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THE DEVELOPMENT PERSPECTIVES FOR THE ICT SECTOR IN NORTH JUTLAND

Christian Østergaard Richter Pedersen

PhD Thesis - February 2005

Department of Business Studies, Aalborg University

Preface

In July 2001 I started as a PhD student at the IKE Group at Aalborg University partly financed by the Digital North Denmark policy programme. I joined Aalborg University's participatory research group who was to carry out research in relation to this programme. I have benefited from this context, but it has also affected the content and size of this thesis.

The writing of this thesis has in many respects depended on help and support from, and interaction with many people. Firstly, I want to thank Bent Dalum for inspiring and good supervision during my period as a PhD student. Secondly, I would like to thank Bent Dalum, Gert Villumsen, and especially Michael Dahl for many talks, discussions, and co-authoring of papers that have resulted in (forthcoming) publications in journals, such as Research Policy, Journal of Engineering and Technology Management, European Urban and Regional Studies, and several book chapters. However, this would not have been possible without the learning and supportive environment of the IKE group. I have benefited greatly from interaction with members of this group. The IKE group and the DRUID conferences have provided an international research training ground for me and given me the opportunity to present my work, receive valuable feedback, and meet other researchers with similar interests.

During the years as a PhD student I have experienced personal development, been travelling, and participated actively in the international research community, e.g. through the ETIC doctoral courses in Maastricth and Strasbourg, the ESSID summer school at Corsica, my visit at Haas School of Business at Berkeley, the CCC colloquium in Atlanta, the EU-TSER project TENIA, and more importantly my six-month stay at SPRU at University of Sussex in Brighton in 2003. A special thanks to my friends at SPRU.

I also wish to thank the participants at my pre-defence December 17th 2004 for valuable comments that added to my frustrations, but definitely improved the final thesis.

Many thanks to Lars Anderson, Nils Østbjerg, and the rest of the IT staff for providing good IT support, and to the IKE secretaries Dorte Køster and Jeanette Hvarregaard for helping me with many practicalities that have hindered my work.

Finally, I want to thank Lena and my family for supporting and encouraging me in writing this thesis, and during my many travels.

Christian Østergaard Richter Pedersen

Aalborg, February 2005

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Chapter 1

Introduction

Introduction

The rapid growth and increasing economic importance of the information and communication technology (ICT) sector during the 1990s has made it an often-studied subject in various fields of economics and economic geography. Geographical agglomerations of ICT firms have been analysed as regional clusters (e.g. Saxenian, 1994), and used in the discussion of whether or not geography matters (e.g. Morgan, 2001). Clusters of firms within the ICT sector have also become a concern for public policy. Especially successful clusters such as Silicon Valley, the Cambridge Phenomenon, Oulu, and Kista, have inspired policy makers to formulate cluster policies focusing on the ICT sector.

The ICT sector in North Jutland has also experienced high growth during the 1990s. The region has traditionally been characterised as a less favoured region with an unemployment rate among the highest in Denmark and an industry structure dominated by more traditional industries. However, the region is also home of a wireless communication cluster, NorCOM. It originates back to the early 1960s when the company S.P. Radio successfully switched from being a consumer electronics producer for the domestic market to radio telephones for small ships. An important trigger for further industrial development was the foundation of Aalborg University (AAU) in 1974. During the last three decades the cluster grew and expanded into other wireless communication technologies, such as mobile communication. The cluster became very successful and accounted for a main share of the total ICT employment in the region in the late 1990s. Most of the cluster firms were very research and development (R&D) intensive, owned by foreign firms, or R&D subsidiaries of well-known multinational companies.

The localisation of a successful high-tech cluster with several multinational firms in a peripheral region like North Jutland attracted a lot of attention.

The attention came especially from policy makers at both the local and national level. A frequent question was: How is it possible to develop a high-tech cluster and be on the technological forefront, in particular, in mobile communication technology in North Jutland? Subsequently it also raised other questions about how to broaden the cluster and improve it, or if the region should focus on developing different industries? These questions became unexpectedly present, when North Jutland was chosen to be a part a national ICT policy programme, the Digital Denmark. The cluster was one of the main reasons for choosing North Jutland.

In 1999 the Danish government had formulated a national policy for the conversion from an information society to a network society. A part of this strategy was to further strengthen

regions with an already proven ICT capability. Therefore North Jutland was chosen to become an IT-Lighthouse that should be a cornerstone of the network society and light up and show the way for the rest of Denmark (Dybkjær and Lindegaard, 1999).

The policy programme, however, faced some tension in the formulation of a goal: *Could* the successful process of clustering be copied and the programme be used to develop other parts of the ICT sector, or *should* it be used to promote development broadly in the region?

The programme in North Jutland, the Digital North Denmark (DDN), was to be a large-scale experiment based on project-offers running from 2000 to 2003. In addition an independent participatory research group consisting of university researchers from Aalborg University was to carry out research in relation to the DDN. The present PhD thesis is a part of this participatory research. The purpose of the thesis is hence to analyse the development perspectives for the ICT sector in North Jutland. However, clusters and the process of clustering are integral in these.

In 2001 when I started on this thesis, the ICT sector in North Jutland was facing the crisis in ICT with downsizing and a few firms had closed down, but the sector was still characterised by the high growth in the 1990s. The main share of the total employment was concentrated in the NorCOM cluster firms, while the IT service and software segment was relatively smaller compared to the large cities of Copenhagen and Aarhus. This segment had a branch structure with the headquarters located outside the region. Two large companies dominated the structure of this segment, KMD with 850 employees and Nykredit Data with 200 employees. Added to this were a couple of medium sized IT service companies focusing on software of logistic solutions and a range of smaller IT companies of which many were branches of national or international companies. There were also a smaller group of firms specialised in printed circuit boards employing from 600 to 1,000 employees, a few consumer electronics manufactures, and a group of medico electronics companies that was closely related to university research. In the region was also a science park, NOVI, and more importantly Aalborg University. The university had several research groups within ICT technologies and had a large production of MSc graduates in engineering and computer science. [1]

A cluster of wireless communication firms and a range of more dispersed activities characterises the structure of ICT sector in North Jutland. The cluster is the main employer and is internationally visible, while the remaining segments are fragmented and mainly directed towards the home market. The cluster has both positive and negative effects on the ICT sector. Its technological strength positively attracts resources in terms of financial funds and human capital. Thereby sustaining a knowledge base in the region from which variety might emerge. Low geographical labour mobility, spinoffs and knowledge spillovers are key

[1] For a detailed analysis see NOVI (2002) or Pedersen (2001).

features. However, it also occupies many of the available resources and raises wages. This structure depicts two different development trajectories that can be influenced by policies: Further development of the already working NorCOM cluster or to focus more efforts on segments that have not reached a size and development stage as the cluster, but have some firms and a knowledge base in the region, such as the IT service and software firms, the printed circuit board firms, the medico electronics firm, and the biomedical research competence. This thesis focuses on development of the cluster. In addition the role of clustering in policy is important. The DDN policy could have played an important role for the development of the ICT sector in North Jutland by supporting user-producer interaction and engaging in field experiments and research that could provide some insights in future demand and technological development paths.

