of new business ideas, therefore, seems more

³⁸ The data for the Cambridge region is based on a survey undertaken in 1996 by the ESRC Centre for Business Research, referred to here as the CBR survey. The survey covers 50 technology intensive SMEs, based on a stratified random sample designed to produce a representative balance of high-tech firms between manufacturing and services (Keeble et al 1999).

pronounced in Cambridge than in Oslo and Trondheim, but the difference is not as great as one might expect, given the focus on Cambridge University as a generator of the high-tech milieu in Cambridge.

Table 5.9: Comparison of data for Cambridge and Oslo and Trondheim

	Cambridge	Oslo and Trondheim
Spin-outs		
By another firm	12%	
As a spin-off	32%	23.5%
As an independent start-up	56%	56.5%
In collaboration with another company or institution		16.5%
Other		3.5%
<i>Total</i>	<i>100%</i>	<i>100%</i>
Previous employment of founder prior to start-up		
Manager/employee in another company	70%	72%
Employed by university/ research laboratory	25%	12%
Self employed/unemployed/ student	5%	11%
No information		6%
<i>Total</i>	<i>100%</i>	<i>101%</i>
Actors of importance to the innovation process^{*)}		
Customers	Important	Important
Standard suppliers	Some importance	Important
Competitors	Important	Important
Specialised Suppliers	Some importance	Some importance
Consultants	Little importance	Little importance
University/Research institutes	Important	Little importance
Public agencies	n.a.	None or little
Banks	n.a.	None or little
Private/informal investors	n.a.	None or little
Venture Capital	n.a.	None or little
Location of actors of importance in the innovation process		
	Main actors located in the rest of the UK.	Oslo: main actors in the region.
	Among those located in the Cambridge region, the University and customers most often mentioned as important.	Trondheim: main actors of importance located nationally.

^{*)} The questions asked in the Oslo/Trondheim study are not exactly comparable to the Cambridge study. The rating of the factors of importance in the Cambridge region is based on our judgement.

However, as discussed earlier in this chapter, these results may underestimate the importance of the universities. Many firms may have indirect links to a university, since first generation spin-outs may serve as incubators for a second generation of spin-outs etc. This seems to be the case in Cambridge; the Norwegian case of Oslonett also indicates a similar pattern.

In Cambridge, the University has also been of importance in cases where the parent companies have not spun-out of the University, as the University has constituted a basic reason for the organisation concerned to stay in the Cambridge region (Segal Quince Wicksteed 1985). We can identify this effect to a lesser extent in Oslo and Trondheim.

The role of different actors in the innovation process are similar in Cambridge and Oslo/Trondheim. In general it is relationships with customers and suppliers together with competitors that are the most important, although there are some minor differences. In the Cambridge survey, universities are noted as being important to the innovation process, while this is not the case in Norway, pointing to the different role of the university in Cambridge versus Oslo and Trondheim.

The two studies vary regarding the location of the most important external sources for the innovation process. In Cambridge a higher proportion of important firms or institutions are located in the rest of UK or globally, than in the Cambridge region. Among the sources rated as important; university resources are reported to be located within the Cambridge region. But also in this case, universities located elsewhere in the UK were often of greater importance than those located in Cambridge.

Therefore, national and global innovation networks are more important than local networks in the case of Cambridge. In the study of the Norwegian high-tech SMEs, the results differ between Oslo and Trondheim. In Trondheim national or international actors are more important than regional actors (with the exception of the university and R&D institutions). In Oslo, on the other hand, the most important actors in the innovation process were located in the local region.

5.7 Summary

According to current theory on innovation systems and cluster evolution, knowledge is the most important resource in the economy, and learning is the most important process (Lundvall 1992). In line with this, processes of collective learning are essential for cluster evolution (Capello 1999, Lawson and Lorenz 1999; Longhi 1999; Longhi and Keeble 2000; Keeble and Wilkinson 1999), i.e. there are processes going on in which different actors in various ways contribute to learning, for instance through entrepreneurial and innovative activities.

The formation of new firms provides a significant contribution to processes of evolution. Generally, and at any time, a large number of entrepreneurs introduce new businesses. Each entrance of a new firm, and each step of development in an existing firm, may be regarded as a contribution to the evolution of the system as a whole. From this perspective each new step may be regarded as based on previous events and adding new knowledge to the system.

The role of small high-tech firms is essential to these processes. Based on a static view, small firms on average account for about fifty per cent of all high-technology employment in Norway, but sectoral differences are significant. Based on a dynamic view, small firms show a diversified pattern, and contribute to evolution in different ways; partly through independent start-ups or spin-outs from other firms or organisations; partly through being part of the process of restructuring, for instance in the case of mergers and acquisitions. In this way small firms contribute to the development of the capitalistic system, as described among others by Bahrami and Evans (1995) and Metcalfe (2000).

Small high-tech firms are highly innovative, and virtually all of the firms that participated in the survey were involved in some kind of innovative activity. Most of them were product-oriented in their innovation, but a significant number were also involved in process innovation, market innovation or the implementation of new technology or systems solutions.

Based on the perspective of collective learning, the nature of 'success' may be reflected on. While the common understanding of success is often related to profit and growth at the firm level, the perspective of cluster evolution leads to a focus on 'performance' and 'success' at an aggregate level. i.e. it is the development of the business community as a whole that is of interest. From this perspective, 'failures' at the individual level in terms of closures and bankruptcies may provide as important a contribution to the process of collective learning as 'success' at the individual level. The point is to what extent mechanisms in the local economy facilitate sharing of knowledge and experiences, and in this way create a process of collective learning.

Given that the capitalist system is not working as a predictable mechanical clock, but is highly unpredictable (Metcalfe 2000), the role of small firms (as well as larger firms, although they may take somewhat different approaches) is to take risks, test out new ideas, develop new knowledge and thereby contribute to processes of learning. It is about a process of trial and error, about making experiments in which the outcome is unpredictable. This calls for the ability to adapt and be flexible. A characteristic feature of the system is that of flexibility at the system level, from which evolution may be regarded as a constant process of recycling and transfer of resources between different business concepts. 'The short life cycle of many high-technology firms may be helpful for sustaining the long-term innovative capability' (Bahrami and Evans 1995).

6 Cluster Evolution and Policy

Possibly the biggest risk in cluster analyses and cluster policies is that policy makers and researchers tend to focus on 'high-tech' clusters and the obvious success stories that abound. This is a major risk as it is usually forgotten that the rise of such clusters in the first place is the result of a combination of an often unique mix of mostly strongly localised factor conditions and development trajectories built up over decades that cannot be replicated overnight. The mechanisms and experience built up in clusters - no matter whether these are labelled as high-, medium- or low-tech - are valuable capacities. As long as clusters have built-in mechanisms to renew and re-invent themselves over time, this is a very precious asset. Therefore, characterising clusters as low- or medium-tech might be misleading. Hauknes ... shows how knowledge-intensive a cluster like agro-food has become; the more so if one does not overlook the non-technological knowledge involved in innovation.

(Hertog, Bergman and Charles 2000:414)

6.1 Introduction

In previous chapters we have analysed cluster evolution. Through different cases we have demonstrated how diverse patterns of evolution may be. One aspect of this diversity is the role of policy in cluster evolution. An important point of departure for our discussion, is that there is no simple recipe for 'successful' cluster policies, and clearly no 'formula' for creating a cluster from scratch by political measures. As indicated earlier in the report, no theory can explain why clusters emerge in some areas and not in others, but based on empirical studies of clusters that are evolving, a lot of knowledge has been developed on what characterises different clusters and what drives this evolution.

A cluster almost by definition represents some kind of success story, and most analyses of clusters have focused on the most successful cases. However, one should not expect that copying policy strategies that have been successful in one place will lead to similar success in another region. Development in a particular area is often based on long traditions and a unique mix of mostly localised factors (Hertog, Bergman and Charles 2000, cf. quote above). Thus, development in one place cannot be replicated elsewhere. Rather than formulating copy-cat strategies, policy makers should focus strategy on the specific qualities of the cluster in question, and design

strategies for developing competitive advantage based on uniqueness (Porter 1998).

Keeping this reservation in mind, there is a lot to learn from policy applied elsewhere. As discussed earlier in this report, even though the role of different factors may vary, the same types of factors are at work. Likewise, similar policy measures have been applied in diverse environments.

The purpose of this chapter is first to summarise theory in the field of cluster policy and then to summarise the role of policy in the three cases of Cambridge, Dublin and Sophia Antipolis. Based on this, and on observations of the situation in Oslo and Trondheim, policy issues related to the future development of the two Norwegian cities will be discussed.

6.2 The role of policy in cluster evolution

The main role of policy is not to ‘create’ clusters, but to facilitate the evolution of clusters by supporting the basic mechanisms of cluster evolution, and intervene, if possible, in fields where mechanisms are not working properly. This means that it is the specific situation in each case that is the basis for strategy formulation and the design of specific policy measures. It is of crucial importance that these processes are developed in close interaction with local authorities and the key actors of the cluster.

As Porter has been very influential to our understanding of clusters, his policy framework may serve as a natural point of departure for this discussion. According to Porter (1998), an understanding of industrial development in terms of cluster dynamics provides a basis for redefining the roles of governments at the national as well as local level. Porter proposes a policy framework based on his cluster model, illustrated in Figure 6.1.

The main idea underlying Porter’s framework is that policy may have a role in supporting or facilitating cluster upgrading by influencing mechanisms of importance to the cluster, for instance by supporting the development of cluster specific infrastructures or institutions, and services crucial to the functioning of the cluster as a whole.

Combining Porter’s ideas with recent approaches based on innovation systems, the OECD has developed different frameworks in a number of studies (Remøe 2000). One important approach used is to identify systemic and market failures and implement measures to compensate for these failures and inefficiencies, as suggested in the framework presented in Table 6.1. Although structured differently, the table shows many similarities between the OECD framework and Porter’s framework above, for instance in the focus on developing adequate institutions for improving the knowledge base, and strategies for networking and improving interaction between different actors.

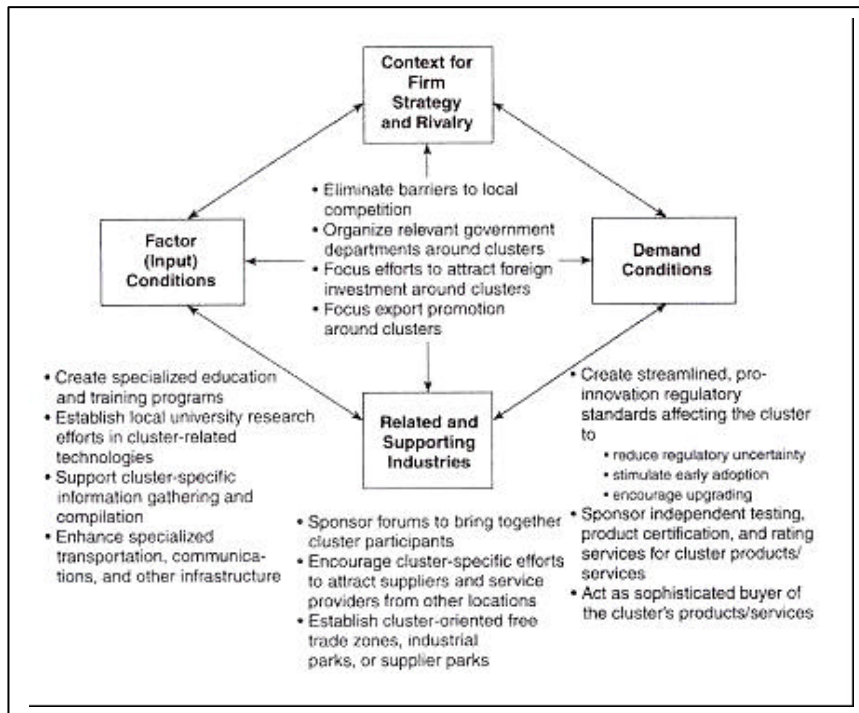


Figure 6.1: Porter's framework for analysing government influences on cluster upgrading (Porter 1998:251)

Table 6.1: OECD framework for responding to systemic and market failures

Systemic and market failures	Policy response
Inefficient functioning of markets	Competition policy and regulatory reform
Informational failures	Technology foresight Strategic market information and strategic cluster studies
Limited interaction between actors in innovation systems	Broker and networking agencies and schemes Provision of platforms for constructive dialogue Facilitating co-operation in networks (cluster development schemes)
Institutional mismatches between (public) knowledge infrastructure and market needs	Joint industry-research centres of excellence Facilitating joint industry-research co-operation Human capital development Technology transfer programmes
Missing demanding customer	Public procurement policy
Government failure	Privatisation Rationalise business Horizontal policy making Public consultancy Reduce government interference

Source: Remøe 2000.

In line with this framework, a number of other authors have also discussed policy issues, but more specifically related to cluster evolution and how policy measures affect mechanisms of evolution (cf. for instance Garnsey 1998, Keeble and Wilkinson 1999 and 2000, Kuijper and van den Stappen 1999). Although it is not possible to determine conclusive growth mechanisms of high-tech clusters, the success of a particular cluster is context specific, the following factors are often regarded as important (Saxenian, 1989):

- A research university
- Supply of venture capital
- Public investment devoted to research and procurement
- A quality of life that will attract and retain footloose engineers and scientists
- The absence of trade unions
- A science park
- Adequate infrastructure.

In her study of the high-tech milieus of Oxford and Cambridge, Garnsey (1998) refers to an almost identical list of factors which are commonly thought to stimulate the growth of high-technology based firms.

According to Garnsey's list, public policies can influence high-technology development in various ways, both through direct public funding of

universities and science parks and through more indirect measures like regulations and tax measures.

The role of venture capital has received substantial interest as a factor of importance for the growth of high-tech firms. The existence of market failure in the provision of risk capital, due to asymmetric information, has been discussed in economic literature for a long time. In particular, this is related to start-ups, as the entrepreneurs' limited tangible assets and high risk reduce their opportunity for collateral-based lending from banks (Murray 1998). Therefore, venture capital is an important source of financing for early stage projects with high risks and potential for substantial returns.

Clearly, public policies can play a role in providing venture capital through direct funding or through specific tax measures that stimulate more private investment in venture capital. However, in studies of high-tech regions, venture capital does not seem to be a sufficient factor in itself for stimulating high-tech development. The success of venture capital provision also depends on complementary, techno-commercial networks to assist the subsequent development of new firms (Murray, 1998). Saxenian (1989) has also discussed this, and points to differences in the development of the venture capital industry in Britain and USA. In Britain, venture capital is a result of government tax legislation, while in the US, the venture capital industry grew from a base of successful entrepreneurs with first hand experience in regions like Silicon Valley. Therefore, they were able to provide start-ups with invaluable advice and access to networks and strategic resources. Institutional investors, on the other hand, tend to maintain an arm's length relationship with young entrepreneurs. Many of them are in the venture capital business primarily for tax advantages, and are only interested in supplying firms with money; not with ideas, guidance, industry contact or managerial resources.

Another important strategy to stimulate cluster evolution, is to set up science parks. Science parks are perceived to be a key factor in the production and diffusion of new knowledge, and serve as an important link between industry and academia. Such institutions provide great political visibility, but are of less value in the absence of mechanisms to ensure the diffusion and commercialisation of research findings. Thus, the effectiveness of science parks has in some cases been questioned (Saxenian 1989, Oakey 1999).

The need for a better understanding of how knowledge is shared and diffused in the economy, is discussed by Garnsey (1998) and Keeble and Wilkinson (2000). Given the complexity of the innovation process, they emphasize that how knowledge is shared and diffused depends on both institutionalised and cultural factors. In order to facilitate development in a

region, they argue, it is necessary to undertake a thorough mapping of the linkages between various actors and institutions to get an understanding of the innovation system and bottlenecks in the system. Furthermore, according to Garnsey (1998), it is necessary to understand how the system is animated by key agents, like entrepreneurs, who form productive enterprises that develop interdependent activities in conjunction with other local institutions. Individuals appear to be the key source of learning as they move from unit to unit of the system and exchange information and expertise. But also new spin-offs from universities and from other firms seem to be an important source of diffusion of knowledge (Keeble and Wilkinson 1999).

Based on her studies of Cambridge, Sophia Antipolis and Silicon Valley, Garnsey (1998) points to the importance of diverse investment sources as being more likely to stimulate sustained expansion in new areas and industries than reliance on one major source of investment. Furthermore, it is important to identify and facilitate local 'champions', i.e. individuals with a strong influence on high-tech development; and to adjust policies to local needs.

In a comparative study of the growth of regional clusters of high-technology firms in Cambridge, Oxford, Grenoble, Sophia Antipolis, Munich and Gothenburg, Keeble and Wilkinson (2000) have pointed to a growing need to shape the knowledge infrastructure and channels of technology transfer to meet changing requirements. This requires a reduction of supply side constraints on the flow of information and knowledge, and an increase in the capabilities and motivation of SMEs to absorb and use effectively new science and technology. A complementary development is the need to foster closer relations between firms to encourage technology diffusion and collective learning. Although this activity can and does occur without policy intervention, the case studies suggest that policy has an important part to play in promoting partnerships and creating channels for learning. Their research also suggests that policies need a locality and industry specific orientation if they are to contribute to building the relationships of trust and confidence essential for effective networking.

Based on their results, the following areas for policy development are suggested (Keeble and Wilkinson 2000):

- Diffusion of knowledge from the science and technology base, for instance by reducing barriers between industry and university by supporting technology consultants helping small firms to utilise knowledge from the university
- Support networking and collective learning processes by for instance supporting research collaboration between local SMEs

- Business support for high-technology SMEs, for instance through education and training facilities targeted at their specific needs and development
- Policies targeted to the specific needs on the regional level in order to develop policies targeting the specific challenges in each region.