1 Cluster theory

Since the early 1990s, the literature on the importance of geography for economic development has been revitalised. The discussion of why particular economic activities tend to cluster spatially has attracted a lot of attention from various research fields of economics, economic geography, and sociology. The vast amount of case studies has proven that clustering is a quite frequent economic phenomenon (widely cited in this thesis). In addition the historical accounts for clusters have shown that it is an old phenomenon and recent research have shown that the evolution of new industries also may lead to clusters. For a review of the literature see Baptista (1998), Brenner (2004), Dahl (2003), Martin (1999), Martin and Sunley (2003), and Moulaert and Sekia (2003).

1.1 Cluster definition

The literature on clusters uses a wide variety of definitions and concepts, such as clusters, agglomerations, (Italian) industrial districts, innovative milieux, innovative clusters, local industrial clusters, industrial clusters, regional clusters, high/low-tech clusters, and localised clusters etc. Brenner (2004) argues that the existence of the many different concepts is due to the large variety of schools within economics and sociology. These concepts are shaped according to the schools' particular focus on various aspects and mechanisms in clusters, such as trust and culture in Italian industrial districts and interactive learning in localised clusters[2]. Martin and Sunley (2003) has surveyed the wide array of cluster definitions applied in the literature more recently. The cluster concept appears to be very elastic and imprecise in academic as well as is policy circles.

[2] The lack of a common definition is commented by Enright: "*Cluster' terminology seems so embedded that one despairs of redefining or sharply defining the term*" (Enright, 2000, p. 327)

Especially the empirical studies stretch the cluster definition, since it is often based on existing classifications of economic activity and administrative geographical borders. However, the results of these studies depend on the classification of industries and division of space into regions, which creates noise (see critique by Breschi and Lissoni (2001; 2001) and Brenner (2004)). This is especially a problem when the data gets too aggregated.

Recent work by Bresnahan and Gambardella (2004) contains international comparisons of clusters as well analyses of their characteristics over time. There are, however, some inherent problems in their levels of aggregation. Silicon Valley is compared with India, Taiwan, Ireland, Israel, and wireless communications in Scandinavia, which by the way contains a series of distinct regional clusters in this field[3]. A more precise definition or at least set of principles for delimitation of clusters appear to be somehow missing in much of the cluster literature, as also emphasised by Maskell (2001). Here Porter (1998) provides one of the most operational approaches:

> "*Clusters are geographic concentrations of interconnected companies, specialised suppliers, service providers, firms in related industries, and associated institutions in a particular field, linked by commonalities and complementarities*." (Porter, 1998, p.199)

It is important how precisely these commonalities and complementarities are conceived and defined. Drawing the boundaries of the cluster is quite difficult. Porter argues that drawing cluster boundaries is a creative process and these depend on the strength of linkages and spillovers[4]. However, when he applies the cluster definition the geographical scope varies and becomes less consistent.

The concept of clusters should not be used on the national level, but rather for regional or geographically delimited concentrations of firms in a given location. Such firms have three common factors, which qualify them for this label: (i) they are coherent, that is, their activities evolve around limited segments of large industries; (ii) they have a common technological knowledge base in a similarly limited area of these industries; (iii) They have a common pool of labour experienced in the specific technology, market and industry segment

[3] The lack of consistency in geographical delimitation principle raises problems about their conclusions in the transmission mechanism for the importance of geographical proximity in the evolution of clusters.

[4] Porter writes:
"*Drawing cluster boundaries is often a matter of degree, and involves a creative process informed by understanding the most important linkages and complementarities across industries and institutions to competition. The strength of these "spillovers" and their importance to productivity and innovation determine the ultimate borders*" (Porter, 1998 p. 202)

in question. Furthermore interactions within the firm population could be added, but these are mainly needed to create a strong self-augmenting process[5].

The present thesis is focused on high technology based regional clusters. For obvious reasons this is inspired by studies of some of the archetype examples, such as Silicon Valley, Boston Route 128, the Cambridge Phenomenon, etc. but does not aim at being a survey of the studies of these. It concentrates on a small cluster, focused on common technological knowledge base, wireless communications technologies - concentrated geographically in a small region, that of North Jutland, Denmark. This narrow focus makes it possible to study detailed interactions in a precisely defined regional cluster.

1.2 Regional clustering - main causes

Alfred Marshall (1920) observed that firms within the same industry often continue to successfully cluster in particular localities. He was among the first to provide rather detailed descriptions of the sources for the concentration of specialised industries in particular localities.

> *"Nearly all important knowledge has long deep roots stretching downwards to distant times; and so widely spread have been these roots, so ready to send up shoots of vigorous life, that there is perhaps no part of the old world in which there might not long ago have flourished many beautiful and highly skilled industries, if their growth had been favoured by the character of the people, and by their social and political institutions (…) So great are the advantages, which people following the same skilled trade get from near neighbourhood to one another. The mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them unconsciously." (Marshall, 1920, pp. 270-271)*

Analyses of the main causes of clustering have started many theoretical discussions. Inside the economics profession Krugman (1991; 1995) has engaged in a 'crusade' aiming at integrating the spatial dimension into mainstream economic theory. From the classical work of Marshall (1920), Krugman (1991) derives three kinds of externality that are important for clustering: (i) economies of specialisation caused by a concentration of firms being able to

[5] Enright (2000) uses the following terms to describe the various development stages of a cluster: *Working clusters* where the cluster has a critical mass of firms, labour, knowledge etc. that initiate self-augmenting processes. *Latent clusters* that has a critical mass of firms, but needs local interaction to start self-augmenting processes. *Potential clusters* that has the potential of becoming a working cluster. It has a few elements, but lacks size, breath, depth, and local interactions. *Wishful thinking clusters* are not a stage in cluster development, but mainly a policy driven cluster or idea. It could develop into a cluster, but do not have the elements to become a working cluster.

attract and support specialised suppliers, (ii) economies of labour pooling, where the existence of a labour force with particular knowledge and skills attracts firms, which in turn attract and create more specialised labour, and (iii) technological externalities or knowledge spillover (LKS), where knowledge and information flow more easily between actors located in a cluster than over long distances. Krugman (1991) dismissed the role of LKS by claiming that although they may exist in some high-tech industries, they are not an important force for agglomeration. Instead, the focus should be directed towards more measurable externalities, such as economies of specialisation and labour pooling. Krugman's claims caused a comprehensive, but rather hostile reaction from the community of economic geographers during the 1990s, surveyed by Martin and Sunley (1996) and Martin (1999), and among other scholars, as illustrated by the critical quotations in Jaffe et al. (1993) and Audretsch and Feldman (1996).

LKS has been a key point in the disagreement between new economic geography powered by Krugman and economic geography. The latter group of literature claims that empirical studies of the geography of innovation provide clear evidence that LKS plays an important role in the evolution of clusters. Thus the explanation for the geographical concentration of innovative activities is that knowledge developed in a cluster flows more easily within it, but more slowly outside and across its borders. Informal networks of contacts is to emerge between individuals across firm boundaries, and act as channels of knowledge flow. However, these studies have been criticised by Breschi and Lissoni (2001), who argues that the concept of LKS is no more than a 'black-box' with ambiguous content.

The sociology literature provides additional insight on identifying the social structures and interactions that contribute to the diffusion of knowledge in clusters. Earlier theoretical contributions argue that knowledge is diffused through informal contacts (Allen and Cohen, 1969). Agents specialise within social networks and integrate via ties of different strength across social networks (Ingram and Roberts, 2000). The networks allow the agents to acquire non-redundant information from different groups. These agents are argued to be central in providing the organisation with new and unique information (Granovetter, 1973; Burt, 2004). There is, however, a tradeoff between cohesion in the social network and non-redundancy, usefulness, reliability and firm-specificity of the knowledge (Løvås and Sorenson, 2004). Across firms, agents provide each other with advice and solutions to problems, but not all social contacts are used to diffuse knowledge. But some times they disclose even valuable firm-specific knowledge with future favours in mind despite the fact that it could be an initial disadvantage to the firm.

Another cause behind co-localisation of firms is the reduction of transaction costs. When users and producers are located near each other, negotiations and monitoring become less costly. This is especially true when communication is based on personal contacts. One important finding in innovation studies is, that the central part of the required knowledge is

difficult to codify and therefore close interaction among actors is important in the innovation process (Lundvall, 1992; Lundvall and Johnson, 1994). Trust also has a geographical dimension; it based on cultural similarities and familiarity with transactions partners (Piore and Sabel, 1984; Pyke et al., 1990). Other researchers have found that geographical concentration of firms attracts sophisticated buyers from the outside (Oakey, 1985; Russo, 1985). These buyers often provide insights concerning advanced demand features. Other demand and supply side effects can be added, such as sophisticated local demand, access to resources or special infrastructure (Porter, 1998; Enright, 2001). Rather sophisticated support and service activities like venture capital, experienced entrepreneurial and managerial knowledge and science parks may also be important for start-ups and subsequent cluster evolution.

The innovation systems literature (Lundvall, 1992) emphasise close proximity between production and related innovation. Innovative activity is often based on tacit knowledge that may require face-to-face contact among development engineers. Innovation is also often an experimental process where researchers achieve new knowledge from the production process and use this in laboratories. Therefore, innovative activity has a tendency to cluster in the same areas as where production is localised[6].

A recent string of literature on the evolution of industries has pointed at importance of entry and pre-entry organisational capabilities. Klepper (2002) analyses the evolution of the U.S. automobile industry and Detroit as its capital. He finds that the geographic concentration of the industry is attributed to the success of four early entrants around Detroit, who in turn spawned a large number of successful firms in the Detroit area that together dominated the industry. Thus spinoffs and pre-entry experiences have proven to potentially be very important for the survival and performance of the new firms. Since these are more likely to be confined in geographical space then these could be a possible explanation for the emergence and evolution of regional clusters. The phenomenon of the most successful entrants having 'inherited' significant amounts of experience from existing firms implies that entrepreneurial activity has a considerable geographical aspect, since the majority of entrepreneurs may tend to found their new firms in close proximity to their previous employers (Sorenson, 2003). The local 'production' of new entrepreneurs, thus, plays a vital role for regional development. New jobs are not only created in incumbent firms but indeed also by the formation of new employers through localised spinoff mechanisms.

Numerous case studies of clusters have found various explanations for the emergence clusters usually linked to some kind of event such as the founding of a firm. Some of these explanations are quite colourful, very unique, and dates far back in time. Van der Linde and

[6] See also Audretsch and Feldman (1996), who analyses the relation between industry life cycles and the tendency to spatially cluster in production and innovation activity in the US.

Porter have recently engaged in tracking the determinants for the emergence of several clusters[7]. The analysis is based on Porters (1990; 1998) diamond model: Factor (input) conditions, context for strategy and rivalry, related and supporting industries, demand conditions, and other (chance and government). They find that many of the clusters dates centuries back in time, such as a cluster that emerged more than three hundred years ago when the French King on a journey stopped an bought some bread. The problem with tracing back to the initial event that started a process that leads to clustering is that the explanation becomes colourful and the causality blurred[8]. Then the emergence of a particular cluster becomes very unique and very hard to generalise without adding some anecdotical story of a founder's personal preferences, luck, and 'foresightedness'. It seems that the specificity of cause for the initial event should be given less weight. Therefore historical and chance events, and path dependency holds some explanation for the evolution of clusters.

The initial activity is often seen as being located in a particular geographical location by chance. Arthur (1990) highlights the claims of Engländer (1926) and Palander (1935) that historical and chance events would have provided a location structure; and that inherited structure combined with agglomeration tendencies would determine the future settlements in a region. New industries will be laid down layer by layer upon inherited structures through the phases of development. In an evolutionary perspective, agglomeration can be interpreted as the mechanism by which existing organisations will breed the new ones founded by entrepreneurs.[9] New firms in a region will mainly emerge from the existing ones as spinoffs. The immobility of labour as a result of social and economic forces will induce entrepreneurs to locate close to their origins, so they can maintain their social ties and continue exploiting their localised knowledge. As a result, the quality of the new organisations and the future development potential in a region at a given time, will be a function of the quality of the stock of existing firms and past entrants (Klepper, 2003). This is in line with Romanelli and Schoonhoven (2001), who argue that most new firms will be founded in the same geographical region, or very close to it, as that of the firm that produced the entrepreneur. Only few entrepreneurs will be attracted to another region because of available technical and market expertise and other resources. Entrepreneurs will more typically be produced within the region itself by existing organisations. This means that a region's future will be closely determined by its present structure and profile.

[7] The first results from their cluster meta-study was presented by Claas van der Linde at the International Workshop on Innovation Clusters and Interregional Competition at Kiel Institute of World Economics November 12-13, 2001. See also van der Linde (2003).

[8] Likewise the aggregation level is varying from within a city to across national borders and the size from less than 5,000 jobs to more than 30,000 jobs. These differences makes is hard to generalise from their conclusions.

[9] Arthur (1994) have argued that similar organisations with a somehow different background and from other regions will be attracted by the growing presence of activities. This tradition goes back to Weber (1928).

Evolution of clusters is also closely linked to the development in cluster's technology base. New disruptive technologies may initiate the emergence of new regional industrial clusters or create opportunities for further development of existing ones. They may, however, also result in stagnation and decline. The term disruptive refers to such significant changes in the basic technologies that may change the industrial landscape (Storper and Walker, 1989; Utterback, 1994; Christensen, 1997). For detailed analysis of clusters in electronics, the theories of technological life cycles seems fit because a given cluster often experiences the passing of several life cycles. It is the capability of a cluster to adapt to these continuous 'bombardments' of new technologies, which is the core field of the study. Saxenian's (1994) account of the history of Silicon Valley is closely related to the emergence of radical new technologies, as is her analysis of how the Route 128 region got stuck in one, at the time highly successful, technology – i.e. minicomputers. Two new technological life cycles (Unix based 'workstation' computers and the PC) were at the heart of the Silicon Valley resurgence in the 1980s, when the Boston area, according to Saxenian, was left behind in the computer industry.

1.3 Cluster dimensions

Clusters may differ along various dimensions. Enright (2001) has proposed a series of dimensions, which are condensed to six below. By definition *geography* itself is central. Some regional clusters are highly localised, others more dispersed.