Both Garnsey (1998) and Keeble and Wilkinson (2000) emphasize the danger of lock in effects caused by strengthening local and regional networks and collective learning. Innovation trends can be self-reinforcing, but they can also be restraining, or can set off counteracting forces. In stimulating high-tech development, it is therefore necessary to ensure that firms build national and international networks.

The strategies and incentives discussed above have been influential among policymakers, and in policy development it has often been implied that once these prerequisites are met, innovation and growth will follow. It seems, however, clear that high-tech development does not automatically occur once these factors are in place. The case of the different patterns of development in Oxford and Cambridge is just one example that high-technology industry does not automatically develop around a well-known research university (Lawton Smith and Garnsey 1998).

In general, it may be summarised that studies of high-tech regions in Europe do not provide us with a straightforward recipe for generating dynamic high-tech regions. Many of the same factors are important, but how these factors combine, and which factors are the most important driving forces vary both between regions and over time within the same region.

6.3 Policy approaches in Cambridge, Dublin and Sophia Antipolis

In chapter three we reviewed the evolution of high-technology clusters in Cambridge, Dublin and Sophia Antipolis. The role of different actors was also summarised (cf. Table 3.7). These cities' case histories confirm what has been emphasised repeatedly in this report; that development in each place is unique and depends on the specific mix of preconditions and actors operating in the milieu. This also applies to policy approaches. When the three places are compared, we find great differences in the importance of policy at the local as well as the national level. The role of specific policy measures varies significantly as well.

In chapter three the role of policy in the three case was only briefly mentioned. In this section we will go into more detail and discuss the role and importance of different policy measures. In order to facilitate this discussion ,

we have made an overview of the most important growth generating factors and how these have been influenced by policy measures in Table 6.1.

In Cambridge, public policy has been of less importance in terms of direct influence on development. Instead development has been characterised by indigenous resources and their dynamics. In particular, the role of Cambridge University has been important, both as an attractive knowledge base that has served to attract a number of leading companies and scientists to the area, as well as an important source of spin-offs of new firms and the development of institutions to facilitate the development of high-technology firms.

However, behind this development one can identify the impact of national policies, for instance in terms of a well-developed university structure, and national strategies for R&D, which have been important as a basis for current development. But the clue to this development has been local actors and their ability to take initiatives and organise adequate activities and institutions at the local level.

Local planning authorities have also played an important role, initially by representing a barrier to development, and later by allocating more land for industrial purposes, but still with significant restrictions. However, restrictive planning policies have been an important precondition in order to retain the qualities of the Cambridge area that make this area such an attractive place to live.

In Dublin, the growth of the ICT cluster may mainly be explained by the large number of international companies which have found Ireland an attractive location for specific types of industrial activity. However, this would probably not have happened unless it had been stimulated by national policy, which, by combining significant tax incentives and a high level of investment in physical infrastructure and human capital, succeeded in making the country attractive as a location for high tech industrial activity. EU membership and substantial EU funding have been important preconditions. In recent years, there has been a significant shift in policy in order to increase indigenous development and innovation.

The development of the high-tech cluster in Sophia Antipolis is an example of a technology policy initiated by the state with an intended regional goal. Through strict planning regulations and by relocating prestigious state research institutes, an attractive infrastructure for a high-tech milieu has developed. However, this development could not have taken place without local initiatives; in this case one individual, a community entrepreneur, has played a crucial role. Furthermore, the attractive location of the area has been important, not least because a well developed infrastructure (airport) serves the region.

In all three cases, public policy has played a role, although this role has been weaker in Cambridge. It is, however, important to keep in mind that successful development in these regions has also depended on other factors. It is for instance less likely that the French technopole strategy would have been successful if implemented in the UK or Ireland.

As Table 6.1 shows, direct policy interventions are similar in the three regions, in the sense that there are many similar strategies and programs that have been implemented. However, the mix of elements and the degree to which central and local authorities have been directly involved, has varied. It is, for instance, interesting to note that 'soft' infrastructure like networks, business clubs and other arenas in which entrepreneurs and business people can meet, are less developed in Dublin.

Table 6.1: The role of policy in Cambridge, Dublin and Sophia Antipolis.

Main factors of growth	Policy measures	Policy roles and impacts
Cambridge		
<ul style="list-style-type: none"> • Cambridge University and its scientific quality • Cambridge University Science Parks • Spin-offs from the University • Spin-offs from large firms • Key entrepreneurs • Culture for innovation • Attractive location and proximity to London 	<p><i>Funds:</i> No initiatives only directed towards high-tech firms, but Cambridge firms can obtain support for R&D and soft investments through national and European funds</p> <p><i>Facilitating agencies and organisations:</i> Some organisations like the Business Link programme provide one stop shop for business support and counselling. A range of business clubs provide opportunities for informal discussions and networks.-</p> <p><i>Technology transfer organisations:</i> Industry and liaison office promotes and reinforces contacts between Cambridge University and industry.</p> <p><i>Science parks/innovation centres:</i> Cambridge Science Park and St Johns Innovation centre have been important. Both initiated by Cambridge University Colleges.</p> <p><i>Venture Capital:</i> Various seed capital funds, venture funds and a networks of business angels.</p> <p><i>Planning/infrastructure:</i> Cambridge is restricted to tight planning controls that restrict further development.</p>	<p>Public policy is perceived to have little direct importance for the development of the high-tech cluster in Cambridge.</p> <p>Public sector has played an important indirect role as financiers of the university and also as founder of a CAD centre (computer aided design)</p>
Dublin		
<ul style="list-style-type: none"> • EU membership • Human capital • Multinational companies • Tax incentive • Infrastructure • Attractive location inside EU for mainly US based companies 	<p><i>Tax incentives.</i> Favourable tax schemes in order to attract multinational companies, later incentives for private investments in new start-ups</p> <p><i>Funds:</i> Funding is available through European, national and regional sources. Special initiative to support high potential start-ups</p> <p><i>Facilitating agencies and organisations:</i> Enterprise Ireland (main offices and regional offices) and local development agencies (Enterprise boards), several industrial parks.</p> <p><i>Technology transfer organisations:</i> Programs in advanced technology (PAT), University Industry Programmes</p> <p><i>Innovation centres:</i> Several small innovation centres developed over the last few years</p> <p><i>Planning/infrastructure.</i> Substantial investments in telecommunication and transport infrastructure, partly financed by EU funds.</p>	<p>Public policy has played an important role in attracting MNE to Ireland. Some evidence of increased indigenous development of high-tech industries.</p> <p>General positive political environment towards business development.</p>

Sophia Antipolis

- Attractive location
- Science park
- Key community entrepreneur
- International companies
- Large national companies
- National research institutes
- Infrastructure, proximity to Nice International Airport

Funds: Funds for SMEs available through European, national and regional sources. Few direct initiatives to high-technology firms. Support is given to research and innovation

Facilitating agencies and organisations: *Chambre de Commerce de la Cote D'Azur* was established in 1996 to help start-ups with access to the various types of public funding. Local business clubs

Science park: International science park of Sophia Antipolis – established in order to provide attractive location of high-tech firms (part of the French technopolis programme)

Planning/infrastructure: Partly a greenfield site developed under strict planning regulations in order to create an attractive international environment for high-tech firms

Decentralisation: Larger state owned companies and national research institutes have established research departments in the Sophia Antipolis science park

Public policy has been very important; based on a combination of centrally based technopole strategy and local planning initiatives to design a large science park.

6.4 The role of policy in the cases of Oslo and Trondheim

Not surprisingly, many of the same policy elements as in the previous cases have been of importance in facilitating high-tech development in Oslo and Trondheim.

The policy field most important to development, is in the area of research and higher education. To take the latter first, universities and other institutions of higher education have played pivotal roles in Oslo as well as Trondheim: in Trondheim, the University of Science and Technology; in Oslo primarily the University of Oslo. R&D policy has also been important, particularly in the case of Oslo where most of the major national research institutions are localised. As discussed in the presentation of Oslo, these institutions have deliberately been concentrated in the three core areas of Gaustadbekkdalen, Kjeller and Ås. Trondheim has also been favoured through national research policies, in particular through the development of SINTEF which has worked in close interaction with the University of Science and Technology.

National policy has also played a major role in the next step of development, i.e. the evolution of various institutions and programs for commercialisation and technology transfer. Virtually all funding of science parks, innovation centres and other schemes is obtained directly or indirectly from the central government. Local and regional authorities have played minor roles. Science parks, however, have been developed in cooperation between local and regional government and higher education institutions, research institutions and private actors. The state has played a role through SIVA.

As Norwegian policy measures are in line with what has been implemented other places, an explanation for the relatively poor performance of Norwegian high-technology industries may not be found in the policy instruments per se, but rather in the strength and priorities given to these policy fields. Over the last few decades, the main driving force in the Norwegian economy has been the oil sector, and the main policy focus has also been on this sector. As briefly commented on in the cases of Oslo and Trondheim, this development has partly diverted R&D focus from other industrial sectors, in particular the high-tech sectors. Furthermore, expansion in the oil sector has had a profound impact on the rest of the economy, and contributed to making it less competitive internationally.