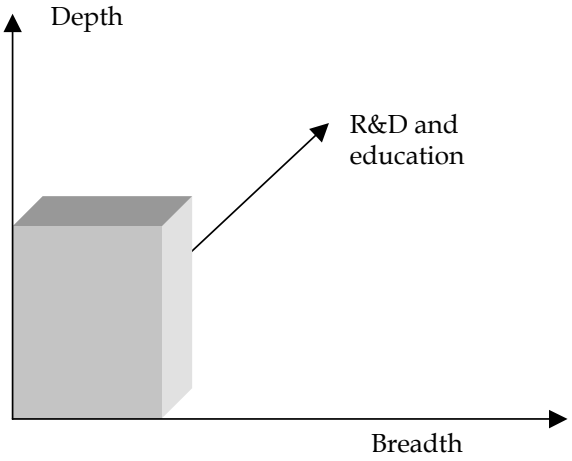
Another central dimension is *depth*, which refers to the range of vertically related industries within the cluster. A deep cluster contains an almost complete supply chain, whereas a shallow cluster relies on inputs from outside the region. The horizontal dimension is important, too. Horizontally related industries are sharing common technologies, end users, distribution channels and other non-vertical relationships. A cluster is said to be broad if it consists of several horizontally related industries. *Breadth* of a cluster will normally be a sign of strength. Externalities related to a pool of skilled labour are important. Maskell (2001) and Kenny (2002) stress the importance of experimenting and testing different technological paths in concentrations of horizontally related firms. By co-locating firms learn from each other's failures and successes and are able to monitor, discuss and compare alternative solutions.[10] Thereby they participate in a continuous learning process by watching competition, compare different solutions, select, differentiate, imitate and add own ideas. And some of the horizontally divided industries may have opportunities to avoid temporary decline of markets. From a cluster point of view the risks are spread in a broader cluster.

[10] In discussing the importance of context in shaping the U.S. Internet industry Kenny (2002) argues that the start-ups in Silicon Valley benefited from the knowledge gained from the concentration of previous start-up attempts and advanced customers.

The vertical (depth) and the horizontal dimensions (breadth) constitute the potential strength of the cluster. However, the dynamics of both depth and breadth can be further enhanced by appropriate knowledge organisations. Of special importance is the presence of *university R&D and education* supporting different industries on the horizontal as well as the vertical axis in Figure 1. It is e.g. a potential weakness if local research activities are limited to only one part of the value chain. Or if important parts on the horizontal axis are not matched locally by appropriately educated engineers.

The three dimensions shown in Figure 1 may be said to represent the activity base of a given cluster. But it may not only be the mere existence of activities along each of the axes that may be of importance but also their *density*. Dense clusters consisting of a large number of firms, some of which may be large, may have a higher probability of success than more 'sparse' ones. Likewise the *size* of the cluster also varies from very large clusters to small clusters.

Figure 1 Characteristics of a regional high-tech cluster



A final dimension to be taken into account is the *ownership structure*. The role of multinational companies is a critical factor. The literature on regional clusters has arguments for both positive and negative effects of multinationals. On the one hand they can fill holes in the local knowledge base and support the firms in the region with financial resources in high-risk development activities. Likewise they may have high promotional value and thereby strengthen the image of the cluster. On the other hand, the presence of multinationals (MNC) may weaken the interaction among local actors. The capacities of a cluster may be hampered by MNC acquisitions because it may break up patterns of networking amongst incumbent firms. Another potential negative effect is the lack of decision-making power in the region. This may lead to a loss of market knowledge and make it more vulnerable to strategic decisions not related to local conditions.

The factors fostering initial emergence of a cluster may be very different from those supporting its further growth (Porter, 1998; Enright, 1999; 2001). During cluster evolution

different congestion effects may appear and the internal dynamics of networks and organisations may become less flexible. The stages of cluster evolution are, however, not predetermined, and revitalisation may, or may not, occur.

As described in this section several possible causes for regional clustering exists. The Marshallian externalities (economies of specialisation, economies of labour pooling, and localised knowledge spillovers) and a higher start-up rate (mainly through spinoffs) seem to cover many of the more specific explanations. However, only a few of the theories of clustering aim to present a more general theory. Porter (1998) provides a general framework for cluster analysis by his Diamond model, but still notes that the emergence and evolution of clusters is to be found in the interaction among the four broad attributes of the diamond and the 'other' attribute (chance and government). Likewise he notes that it is not the attributes as a stock that is important, but the change and direction of these. Enright (2001) provides a framework by proposing several dimensions by which a cluster could be analysed. But this is mainly a descriptive way of characterising clusters to understand their potentials and problems in ways that can inform policy and strategy.

Another approach to cluster analysis is presented by Brenner (2004), who analyses the existence, emergence, and evolution of local industrial clusters in Germany. He identifies four main causes for clustering:

1. *Natural resources* – clusters might appear where the necessary natural resources are available (or available more cheaply than other locations).
2. *Close to customers* – clusters might be caused by the necessity to be close to customers.
3. *Statistical reasons* – clusters might be caused by a random effect, where some locations by chance have more firm than average[11]. There is only little interaction between these firms.
4. *Self-augmenting process* – clusters might be caused by forces that make the location of a firm in a particular region more likely once there are other firms in the same industry located in this region.

The latter cause is path dependent, since no regions might be advantageous in the beginning, the location of the first few firms favour some regions, which gradually becomes more attractive for further firms. Various local mechanisms might cause a self-augmenting process. These are related to the entry of firms and the survival of existing firms. The entry occurs through start-ups, establishment of branches and by the movement of from other regions. The survival of existing firms occurs through a competitive advantage because of

[11] This notion was put forward by Ellison and Glaeser (1997) who argued that a random location of an industry across U.S. would result in a non-uniform geographical distribution.

innovations or a decrease in cost (Brenner, 2004). Three kinds of local interactions can be identified: Interaction within the firm population, interaction between the firm population (cluster firms) and another firm population in the region, and interaction between the firm population and local conditions. The character of these interactions is:

- ***Interaction within the firm population*** includes spinoffs where the existing firms act as incubators. The number of spinoffs increases with firm population and spinoffs are mainly founded in close distance to parent firm. Likewise existing firms can assist new startups. Increased innovativeness caused by knowledge flows (spillovers) through: Informal contacts, formal cooperation, mobility of employees, and joint research projects. Interaction within firm population might also lead to reduced costs through cooperating, using a certain resource, or supplier-buyer relations.
- ***Interaction with another firm population in the region*** is related to pairs of industries that depend on each other through user-producer interaction, spillovers or mobility of employees.
- ***Interaction with local conditions*** is a broad category that includes various factors:
    - *Human capital* related to the existence of a skilled labour force that is less intra-regional mobile and tacit vs. codified knowledge.
    - *Local education system and public research* creates human capital outside the firms in the region. Spinoffs from the university and knowledge flows to industry are also important.
    - *Local capital market* is related to availability to venture capital and experienced venture capitalists and specialised banks.
    - *Culture and historical specificities* are agued to be important especially in the literature on Italian industrial districts. It is also related to willingness to diffuse knowledge, mobility, and cooperation.
    - *Local attitudes* are somehow overlapping with local culture and deal with attitudes towards entrepreneurship and willingness to work in certain industries.
    - *Local policy* might affect the emergence of clusters through a variety of direct and indirect effects such as support programs, cheap land prices, infrastructure, and founding and orientation of universities etc.

The self-augmenting process have to be somehow bounded in space and only firms with specific relationships, such as common technology base, spillovers and buyer-supplier relations, might interact in this process. These interactions between firms are bounded in

space, but each type of mechanisms behind the self-augmenting processes might have a different range and a different spatial structure. Likewise the self-augmenting processes holds specific industrial and regional characteristics, which causes differences in the emergence and evolution of clusters (Brenner, 2004).

The framework presented by Brenner is focusing on interactions and the dynamics of the cluster, while Enright is more descriptive, but also analytical by focusing on the dimensions of the entire cluster. In cluster analysis a mix of both is beneficial, because the cluster dimensions are useful in characterising the cluster at a given time, while the processes and interactions are necessary to create an understanding of the emergence and evolution of the cluster, and the relations between the various dimensions of the cluster. The Enright dimensions are applied in the analysis of the wireless communication cluster in Chapter 8 and the focus is on the interactions within the cluster in chapters 5, 6, 7, and 'partly' 8.

The description of the main causes for regional clustering contains a wide variety of explanations. Therefore it seems plausible that the explanation is to be found in a mix of these causes. Many problems relate to that clusters only can be identified ex ante, and there exist no simple solution to the problem of when a group of firms become a cluster. The foundation of the first firm is often a result of chance or historical specificity, but a single firm does not constitute a cluster. The firm brings variety to the existing innovation system. It has to perform well, grow, and survive for a period to create a base for spinoffs (note that better performing firms are more likely to create better performing spinoffs), attract other firms, or shape the human capital in the region. Spinoffs are important in creating additional firms, since the attractiveness of the region for this particular industry might be very small initially. Spinoffs continue to be important for the evolution of the cluster (see Chapter 5)

The common knowledge base of the cluster is important and it gradually evolves within the region. The Marshallian externalities also become important. The firms create specialised labour with particular knowledge and skills, which attracts firms, which in turn attract and create more specialised labour. As additional firms enter the cluster informal networks between individuals across firm boundaries act as channels of knowledge flow (see Chapter 6 and Chapter 7). Mobility of employees within the cluster and interaction among firms is likely to foster social networks and knowledge flows. The process is somehow path dependent since it interacts with the existing innovation system, but it is not deterministic, since the emerging 'cluster' could fail to grow or develop the interactions that initiate and sustain the self-augmenting processes.

It should not be forgotten that the cluster is a part of the national and sectoral innovation systems and dependent on the development in these. For the wireless communication cluster in North Jutland it is interesting that the strength in wireless technologies is not delimited to firms in North Jutland, but also firms in other parts of Denmark have developed successfully, such as the Nokia division in Copenhagen that is an important part of the R&D

in Nokia, and Thrane & Thrane that is among the world leaders in satellite and maritime communication. Thus the Danish strength in wireless communication is based on several firms in several locations.

The development in the underlying knowledge base of the cluster is also important for the evolution of clusters. The technological life cycles can initiate the emergence, create opportunities, or result in stagnation and decline of clusters (see Chapter 8).

Many of the interactions with local conditions and within firm population also have a downside. The development of a cluster in a region can lead to a lock-in situation and the increasing demand in a region for specialised skilled labour subsequently leads to increase in wages and other congestion effects. The knowledge flows through informal contacts and mobility of employees may have negative effects, for example the loss of information to competitors could potentially weaken a firm's performance. Likewise spinoffs may also have a negative effect on the mother firm. These effects have not been treated sufficiently in the above theories and could be subjects for future research on clusters.

Are firms in clusters better performing (innovation, growth, and revenues etc.) than firms outside clusters? This is still an unsolved question in cluster studies. Several attempts have been made to bring forth evidence, but the results are mixed. However, this is not the focus of this thesis, and clusters still continue to exist.

2 Research questions

The purpose of this thesis is to *analyse the development perspectives for the ICT sector in North Jutland*. This main research theme is investigated in nine chapters grouped in three parts. The first part deals with setting the stage by presenting the North Jutland region, the development of the ICT sector in North Jutland, and knowledge flows in the Danish ICT sector. The second part deals with cluster analysis, and Part three is focused on the Digital North Denmark policy programme.

The Danish ICT sector experienced a rapid growth during the 1990s and became increasingly economic important. But even though Denmark is one of the most advanced user nations, measured by conventional indicators for user penetration it is not one of the major players in the international ICT markets, even allowing for country size. The nearby and somewhat similar countries of Sweden, Finland and the Netherlands, are living proof that small countries can be very visible in this field. The role of domestic demand plays an important part in the evolution of industries (Lundvall, 1992; Mowery and Nelson, 1999). It can lead the producers on a development trajectory that could prove to be beneficial and create growth and innovation, but also lure the producers into unfavourable position. One of the prerequisites is close interaction between users and producers. A lack of interaction or less competent users can lead to unsatisfactory innovations, while advanced and competent

users can lead to innovations and a competitive advantage since advanced domestic users tend to demand higher quality goods and thereby forcing the producers to innovate and upgrade. (Lundvall, 1985; 1988; von Hippel, 1988):

Why does Denmark have rather weak supply in terms of production of ICT equipment and services when it also have advanced demand from the Danish consumers, firms, and government agencies?

A recent string of literature on the evolution of industries has pointed towards importance of entry and pre-entry organisational capabilities (Klepper, 2002) Spinoffs and pre-entry experiences have proven to potentially be very important for the survival and performance of the new firms. Since spinoffs (and pre-entry experiences) are more likely to be confined in geographical space then these could be a possible explanation for the emergence and evolution of regional clusters. The existing literature on the NorCOM cluster had provided some evidence on spinoffs by drawing a 'family tree' containing the relation between the founders of new NorCOM firms and the existing cluster firms (Gelsing and Brændgaard, 1988; Dalum, 1993; Dalum, 1995). This lead to the following research question:

Does new firm formation and the organisational background of the founders determine geographical clustering of economic activity?

The existence and importance of localised knowledge spillovers (LKS) and their importance in the emergence and evolution of regional clusters has been a subject of many debates in the literature. Krugman's (1991) contribution to the debate caused a large string of literature investigating LKS and 'proving' its existence and importance. However, these traditional views have been criticised by Breschi and Lissoni (2001), who argue that LKS is a 'black-box' with unclear content. Much of the existing research has analysed LKS by tracing patent citations, interviewing managers or using anecdotical evidence. However, interviews with the managers of the firms cannot reveal completely the extent and importance of informal contacts. The manager then becomes the only representative for matters inside the firm and in relation to the behaviour of the employees. The results are likely to be biased towards the firm's organisational policy and the manager's personal opinion. These limitations in the existing literature lead to the following research question:

What is the extent of informal contacts between engineers in separate organisations in a regional cluster and what is their role as channels of knowledge diffusion?

This debate on knowledge flows through informal contacts relates to discussions in the sociology literature on the social networks of individuals (Allen and Cohen, 1969; Granovetter, 1973; Coleman, 1990; Burt, 2004). The sociology literature provides additional insights to the theoretical discussions in the cluster theory on identifying the social structures and interactions that contribute to the diffusion of knowledge in social networks. This leads to a different investigation of the knowledge flows in the NorCOM cluster, based on the following questions:

To what extent are social networks among R&D engineers carriers of knowledge between firms? What is the relationship between the probability of acquiring knowledge and the various characteristics of the engineers?

The development perspectives for the ICT sector in North Jutland is closely connected to the development perspectives for the NorCOM cluster. Many of the wireless communication cluster firms are working within mobile communication technologies and the development and production of handsets in particular. The evolution of clusters is closely linked to the development in cluster's technology base. New disruptive technologies may initiate the emergence of new clusters, create opportunities for further development of existing ones, or result in stagnation and decline (Storper and Walker, 1989; Utterback, 1994; Christensen, 1997; Porter, 1998). After several years with continuously growth the NorCOM cluster was anticipating a new disruptive technological life cycle based on the third generation of mobile communication technology. The cluster had previously experienced two technological life cycles, and the firms had applied various strategies to move into the next, when the crisis in the ICT sector also hit mobile communication in 2001. This uncertain situation leads to the formulation of the following research question:

How may clusters react on the emergence of new disruptive technologies?