Although the main causal relationships are not straightforward, the situation around policy and high-technology industrial development in Norway may be characterised by the following three tendencies; 1) policy measures have been implemented later and to a lesser extent than in the leading European clusters, 2) the industrial environment has turned out to be less

dynamic and less likely to generate synergies in interaction with the institutional structure, and 3) the main focus of Norwegian industrial policy has been on rural areas, rather than growing urban areas.

Regarding the first point, although Oslo and Trondheim now have a rich flora of institutions for research and mediation between R&D and industry, initiatives for developing this structure were taken fairly late, compared to other places. For instance, while visions and plans for Sophia Antipolis were developed around 1970, and the Cambridge Science Parks were established in 1974, initiatives for the predecessors of Oslo Science Park were not taken until 1985, and the Park was first in place in 1990. Similarly, SINVENT in Trondheim was not started until 1985. Furthermore, most of the other initiatives for setting up innovation centres and incubators and related programs for commercialisation, were taken during the late 1990s. Also, awareness of the vital role of risk capital developed late, and institutions for providing risk capital were not in place until the second half of the 1990s. There is still a long way to go before an adequate financial infrastructure is in a position to provide, in particular, seed money and early stage risk capital.

Regarding the second point, there is a general problem of little industrial dynamism and less entrepreneurial capacity in Norwegian high-tech industries. In particular, Trondheim has suffered from a poor industrial environment around the academic institutions, and there has been less synergy due to this. Multinational companies are virtually absent in Trondheim, and there are relatively few large national companies. Opportunities for creating spin-off firms have been limited.

The situation in Oslo may be characterized in similar terms, although the industrial environment is much richer. Multinational and large national companies are present in the capital city, but as discussed earlier, their activities are biased towards service and distribution, rather than R&D.

In general, neither Trondheim nor Oslo seems to be an attractive location for international companies to set up R&D related activities in order to take advantage of the local knowledge base.³⁹ With the exception of the IT Fornebu project, this problem has hardly been addressed in the political arena.⁴⁰

³⁹ According to a survey from 2001, Oslo is ranked at the bottom of a list of 50 European cities as the least attractive city for investments. Source: *Dagens Næringsliv* 28 Sept 2001. The ranking was determined through an analysis based on statistical indicators, by Jones Lang LaSalle. The first cities on the list were Paris, Dublin, Helsinki and London.

⁴⁰ IT Fornebu is discussed in the final sections of this chapter.

The third point reflects a traditional focus on rural development in Norway. The purpose of policies implemented has been to slow down the growth of the cities in an attempt to stop the flow of people from the countryside into the larger cities, rather than stimulating further growth in urban areas. An illustration of this is, for instance, that the national incubator programme first and foremost is an incentive to develop rural economic activity.

6.5 High-tech firms and the role of policy

We will now turn to the issue of how high-tech firms perceive the importance of different factors relevant to policy. The data presented in the following are obtained from the survey presented in chapter 5. First, we will look at how firms assess the importance of other local actors. Data are compared for firms located in Oslo and Trondheim, cf. Figure 6.1.

As illustrated in the figure, customers are by far the most important local actors to be in contact with, followed by suppliers, business colleagues, businesses in related industries and universities and R&D institutions. It should be noticed that the data reflect local contacts, i.e. actors located in the region with whom it is important to have contact. On the whole, firms in Oslo perceive local contacts as more important than do firms in Trondheim, probably because the local business environment in Oslo is much richer than in Trondheim. However, there is one important exception to this, i.e. university contacts. A significantly higher share of high-tech firms in Trondheim regard the University as an important local actor than do their counterparts in Oslo. This may reflect the fact that the University in Trondheim has traditionally had strong links with SINTEF, and that a significant number of high-tech firms in Trondheim started as spin-offs from SINTEF or the University.

Regarding policy implications, it should be noted that local contact with venture capital, private investors, public agencies and local authorities is regarded as relatively less important. This may be an indication that these actors do not play an important role in the local environment.

Concerning bottlenecks to future development, access to highly educated labour is ranked first (Figure 6.2). More than 50 per cent of all companies report that a lack of highly educated labour will be the most important barrier to future development.

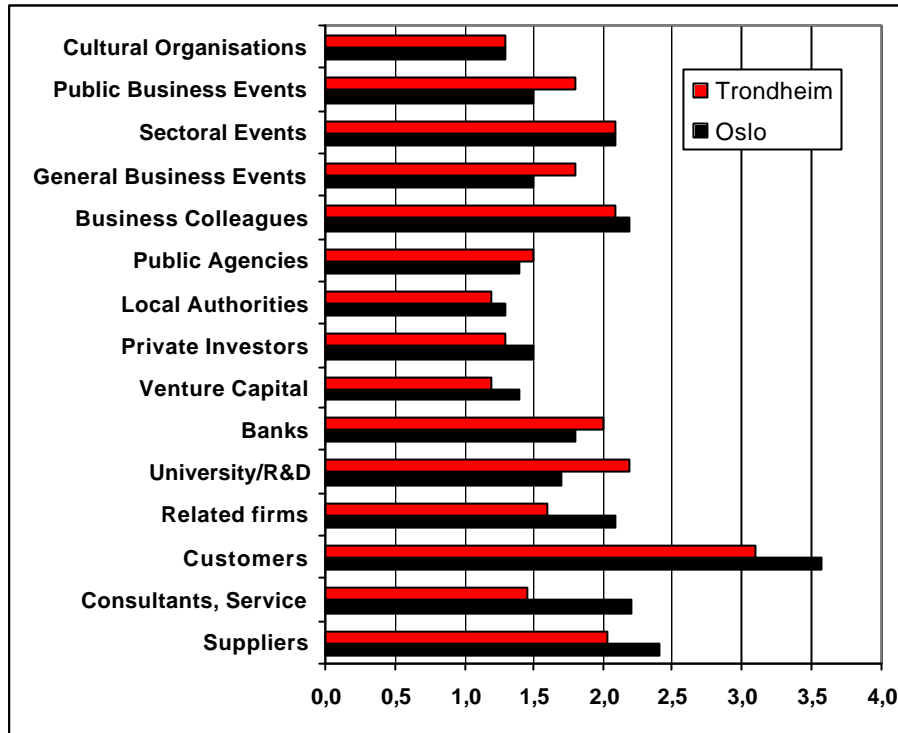


Figure 6.1: Importance of local actors for high-tech firms in Oslo and Trondheim
 1= Not important, 4= Very important

Given the importance of employees with higher education, this result is not very surprising. In this context, however, it is noteworthy that access to R&D services is not regarded as an important bottleneck. This might, of course, imply that the firms in question regard the R&D services available as sufficient for their future development. Many high-tech firms are also part of international networks, and are therefore not dependent on local R&D services. This result may also imply that many high-tech firms do not take advantage of R&D services in general.

The second most important factor is risk capital. Approximately 25 percent of the firms surveyed think that a lack of risk capital will be a hindrance to future development. The insignificance given to the importance of contacts with local capital providers (cf. Figure 6.1), may be surprising. However, it may also be understood as an indicator that the venture capital function is not well developed in Norway

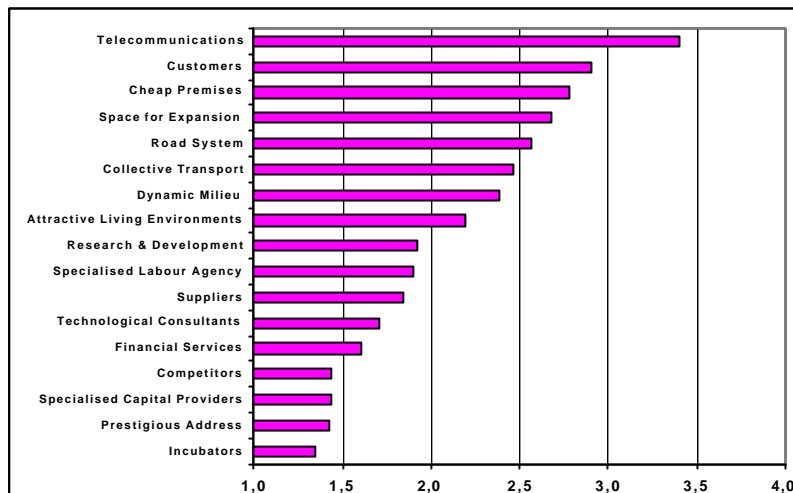


Figure 6.2 Perceived bottleneck to future development for high-tech firms in Oslo and Trondheim

Furthermore, it is noteworthy that hard infrastructure is given more emphasis for future development than soft infrastructure. 15 per cent of the companies have listed lack of public support as a bottleneck to future development.

In order to develop a further understanding of the importance of various factors, the firms surveyed were asked what factors they would consider as important if they were to relocate. As shown in Figure 6.3, telecommunications are regarded as the most important factor, while proximity to important customers and access to cheap premises were the second and third most important factors. Therefore, it seems like a well-developed infrastructure is more important than access to innovation resources such as universities and R&D institutions.

It is also interesting to note the importance of cheap premises. This may be explained by the fact that many of the firms are new and cannot afford expensive facilities. However, in terms of policy implications, it is interesting that high-tech firms do not perceive location in an incubator as important.

On the whole, our results show little variation between firms in Oslo and Trondheim, however, the importance of being part of a dynamic milieu is ranked as more important to the Trondheim firms than their counterparts in Oslo. This may reflect that more firms in Oslo already regard themselves as part of a dynamic milieu than do firms in Trondheim.

When considering these results, it is important to keep in mind that only 28 percent of the firms surveyed had concrete relocation plans. Among these, a significant majority planned to move within the region, while only a fraction were considering moving abroad.

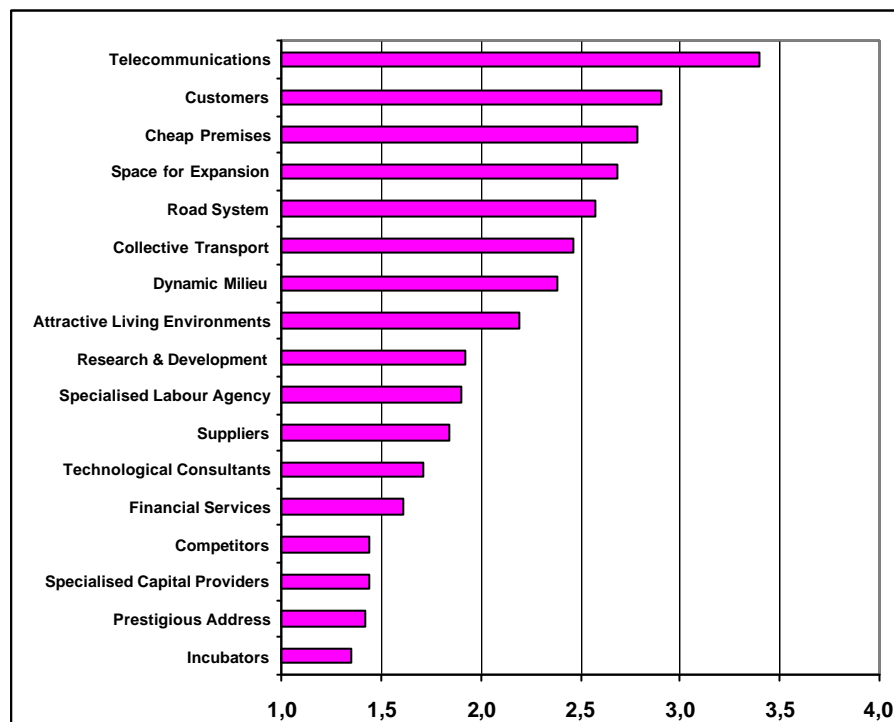


Figure 6.3: Factors of importance if relocating

1 = not important, 4= very important

One of the striking results from the survey is the firms' indication that universities and R&D institutions are of little importance to their development. The majority do not regard these institutions as important local partners; they are not seen as bottlenecks for future development; and they are not considered in the case of relocation. The university is, however, important as provider of qualified graduates to high-tech firms, an issue left unexamined by this study.

It may, then, be queried whether these kinds of institutions are less important to the evolution of high-technology clusters in Norway than various theoretical and empirical studies of high-tech growth and development suggest. In both Cambridge and Sophia Antipolis the importance of the knowledge infrastructure as a driver of growth is generally acknowledged. How-

ever, in both Cambridge and Sophia Antipolis other factors such as key entrepreneurs and an attractive location were given importance. In Cambridge the development of local networks and a collective regional learning capacity (Keeble et al 1998) have been additional growth factors. In Dublin, on the other hand, universities and research institutes are not regarded as important for the growth of high-tech firms, illustrating the possibilities of developing high-tech industry without strong links to university and research institutes. As discussed in chapter three, this has had important implications for the structure of the high-tech industry in Dublin; the long-term sustainability of the Irish strategy is uncertain.

In the case of Oslo and Trondheim, the survey results reflect the dominant structure of high-tech industries. As discussed earlier in this report, this structure does not include a large number of R&D-based businesses, but rather companies within distribution, consultancy and data processing. These types of firms do not require close contact with universities or research institutes.

Although the inherent structural weakness of high-tech firms in Norway is generally recognised, the data examined in this study may underestimate the extent to which there are contacts or links between industry and the university and R&D sector in general. We have four observations to make regarding this. First, knowledge accumulated in research institutions and universities may be diffused through spin-offs, and when the spin-offs are realised, it may no longer be necessary to maintain contacts. Second, links to academic institutions may be even more indirect as the commercialisation of academic knowledge may go through several stages of firm formation and processes of sequential entrepreneurship, as demonstrated in the Oslonett case in Chapter 5. Third, links between academic institutions and the business community may be maintained through alumni employed by the firm. Fourth, different forms of informal contact between R&D institutions and industry may be upheld through, for instance, personal networks, articles or seminars. Thus, it is not easy to make a total assessment of the interface between academic institutions and the business community. But this should not be an excuse for not searching for greater potential for spin-offs from the academic milieus in Oslo and Trondheim.

The role of risk capital seems important to firms in Oslo and Trondheim, even if the results give a mixed picture. Although the lack of risk capital is regarded as an important bottleneck for future development, venture capitalists are not regarded as important local actors or as a reason for relocating. Evidence from the other three regions confirms the relatively minor importance of venture capital compared to other factors. In Cambridge

the role of previous entrepreneurs as financiers of new start-ups has been of some importance, but venture capital is not regarded as the main factor behind development in any of the three regions. In terms of policy implications, and as discussed in previous sections, the success of venture capital is dependent on the ability of the venture capitalists to provide additional benefits to the entrepreneurs.

According to the survey, it is important for high-tech firms in Oslo and Trondheim to be part of a dynamic milieu, possibly reflecting the importance of the regional collective learning capacity as suggested by theoretical approaches. Proximity to the most important actors in the innovation process, such as customers and suppliers eases communication and enhances shared learning. The importance and advantages of being part of a dynamic milieu is also identified as an important factor for the development of the high-tech cluster in Cambridge. Through a wide range of business networks and clubs, informal discussions are facilitated. Furthermore, the mobility of employees and many new start-ups and spin-offs contribute to the transfer and diffusion of embedded knowledge in the region (Keeble et al 1999).

Provision of physical infrastructure is also rated as important for high-tech firms, which is also confirmed by other studies. In Cambridge and Dublin congestion problems are regarded as a threat to further development, nevertheless, proximity to airports and major cities is seen as advantageous in both Cambridge and Sophia Antipolis.

6.6 Policy implications

The main impediment to high-tech development in Oslo as well as Trondheim is quite simple; it is the absence of leading international industry combined with little focus on commercialisation in leading university departments and research institutes. Partly, this is the result of a national policy which does not focus sufficiently on developing the knowledge base for future industrial development. It is also the result of a weak culture for commercialisation and mediation between academia and industry. Furthermore, it is the result of a weak industrial culture which has not been able to demonstrate sufficient dynamics and legitimise stronger emphasis on high-tech related initiatives and priorities.

Norway lags far behind the other Nordic countries in R&D investments,⁴¹ and is significantly below the OECD average. Admittedly, R&D

⁴¹ In 2001, Norway spent 1.6% of GDP on R&D activities, while Sweden spent 4.3%, Finland 3.4%, Denmark 2.4% and Iceland 3.0%.

policy measures face complicated issues related to operationalisation, yet it seems reasonable to conclude that over the last few decades, strengthening the knowledge base has not been the primary concern of any Norwegian government. Despite acknowledgement of the importance of research for industrial development, R&D and innovation budgets have repeatedly been among the first budgetary expenditures cut by the Government in attempts to balance the budget. The present Government has announced that R&D investment in Norway should reach the OECD average by 2005⁴². Thus far, the Government has taken interesting initiatives to expand public R&D budgets and stimulate private actors to increase their research and innovation activities. The Prime Minister has also signalled that an integrated national plan for innovation will be put into effect. However, it remains to be seen to what extent this will be persistent policy, and not just temporary rhetoric.

A discussion of policy implications may take place along the following lines:

- 6) Strengthen the knowledge base
- 7) Strengthen the capacity for commercialisation
- 8) Develop more research-based industrial activity

And, as local organisation is crucial for implementing policy, two more points should be added:

- 9) Develop regional organisation(s) that can facilitate information and communication between actors and provide the necessary regionally based initiatives
- 10) Develop appropriate physical infrastructure.

Strengthen the knowledge base

A solid knowledge base is imperative for development. As we have seen, particularly in the case of Cambridge, a high quality academic environment with open links to industry may serve as an important driving force for high-tech industrial development. In Cambridge as well as Sophia Antipolis, the strength of the local knowledge base has been important for attracting international companies to the area.