The DDN programme was initiated in 2000 and ended in early 2004. It was organised as project offers within four themes: IT infrastructure, IT industrial development, qualification and education, and digital administration. 90 projects were initiated as a part of DDN. The projects covered a wide variety of topics, such as digitalising the county administration, selling fresh fish over the Internet, remote monitoring cardiac patients, digital democracy, and digital art in schools etc. It also included a few radical change projects such as Digital TV, a Digital Mall, and IT infrastructure. These projects could potentially have an effect on

the ICT sector in the region. The main argument for getting funds for DDN was the cluster. Initially DDN was planned as a programme to promote incremental change in ICT sector, but it was initiated as a radical change project focused on the users.

How was DDN planned and implemented? Why did the profile change?

The overall Digital Denmark programme included two IT Lighthouses: One in North Jutland and one in Copenhagen. The Copenhagen programme was concentrated on construction of a new IT University, a new neighbouring science park, and a new media centre for the public broadcaster, Danmarks Radio. This new concentration of knowledge-based institutions was to be located in Ørestaden near Copenhagen Airport. The Copenhagen IT Lighthouse was narrowly focused on the supply side, while the North Denmark Lighthouse was to be focused on user-producer interaction, but mainly targeted a broad spectre of users. However, the IT lighthouse policies might have an effect on the development perspectives for the Danish ICT sector given the problems of advanced demand, but mediocre supply in the Danish ICT sector, and the technological challenges for the NorCOM cluster. This lead to the following research question:

How may the DDN have long-term consequences for the development perspectives for the regional ICT sector?

3 Outline of the thesis

This thesis consist of three parts. The first part is *setting the stage,* the second part is *cluster analysis*, and the third part is analysis of *the Digital North Denmark*.

Part one is setting the stage. *Chapter 2* analyses the development in the Danish ICT sector from 1992 to 2002, while *Chapter 4* introduces the North Jutland region and analyses the development in the industry structure from 1983 to 2002. These chapters are mainly descriptive and the purpose is to present the context (industry and region), in which this thesis is written.

These chapters are based on detailed geographical employment data from Statistics Denmark. This data, however, only represents a snapshot of the employment at November 1st a given year. Employment specialisation is a convenient measure for analysing the relative employment structure of a region (municipality or county) vis-à-vis the average pattern of the remaining Danish regions Specialisation is the relative share of employment from a given region compared to the national average. If the indicator is above 1.0 the region

has an above-average employment share - i.e. is 'specialised'. This indicator is presented in tables and on maps. However, it has some well-known limitations, since it is a relative measurement. A small region could be specialised with only 100 employees in a particular industry, while a large region needs thousands of employees. Likewise an increasing specialisation could be due to a decline in employment in other regions. Therefore it is necessary to also look at the actual number and shares of total employment in this industry. It is also beneficial to search account databases, provided by information bureaus, to identify the firms in specialised regions[12].

Chapter 3 analyses the paradox of advanced demand and rather mediocre supply in the Danish ICT sector. This is examined by studying the structure, strengths and weaknesses of the industry in Denmark compared to the rest of western Europe and the U.S. The theoretical framework includes theories of innovation systems, lead users, and user-producer interaction. It draws on data from various sources, such as government reports, OECD reports, OECD export statistics, employment data from Statistics Denmark, and consultancy reports.

Part two is cluster analysis. *Chapter 5* investigates the role of spinoffs in the evolution of clusters. It is based on theories on spinoffs, organisational ecology, sociology, and evolutionary theory. The aim is to analyse the dominating forces behind the emergence and growth of the NorCOM cluster using detailed information about the founding events and organisational background of the individual entrants in the cluster. The tracing of founders is based on extensive research of local and national newspaper articles, existing literature, interviews, and informal conversations with founders and other actors[13].

Chapter 6 investigates knowledge flows through informal contacts in a regional cluster. The point of departure is the LKS debate in cluster theory. This chapter examines empirically the role of informal contacts in the NorCOM cluster and whether the engineers actually acquire valuable knowledge through these contacts. It is based on data from a questionnaire survey of the NorCOM cluster. The survey covers more than 350 engineers and computer scientists employed in 19 different firms.

Chapter 7 examines social networks of informal contacts between employees in the NorCOM cluster It includes theories from sociology on the social networks of individuals and theories of the economics of knowledge. The purpose of this chapter is to study the factors, which influence the likelihood that the individual engineer will be an active part of the social networks between the local firms. Furthermore, the likelihood that this engineer

[12] The account data has many limitations that make them less reliable and useful compared to data from Statistics Denmark.

[13] An early version of this chapter was presented at a NorCOM association meeting. The comments from participants at this meeting and readers of the DRUID working paper version have added valuable comments.

receives knowledge, and knowledge of high value more specifically is investigated. The analysis is based on the same data source as Chapter 6.

The final chapter in part two, *Chapter 8*, analyses how regional clusters may react on the emergence of new disruptive technologies. The wireless communication cluster is analysed over an extended time period and two technological life cycles. The theoretical framework includes cluster theory, innovations systems, technological and industry life cycles, and disruptive technologies. Chapter 8 is based on interviews with various actors in the wireless communication industry, desk research and employment data from Statistics Denmark.

Part three is focused on the Digital North Denmark. *Chapter 9* analyses the history, planning, and intended versus realised implementation of DDN. The theoretical framework is based on the notions of radical, incremental, localised, and structural change. These are used to analyse the change from initial profile to the implemented profile, and the change in focus and project types during the period. Chapter 9 is based on participatory research of the projects in the DDN, such as interviews with participants, desk research, and informal conversations and formal presentations at the project partner seminars arranged by the IT Lighthouse Secretariat.

Chapter 10 investigates three themes in relation to DDN: Digital TV, m-commerce, and the future IT infrastructure. The focus is on firms from the ICT sector in North Jutland that participated in the DDN programme. The projects were selected because they were located in the region. It investigates the move towards digital TV, m-commerce, and the future IT infrastructure in North Jutland. Chapter 10 is based on similar data sources as Chapter 9.

Finally, *Chapter 11* presents the conclusion

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Part One

Setting the Stage

Chapter 2

The Danish ICT Sector from 1992 to 2002

The Danish ICT Sector from 1992 to 2002

1 Introduction

Various chapters in this thesis analyse problems related to the development perspectives of the information and communication technology (ICT) sector in North Jutland. The purpose of this chapter is to set the stage by presenting a descriptive overview of the development in employment of the Danish ICT sector from 1992 to 2002. The period is divided into 1992 to 2000 before the ICT crisis began and the subsequent development from 2000 to 2002. This chapter analyses the development based on employment, number of firms, and geographic specialisation.

The worldwide crisis in the ICT sector 'started' with the burst of the dotcom bubble in March 2000 when the share prices at the stock markets started dropping. During 2000-2001 the economy-wide business cycle also experienced a downturn, starting in USA and quickly spreading to Europe and the rest of the world. This reduced the end-user demand for ICT equipment and services, which added to the crisis (Fransman, 2002). There are several causes and effects of the burst and it is not within the reach of this chapter to explain all causes and effects. These are also intermingled and hard to separate, because of negative feedback effects. E.g. the heavy financial investments in the ICT sector were reduced dramatically in 2000, which were an effect but also a cause. There are, however, a few main features to be emphasised.