⁴² Prime Minister Bondevik in his inaugural speech to the Parliament 23 October 2001: 'The government will gradually increase Norwegian research efforts to at least the average OECD level by 2005. A significant part of the growth will go to basic research. Tax incentives will be offered to companies for research and development.'

In the case of Oslo and Trondheim, and more generally Norway, internationally leading research groups seem to be missing; neither Oslo nor Trondheim has demonstrated sufficient quality to attract multinational companies to the area. As discussed earlier, the majority of multinational companies in Oslo are there for other reasons than taking advantage of the local knowledge base; for the most part, they are present to exploit market opportunities.

In order to strengthen the knowledge base there are no alternatives to expanding national R&D budgets, stimulating and building research centres of excellence, and ensuring a good mix of basic and applied research. Furthermore, priority should be given to specialised fields in which Norway either has, or may develop, competitive advantage. R&D efforts should be concentrated in programs and research centres that are capable of taking a lead internationally. The new programme for centres of excellence is therefore a promising start. Of 13 centres, 6 were placed in Oslo and 4 in Trondheim.

As demonstrated in the case of Cambridge, it is important that these research activities be organised with open links to, and in interaction with, relevant industries. However, one should also be aware of possible lock-in effects, i.e. one should not be restrained by current industrial structures and allow influential companies to set the agenda. It is important to keep in mind that in the long run, 'new' industries and companies yet to come will be the most important target groups for the future industrial implementation of the knowledge base.

Strengthen the capacity for commercialisation

One main reason, perhaps the most important, for Norway's poor performance in the field of high-technology, is the inability to commercialise research. From the perspective of high-technology evolution, the culture for entrepreneurship is limited, particularly in the sense that relatively few entrepreneurs are able to develop companies with potential for high growth.

In particular, the disparity between Oslo and Trondheim, on the one hand, and Cambridge on the other, is related to spin-offs effects. Over the years, an impressive number of new companies have spun out of, directly or indirectly, Cambridge University (Segal, Quince and Wickstead 1985)

Entrepreneurial culture and the capacity for commercialisation is embedded in localised factors, and it is not easy to replicate such a culture of innovation among scientists. A number of strategies have to be implemented.

First, universities and other institutions of higher education should become more entrepreneurial, i.e. students should be offered programs in en-

trepreneurship, and stimulated in other ways to consider a potential future career as an entrepreneur, as an alternative to traditional careers as employees in large firms or the public sector. In particular this applies to students in science, engineering and business economics. However, there is hardly a discipline which does not provide opportunities for commercial activity, so there should be optional programs for students in all disciplines. Entrepreneurship programs, business contests (like, for instance, Venture Cup) and on campus incubation facilities for students may be important instruments to stimulate entrepreneurial attitudes and behaviour.

Second, R&D institutions, i.e. university departments as well as independent research institutes, should develop clear policies of commercialisation and entrepreneurship by implementing mechanisms that identify all potential opportunities for commercialisation and explore these opportunities in a systematic way. Developing systems for handling intellectual property rights (IPR) is an important part of this. With regard to this, the Norwegian Parliament has recently passed a law that gives universities the rights of commercial exploitation of results obtained from research. Interesting processes are underway at all four Norwegian universities to implement this by organising, for instance, industry liaison offices and developing systems for surveillance and testing commercial opportunities. It remains to be seen what kind of organisational solutions will be chosen, for instance, whether they will be in the form of in-house functions or organised externally in collaboration with a science park or an innovation centre.

Third, more capable institutions and programs for mediating and brokering between the institutional knowledge base and industry should be developed. As mentioned earlier, a number of institutions have developed in Norway recently, including science parks, innovation centres and incubators. Various programs for stimulating technology transfer and contact between knowledge institutions and industry have also been organised. The issue of how this structure should be organised in the future, is related to quantitative capacity as well as quality. Regarding quantity, programs for funding science parks and innovation centres (i.e. FORNY and related programs) are too limited and should be expanded. Regarding quality, serious questions may be raised regarding segments of this new structure. It is important to undertake evaluations and benchmarking in order to improve the operation and further development of this institutional structure.

Fourth, the risk capital function needs to be developed. Partly, this is about cultivating the venture capital market, which may be characterised as immature. More importantly, it involves developing funding mechanisms for

early stage development, i.e. seed capital funding, in which public funding as well as informal investors and business angels are important.

Survey results indicate that high-tech firms do not view venture capitalists as important actors in the innovation process, nevertheless, lack of risk capital is rated as an important bottleneck for future development. However, evidence from other high-tech regions shows that the kind of actors that provide capital makes an impact. In Silicon Valley, and to a certain extent in Cambridge, risk capital for start-ups has been provided by local business angels willing to invest on the long-term, and able to provide valuable advice and access to strategic networks. It seems likely that risk capital provided by institutions without the same 'hands on' approach is not as conducive to the success and development of viable high-tech firms. Norway has a long way to go in this area.

Research based companies

We have commented on the small share of research-based companies in the Norwegian high-tech structure. There are, in relative terms, few companies with R&D activity, and few companies in close contact with R&D institutions. In Cambridge the number of entrepreneurs with a background from either a university or research institute is almost twice as high as in Oslo and Trondheim. The need for more research-based companies and increased cooperation between research institutions and industry in Norway is obvious. However, as stated in a white paper submitted by the Ministry of Industry and Trade, 'firms evolve, they are not decided'.⁴³

However, successful strategies along the lines indicated above, will contribute to development in the right direction. Strengthening the capacity of commercialisations, spin-offs from academic institutions and the research units of private companies will increase the number of research-based companies. If necessary, procedures for recruiting and selecting new business ideas, should be biased towards research-based ideas.⁴⁴

Furthermore, the minor relevance of universities and research institutes to small high-tech firms may be explained by limited opportunities for small firms to finance and utilize research, compared to larger firms. An issue for further analysis might therefore be to find policy measures which will stimulate interaction between small firms and research institutions, as well as between small firms and large firms.

⁴³ Government White Paper on Industrial Development, St. meld. nr 41, 1997-98.

⁴⁴ There are indications that little business passing through the current system of innovation centers and incubators is research-based.

Another way to develop the knowledge base of a cluster, is related to the ability to attract the research activities of multinational companies. A successful strategy of developing centres of excellence may, in conjunction with other measures, contribute to making Oslo and Trondheim more attractive for foreign investments.

The IT Fornebu project represents the only serious attempt to address the issue of cluster formation in Norway, but thus far it has not been successful. There may be many reasons for this, one obvious reason is timing, i.e. the project was finally realised during a downturn in the ICT sector.

However, the idea of developing a new centre in a greenfield area like Fornebu may have been flawed at the outset. Although Fornebu lies just outside Oslo, there are strong indications that even closer proximity is necessary for actors in a cluster to obtain synergies, i.e. 'next door' or 'on campus' localities. As shown on the maps (Figure 4.3 and 4.4) of Oslo, high-tech sub-clusters have developed in different parts of the city. A better location for the new centre would most likely have been in Gaustabekkdalen, providing close proximity to the university campus and its research centres. The IT Fornebu initiative has been met with great scepticism in the ICT community of Oslo. These prejudices will not be easily overcome even though IT Fornebu is part of a national network of science parks and innovation centres, and formal agreements on collaboration with the University of Oslo and the research institutes in Gaustabekkdalen have been made.

Local organisation

As discussed earlier in this report, successful development of a cluster is heavily dependent on local preconditions and the ability of local actors to take adequate initiatives and develop appropriate organisational structures. In order to improve the situation in Norway, it is therefore necessary to take different approaches in Oslo and Trondheim. Policy measures should meet the specific challenges in the respective region, and local actors are instrumental in this respect.

Regional policies are best developed by persons with proximity to the region, not least in order to identify key persons of importance for development. Both in the case of Cambridge and Sophia Antipolis, specific individuals have played central roles. If possible, such persons should be stimulated and supported. However, in order to develop policy measures designed for the specific challenges in each region, it is necessary to undertake a more thorough analysis of the most relevant bottlenecks in the two regions.

In the case of Oslo, the RITTS programme at the University of Oslo, has been instrumental in identifying future policy issues, not least in order to create a common regional understanding of opportunities and threats for future development. To a large initiatives stemming from the University have been about creating industry specific arenas and improving networks, and developing consensus on future strategies. Small budgets for industrial development have impeded the implementation of policy measures of any financial significance.

Adequate infrastructure

Our survey of high-tech firms in Oslo and Trondheim illustrates the importance of a well-developed physical infrastructure. Although this was not perceived as a very serious bottleneck for the future development of the companies participating in the survey, provision of an adequate infrastructure should be a clear priority of central government as well as local authorities. A clear policy implication, therefore, is to provide a well-developed telecommunications and transport infrastructure. Furthermore, land should be allocated for further industrial development, preferably centrally located. Likewise office facilities should be made available to allow for expansion in current companies. In particular, office facilities for new companies at reasonable prices, may be important. Easy access to an airport, with direct connections to the most important strategic gateways in the world also seems to be of great importance.