The crisis hit the dotcom segment and the telecommunication service providers first, and then it spread worldwide throughout the sector. In the dotcom segment many of the firm's had negative profits that caused bankruptcies. The dotcom's are a part of the IT services and software segment. The remainder of this segment was also hit by reduced revenues and decreasing demand. Overinvestment in telecommunications infrastructure during the late 1990s and decreasing revenues in the telecommunications service industry lead to declining investments in telecommunications equipment, which caused crisis in this segment in 2000 (Fransman, 2002). The telecommunications service providers ran into problems in mid 2000 and downsized their employment heavily during the following years. The mobile communications industry remained fairly stable until early/mid 2001. The mobile communications operators also faced problems with increasing competition and reduced profitability. In addition they spent enormous amounts of money on licenses for the forthcoming third generation mobile communications, which added to the problems (see

Chapter 3 and Chapter 8). The mobile communications equipment manufactures were hit by falling sales of mobile phones, increased competition, decreasing prices and disruption caused by the delay the introduction of third generation mobile phones. This envisaged a major restructuring process in the industry with downsizing and outsourcing of production and partly R&D from US and Europe to Asia.

It is hard to separate the direct and derived effects of the burst of the dotcom bubble and the downturn in the economy-wide international business cycles. But for an analytical purpose it seems valuable to split the period from 1992 to 2002 into two periods: 'the golden growth period' before the crisis (1992-2000) and the beginning of the crisis (2000-2002).

The restructuring of the global mobile communications industry continued after 2002. This process had a major effect in North Jutland because some of the subsidiaries of multinational companies located in the region chose to concentrate the R&D in their home countries (see also Chapter 5 and Chapter 8). I June 2004 Flextronics decided that a major mobile phones manufacturing plant in North Jutland was to be closed down. In 2003 at its peak it employed 1,700 persons in Pandrup, North Jutland. This will have a significant effect on the ICT employment data for 2004, which are not available yet.

2 Definition of the ICT sector

OECD (2000) uses the following principles in their definition of the ICT sector:

> *"For manufacturing industries, the products of a candidate industry: Must be intended to fulfill the function of information processing and communication including transmission and display, and must use electronic processing to detect, measure and/or record physical phenomena or to control a physical process. For services industries, the products of a candidate industry: Must be intended to enable the function of information processing and communication by electronic means" (OECD, 2000, p. 7)*

The definition used in this chapter is based on Statistics Denmark's definition, but manufacturing of electro medical equipment is added since it corresponds with the OECD principles. Table 1 shows the definition of the ICT sector using NACE/DB93 activity codes. The NACE and DB93 codes are equal at the four-digit level, while the Danish classification, DB93, is further divided into a six-digit level.

Table 1 Segmentation of the ICT sector

NACE/DB93 Codes
Manufacturing
Office Machinery
3001 Manufacture of office machinery
Computers
3002 Manufacture of computers and other information processing equipment
Electronic components and wire
3130 Manufacture of insulated wire and cable
321010 Manufacture of printed and electronic integrated circuits
321090 Manufacture of semi-conductor devices, condensers, resistors, etc.
Telecommunications equipment
322010 Manufacture of transmission apparatus for radio-telegraphy and radio-telephony
322020 Manufacture of telephone sets, switchboards, and telex apparatus
Consumer electronics
323010 Manufacture of radio and television receivers, etc.
323020 Manufacture of loudspeakers, etc.
323030 Manufacture of aerials and aerial equipment
Electro medical
331020 Manufacture of hearing aids and parts thereof
331030 Manufacture of electro-diagnostic apparatus
331090 Manufacture of X-ray apparatus, dental apparatus, respiration apparatus, etc.
Instruments etc.
332010 Manufacture of navigation equipment
332020 Manufacture of apparatus for measuring the flow, level pressure etc. of liquids or gases
332030 Manufacture of apparatus for measuring and checking electrical quantities
332040 Manufacture of apparatus for carrying out physical and chemical analyses
332090 Manufacture of other measuring and checking equipment
333000 Manufacture of industrial process control equipment
Services
Wholesale
514320 Wholesale of radio and television goods
516410 Wholesale of computers, office machinery and equipment
516520 Wholesale of electronic components
Telecommunications
642000 Telecommunications
IT service and software
713310 Renting of office machinery and equipment, including computers
7210 Hardware consultancy
7220 Software consultancy and supply
7230 Data processing
7240 Database activities
7250 Maintenance and repair of office, accounting and computing machinery
7260 Other computer related activities

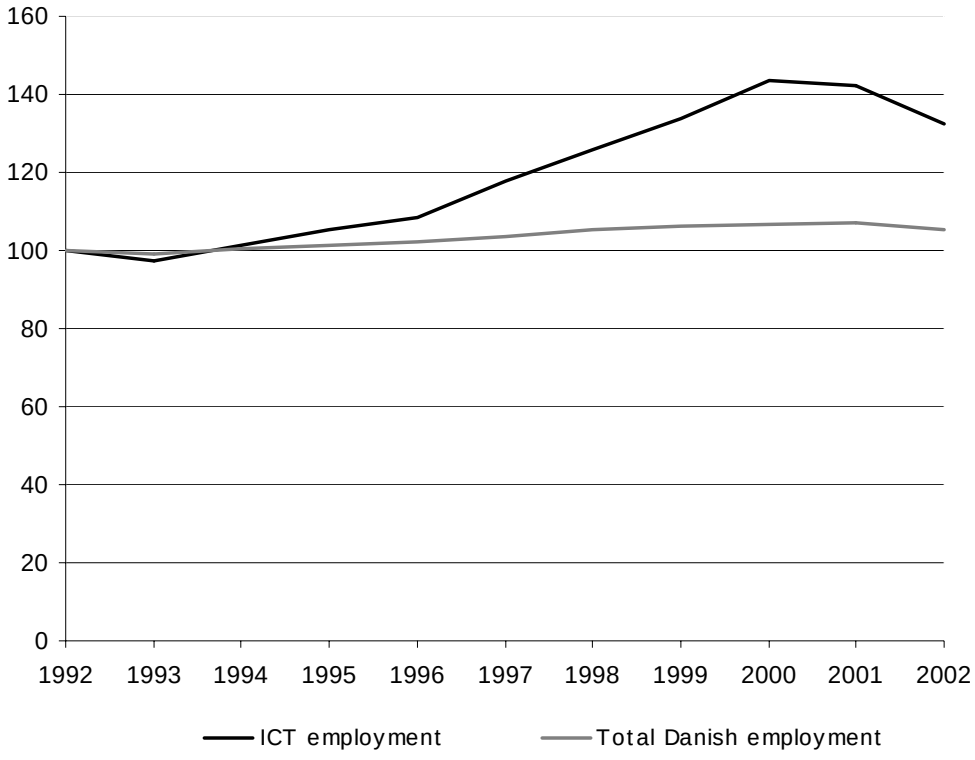
Note: Instruments etc. are instruments and equipment for detecting, measuring, checking and controlling physical phenomena or processes.

3 The development of the ICT sector from 1992 to 2002

From 1992 to 2002 the ICT sector in Denmark experienced a very high growth in employment of 32%. The sector grew from 81,600 to 108,000 employees, and it amounted to 4% of total employment in 2002[1]. The period has been very turbulent, consisting of a long high growth period from 1993 to 2000, followed by stagnation in 2001, and decline in 2002. The growth was supported by the relative fast economic growth in Denmark in the 1990s, where aggregate unemployment decreased from a level of 12% in 1992-1993 to 5-6% in 2002.