Literature

- Aldrich, H. (1999). *Organizations evolving*. London, Thousand Oaks, New Dehli, Sage Publications.
- Andersen, E. S. (1994). *Evolutionary Economics. Post-Schumpeterian contributions*. London and New York, Pinter Publisher.
- Asheim, B. T. (1992). Flexible Specialisation, Industrial Districts and Small Firms: A Critical Appraisal. In H. Ernste and V. Meier (eds.) *Regional Development and Contemporary Industrial Response. Extending Flexible Specialisation*. London, Bellhaven Press: 45-63.
- Asheim, B. T. (1996). Industrial districts as 'learning regions': a condition for prosperity. *European Planning Studies*. 4(4): 379-400.
- Asheim, B. T. (1998). Learning regions as development coalitions: partnership as governance in European workfare states. Second European Urban and Regional Studies Conference on "Culture, place and space in contemporary Europe", Durham, UK.
- Asheim, B. T. (2001). Localised learning, innovation and regional clusters. In Å. Mariussen (ed.) *Cluster Policies - Cluster Development?* Stockholm, Nordregio: 39-58.
- Autio, E. (1995). Four types of innovators: a conceptual and empirical study of new, technology-based companies as innovators. *Entrepreneurship & Regional Development*. 7(3): 233-248.
- Bakkevig, M. K., C. Salter and E. W. Jakobsen (2002). Now Boarding! Ufordringer i utviklingen av et høyteknologisk kunnskapsmiljø på Fornebu, Norwegian School of Management BI.
- Bahrami, H. and S. Evans (1995). Flexible re-cycling and high-technology entrepreneurship. *California Management Review*. 37(3): 62-89.
- Becattini, G. (1990). The Marshallian industrial district as a socio-economic notion. In F. Pyke, G. Becattini and W. Sengenberger (eds.) *Industrial Districts and Inter-Firms Co-operation in Italy*. Geneva, ILO: 37-51.
- Bergman, E. M., D. Charles, et al. (2001). In pursuit of innovative clusters. In OECD (ed.) *Innovative clusters. Drivers of national innovation systems*. Paris, OECD: 7-15.
- Bernasconi, M. (2002). The innovation system of Sophia Antipolis. Presentation, CERAM Sophia Antipolis, May.
- Braczyk, H.-J., P. Cooke, et al. (eds.) (1998). *Regional Innovation Systems*. London, UCL Press.
- Brusco, S. (1986). Small Firms and Industrial Districts: The Experience of Italy. In D. Keeble and E. Wever eds. *New Firms and Regional Development in Europe*. London, Croom Helm: 184-202.
- Brusco, S. (1990). The idea of the Industrial District: Its genesis. In F. Pyke, G. Becattini and W. Sengenberger eds. *Industrial Districts and Inter-Firms Co-operation in Italy*. Geneva, ILO: 10-19.

- Butchart, R. L. (1987). A new UK definition of the high technology industries. *Economic Trends*(400): 82-88.
- Camagni R. and R. Capello (2000) The role of inter-SME networking and links in innovative high-technology milieux. In D. Keeble and F. Wilkinson (eds.) *High-technology clusters, networking and collective learning in Europe*. Aldershot, Ashgate.
- Capello, R. (1999). Spatial transfer of knowledge in high technology milieu: learning versus collective learning processes. *Regional Studies*. 33(4): 353-365.
- Carlsson, B., S. Jacobsson, et al. (2002). Innovation systems: analytical and methodological issues. *Research Policy* 31: 233-245.
- CEBR (2001). Seed Capital in the Nordic Countries: Best Practice. A report prepared for the Nordic Industrial Fund. Centre for Economic and Business Research, Copenhagen
- Cooke, P. (1998). Introduction. In H. J. Braczyk, P. Cooke and M. Heidenreich (eds.) *Regional Innovation Systems*. London, UCL Press: 2-25.
- Cooke, P. (2001). Clusters as key determinants of economic growth. In Å. Mariussen (Ed.) *Cluster Policies - Cluster Development?* Stockholm, Nordregio: 23-38.
- Dahlstrand, Å. L. (2000). Large firm acquisitions, spin-offs and links in the development of regional clusters of technology-intensive SMEs. In D. Keeble and F. Wilkinson (eds.) *High-technology clusters, networking and collective learning in Europe*. Aldershot, Ashgate: 156-181.
- Dalum, B., B. Johnsen and B. Å. Lundvall (1992). Public Policy in the Learning Society. In B. Å. Lundvall (ed.) *National systems of innovation. Towards a theory of innovation and interactive learning*. London, Pinter Publisher: 296-317.
- den Hertog, P., E. M. Bergman and C. David (2001). Creating and sustaining innovative clusters: Towards a synthesis. In OECD (ed.) *Innovative clusters. Drivers of national innovation systems*. Paris, OECD: 405-419.
- Dublin City Development Board (2001) Dublin City Profile, prepared by the National Institute for Regional and Spatial Analysis (NIRSA) on behalf of Dublin City Development Board
- Dublin City Enterprise Board (1996) Action Plan, Strategic Business Plan 1997-199. Dublin.
- Edquist, C. (1997). Systems of innovation approaches - their emergence and characteristics. In C. Edquist Ed. *Systems of innovation. Technologies, institutions and organizations*. London and Washington, Pinter: 1-35.
- Eikeland S. and J. Johansen (2000). Regional utvikling på 1990-tallet Oppsummering av 'klassiske analyser' Prosjektrapport 2000:15. NIBR, Oslo.
- Eliasson, G. (2000). The role of knowledge in economic growth. Stockholm, KTH.

- Ervervsfremme Styrelsen (2001). Kompetenceklynger i dansk erhvervsliv - en ny brikke i erhvervspolitikken. København.
- European Observatory for SMEs. (1997). *Fifth annual report: European Network for SME Research*.
- Fjeldstad, Ø. D., E. Andersen and M.B. Viken (2000). Verdiskaping og internasjonal konkurransedyktighet i norsk IKT sektor. Norwegian School of Management BI.
- Garnsey, E. (1994). Employment implications of science-based industry; a regional case study from Cambridgeshire, UK. In J. Massey and J. Harrison (eds) (1994) *Employment, growth and SMEs*. Plasley
- Garnsey, E. (1998) Proximity and Complexity in the emergence of High-technology Industry; The Oxbridge Comparison, *Geoforum*.
- Garnsey, E. and A. Cannon-Brookes (1993). The 'Cambridge Phenomenon' revisited: aggregated change among Cambridge high-technology companies since 1985. *Entrepreneurship and regional developmen*. **5**: 179-207.
- Garnsey and Lawton-Smith (1998) The evolution of high tech industry in Cambridge and Oxford, *Geoforum*.
- Garofoli, G. (1984). Regional Development and small firms: The Italian Pattern of the 70's. XXIV European Congress of the Regional Science Association, Milan.
- Grimes, S. (1999). The Information Society in Ireland - a late developer catches the wave. Paper presented at the European Regional Science Association Conference, University College Dublin, August.
- Gunnigle, P. and D. McGuire (2001). Why Ireland? A qualitative Review of the Factors Influencing the Location of US Multinationals in Ireland with Particular Reference to the Impact of Labour Issues, *The Economic and Social Review*, 32 (1): 43-67
- Hertog, P. d., E. M. Bergman and D. Charles (2001). Creating and sustaining innovative clusters: Towards a synthesis. In OECD (ed). *Innovative clusters. Drivers of national innovation systems*. Paris, OECD: 405-419.
- Hodgson, B. and M. Lacave (1995). Oslo Research Park Evaluation Study. Final report, Segal Quince Wicksteed Ltd and Ismeri Europe srl.
- Industrial-Policy-review-group. (1992). A time for change: Industrial policy for the 1990s. Dublin.
- Isaksen, A. (2001). Regional clusters between local and non-local relations. A comparative European study, Paper prepared for the IGU Conference on "Local Development: Issues of Competition, Collaboration and Territoriality", Turin July 2001.
- Johnstad, T. (2003). Kunnskapsbyen Oslo. Forskningstiangelet rundt Blindern og Universitetet i Oslo. Oslo, NIBR.

- Keeble, D. (1988). High-technology industry and local environments in the United Kingdom. In P. Aydalot and D. Keeble (ed). *High-technology industry and innovative environments: The European experience*. London and New York, Routledge: 65-98.
- Keeble, D (1989) High-technology Industry and Regional Development in Britain: the Case of the Cambridge Phenomenon. *Environment and Planning C: Government and Policy*, 1989, 7: 153-172
- Keeble, D. (1994). Regional influences and policy in new technology-based firm creation and growth. In R. Oakey (ed.). *New technology-based firms in the 1990s*. London, Paul Chapman: 204-218.
- Keeble, D. and A. Gould (1985). Entrepreneurship and manufacturing firm formation in rural regions: the East Anglian case. In M. J. Healey and B W. Ilberg eds. *The Industrialization of the Countryside*. Geo Books, Norwich: 197-220
- Keeble, D. and F. Wilkinson (1999). Collective learning and knowledge development in the evolution of regional clusters of high technology SMEs in Europe. *Regional Studies*. **33**(4): 295-303.
- Keeble, D. and F. Wilkinson (2000). High-technology SMEs, regional clustering and collective learning: an overview. In D. Keeble and F. Wilkinson (eds.) *High-technology clusters, networking and collective learning in Europe*. Aldershot, Ashgate.
- Keeble, D. and T. Kelly (1986). New firms and high-technology industry in the United Kingdom: the case of computer electronics. In D. Keeble and E. Wewe eds. *New firms and regional development in Europe*. Croom Helm, Beckenham, Kent, pp 75-104.
- Keeble, D. et al. (1999). Collective learning processes, networking and 'institutional thickness' in the Cambridge region. *Regional Studies*. **33**(4): 319-332.
- Keeble, D., C. Lawson et al. (1998). Internationalisation processes, networking and local embeddedness in technology-intensive small firms. *Small Business Economics*. **11**(4): 327-342.
- Kuijper, J. and H. van den Stappen (1999). Clusters and clustering: genesis, evolution and results. In R. Oakey, W. Doring and S.-M. Mokhtar Ed. *New technology-based firms in the 1990s*. London, Paul Chapman: 105:121.
- Lawson, C. and E. Lorenz (1999). Collective learning, tacit knowledge and regional innovative capacity. *Regional Studies*. **33**(4): 305-317.
- Longhi, C. (1999). Networks, collective learning and technology development in innovative high technology regions: the case of Sophia-Antipolis. *Regional Studies*. **33**(4): 333-342.
- Longhi, C. and D. Keeble (2000). High-technology clusters and evolutionary trends in the 1990s. In D. Keeble and F. Wilkinson (eds.) *High-technology clusters, networking and collective learning in Europe*. Aldershot, Ashgate: 21-56.

- Loveman, G. and W. Sengenberger (1991). The Re-emergence of Small-Scale Production: An International Comparison. *Small Business Economics*. **3**: 1-37.
- Lundvall, B. A. (ed.) (1992). *National systems of innovation: Towards a theory of innovation and interactive learning*. London: Pinter.
- Malinen, P. (2001). Assisting Potential Fast Growth SMEs - Case Dublin Business Innovation Centre. Turku School of Economics and Business administration - Business research and development centre.
- Maillat, D. (1995). Territorial dynamic, innovative milieus and regional policy. *Entrepreneurship and Regional Development*. **7**(2): 157-165.
- Maillat, D. (1998). Innovative milieus and new generations of regional policies. *Entrepreneurship and Regional Development*. **10**(1): 1-16.
- McKelvey, M. (1997). Using evolutionary theory to define systems of innovation. In C. Edquist (ed). *Systems of innovation. Technologies, institutions and organizations*. London and Washington: 200-222.
- Metcalfe, J. S. (2000). Restless capitalism, experimental economies. In W. Daring, R. Oakey and M. Kipling (eds.) *New Technology-Based Firms at the Turn of the Century*. Amsterdam, Pergamon: 4-16.
- Ministry-of-Finance (1999). *National development plan 2000-2006*. Dublin.
- Moen, E. (2002) Globaliseringen og industripolitiske strategier. En sammenligning av Finland og Norge. Makt- og demokratiutredningen 1998-2003. Oslo.
- Murray G.C., (1998) A policy response to Regional Disparities in the Supply of Risk Capital to New Technology-based firms in the European Union: The European Seed Capital Fund Scheme. *Regional Studies* **32**(5): 405-419.
- Nelson, R. R. (ed.) (1993). *National innovation systems: a comparative analysis*. Oxford: Oxford University Press.
- Nelson, R. (1995) Recent evolutionary theorizing about economic change. *Journal of Economic Literature*, **33**, March, 48-90.
- NVCA Norwegian Venture Capital Association (2001). Activity in the Norwegian VC-market 2001. Oslo.
- Oakey, R. P. (1999). United Kingdom high-technology small firms in theory and practice: a review of recent trends. *International Small Business Journal*. **17**(2): 48-64.
- OECD (1999). *Boosting innovation: The cluster approach*. Paris, OECD.
- OECD (2001). *Innovative clusters. Drivers of national innovation systems*. Paris, OECD.
- O'Gormann, C. (2001). *Role of the public policy in 'seeding' new high-tech enterprise in Dublin*. Paper presented at the European Small Business Seminar, Dublin.
- O'Riain, S. (1997a). The Birth of a Celtic Tiger. *International perspectives*, **40**(3), 11-16.

- O'Riain, S. (1997b). An offshore Silicon Valley? The Emerging Irish Software Industry. *Competition and Change*.
- Piore, M. J. and C. F. Sabel (1984). *The Second Industrial Divide*. New York, Basic Books.
- Porter, M. E. (1990). *The Competitive Advantage of Nations*. London, Macmillan Press.
- Porter, M. E. (1998a). Clusters and the new economics of competition. *Harvard Business Review* (November-December): 77-91.
- Porter, M. E. (1998b). *On competition*. Boston, Harvard Business School Press.
- Pouder, R. and C. H. StJohn (1996). Hot spots and blind spots: Geographical clusters of firms and innovation. *Academy of Management* 21(4).
- Pyke, F., G. Becattini, et al., eds. (1990). *Industrial Districts and Inter-Firms Co-operation in Italy*. Geneva, ILO.
- Remoe, S. O. (2000). Towards a knowledge based industrial policy - lessons from OECD. Paper presented at the seminar "Mot en regionalisert næringspolitikk", Oslo, June.
- Reve, T. and E. W. Jakobsen (2001). *Et verdiskapende Norge. (The value creating Norway.)* Oslo, Universitetsforlaget.
- RITTS (2000) Summary report; Oslo business region 2000.
- Roelandt, T. J. A. and P. den Hertog (1999). Cluster analysis and cluster-based policy making in OECD countries: An introduction to the theme. In OECD Ed. *Boosting innovation: The cluster approach*. Paris, OECD: 9-23.
- Saxenian, A. (1989). The Cheshire cat's grin: innovation, regional development and the Cambridge case. *Economy and Society* 18(4): 448-477.
- Schumpeter, J. A. (1934, 1996). *The theory of economic development*. London, Transaction Books.
- Schumpeter, J. A. (1943, 1996). *Capitalism, socialism and democracy*. London and New York, Routledge.
- Segal Quince Wicksteed (1990/1985). The Cambridge Phenomenon. The growth of high technology industry in a university town. Cambridge, Segal Quince Wicksteed Limited.
- Segal Quince Wicksteed (1998) Evaluation of Cambridge Science Park and St John's Innovation Centre.
- Segal Quince Wicksteed (2000). The Cambridge Phenomenon Revisited. Cambridge, Segal Quince Wicksteed Limited.
- Sengenberger, W., G. W. Loveman, et al., (eds.) (1991). *The re-emergence of small enterprises. Industrial restructuring in industrialised countries*. Geneva, ILO.
- Simmie, J. (2001). Innovation and agglomeration theory. In J. Simmie (ed.) *Innovative Cities*. London and New York, Spon Press.
- Sogner, K.(2002) En liten brikke i et stort spill. *Den norske It-industrien fra krise til vekst 1975-2000*. Fagbokforlaget

- Spilling, O.R. (2000) SMB 2000 – fakta om små og mellomstore bedrifter i Norge, Fagbokforlaget
- Steinsli, J. and O.R. Spilling (2002). On cluster evolution and the role of small firms: The case of internet development in Norway. Paper prepared for the 12th Nordic Research Conference on Small Business, Kuopio, Finland, May.
- Steinsli, J. and O.R. Spilling (2000). On the role of high technology small firms in cluster evolution. Paper prepared for the Tenth Annual High Technology Small Firms Conference, Enschede, The Netherlands, June.
- Storper, M. (1995). The resurgence of regional economies, ten years later: the region as a nexus of untraded interdependencies. *European Urban and Regional Studies* 2(3): 191-221.
- Strategic Management Institute – SMI (2001). Sophia Antipolis - Creation of a Greenfield Cluster. Stockholm.
- Travers, J. (1999). Case study: Dublin, Ireland The role of information technology in attracting foreign investment, creating industrial zones and developing human resources. Paper presented at the World Competitive Cities Congress at the World Bank, Washington D.C, May.
- Verspagen, B. (2000). Economic growth and technological change. An evolutionary interpretation, Eindhoven Centre for Innovation Studies (ECIS) NS Maastricht Economic Research Institute of Innovation and Technology (MERIT).
- Waagø S. et al. (2001). The Role of the University in Economic Development: NTNU GREI - Gruppen for entreprenørskap og innovasjon, Trondheim.

Appendix

Questionnaire for survey on small high-tech firms
(in Norwegian)