From 1997 to 2000 the annual growth rates in ICT employment were above 6%, and the sector peaked at 117,000 employees in 2000 or 43% more employees than in 1992. The dotcom bubble burst in 2000 and the sector went from boom to crisis. In spite of the crisis, employment still grew with 7.3% in 2000. However, the ICT employment declined with 0.7% in 2001 and almost 7% during 2002, see Figure 1.

Figure 1 Development in Danish employment from 1992 to 2002 (1992 = 100)



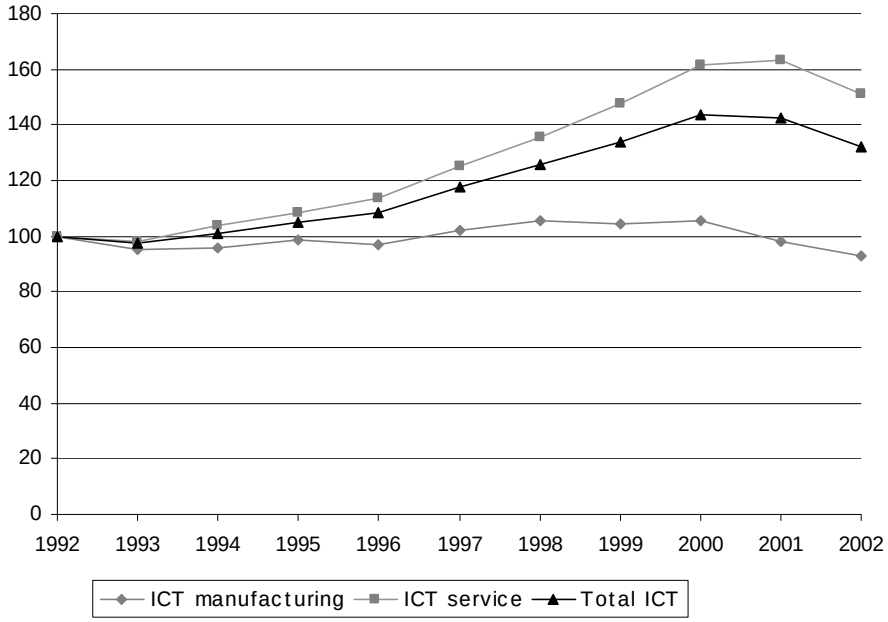
Source: Based on data from Statistics Denmark

The development patterns in the sub segments have been uneven, where traditional manufacturing of ICT equipment has declined from 1992 to 2002, while ICT services have been the driver behind growth in total ICT employment. ICT service employment grew with

[1] The number of employees is based on data from Statistics Denmark measuring employment on November 1st e.g. 2002 employment is based on the individual's employment November 1st 2002.

51%, while manufacturing declined 7% from 1992 to 2002. Figure 2 shows the development of the different segments.

Figure 2 Employment growth in the ICT segments (1992 =100)



Source: Based on data from Statistics Denmark

The differences in growth rates have pushed the transition from manufacturing to services, and the manufacturing share of total ICT employment has dropped from 32.4% to 22.7% in a decade. When investigating this change in more details, it can be seen that the growth is concentrated in telecommunications services, and IT services and software. The development in the various sub segments is shown in Table 2.

Table 2 The development in employment in the ICT sector in Denmark 1992 - 2002

	1992		2002			
	Employment (persons)	Share of ICT (%)	Employment (persons)	Share of ICT (%)	Development 1992-2002 (1992 =100)	Change (persons)
Manufacturing	26,434	32.4	24,499	22.7	92.7	-1,935
Office machinery	642	0.8	59	0.0	9.2	-583
Computers	1,734	2.1	1,414	1.3	81.5	-320
Electronic components and wire	4,544	5.6	3,242	3.0	71.3	-1,302
Telecommunications equipment	3,344	4.1	2,883	2.7	86.2	-461
Consumer electronics	4,903	6.0	4,840	4.5	98.7	-63
Electro medical	5,390	6.6	5,431	5.0	100.8	41
Instruments etc.	5,877	7.2	6,630	6.1	112.8	753
Services	55,209	67.6	83,581	77.3	151.4	28,372
Wholesale trade	20,894	25.6	21,185	19.6	101.4	291
Telecommunications	16,027	19.6	20,532	19.0	128.1	4,505
IT services and software	18,288	22.4	41,864	38.7	228.9	23,576
Total ICT sector	81,643	100	108,080	100	132.4	26,437

Source: Based on data from Statistics Denmark

IT services and software employment has more than doubled (128.9% growth), and it has become the largest segment of the ICT sector in Denmark (38.7%). Most of the IT companies that emerged during the 1990s have been placed in this segment, and the outsourcing of IT activities has contributed to the growth[2]. Telecommunications services also experienced a high growth in employment (28%) mainly fuelled by the successful introduction of 2G mobile communication services. The majority of the ICT manufacturing industries have experienced a decline in employment. Especially electronic components and wire, that also includes printed circuit boards, has had declining employment (-1,300 employees), while the instruments etc. segment has grown almost 13%. The latter includes some of the older large international successful Danish companies[3] (this segment is investigated further in Chapter 3).

If the period from 1992 to 2002 is divided into two periods before and after the beginning of the crisis, it can be seen that the major changes occurred after 2000. Employment boomed

[2]When a firm is founded it is required to choose an activity code. Afterward, this code is checked by Statistics Denmark. The principle is: Firms are assigned to an activity code according to the dominant activity of the firm, defined by highest value-added. This activity is measured by the easiest accessible measure such as net revenue minus consumed goods. However, it is often necessary to use measures such as wages, number of employees, production, or sales. Firms that have activities in multiple industries (e.g. vertically integrated industries) can be placed in an activity code according to the end product. These principles combined with the (outdated) international classification codes, and the industrial development, have caused many firms to be located in the IT services and software segment. This development is also enhanced by the separation of R&D and production in space. An illustrative example is the split of Bosch Telecom located in North Jutland in 2000. Bosch was developing and manufacturing mobile phones (telecommunication equipment). In 2000 Flextronics International Denmark acquired Bosch, sold the R&D department to Siemens, and continued manufacturing mobile phones. This change affects the data, because Flextronics continued to be a part of the telecommunication equipment segment, while Siemens Mobile Phones (350 employees) was assigned to the IT services and software segment. This can be seen in a report from the Ministry of Research and Information Technology (2003, pp. 141- 143).

[3] Such as Kamstrup, Brüel & Kjær, and Radiometer.

in 2000 with 117,000 employees, and also the ICT manufacturing industries had experienced employment growth (almost 6%) in employment since 1992. Table 3 shows this development.

Table 3 Development of the Danish ICT sector before and after the beginning of the crisis

	1992 Employment (persons)	2000 Employment (persons)	Development 1992-2000 (1992 =100)	2002 Employment (persons)	Development 2000-2002 (2000 =100)	Change 2000-2002 (persons)
Manufacturing	26,434	27,945	105.7	24,499	87.7	-3,446
Office machinery	642	198	30.8	59	29.8	-139
Computers	1,734	1,613	93.0	1,414	87.7	-199
Electronic components and wire	4,544	4,641	102.1	3,242	69.9	-1,399
Telecommunications equipment	3,344	3,357	100.4	2,883	85.9	-474
Consumer electronics	4,903	6,487	132.3	4,840	74.6	-1,647
Electro medical	5,390	5,207	96.6	5,431	104.3	224
Instruments etc.	5,877	6,442	109.6	6,630	102.9	188
Services	55,209	89,112	161.4	83,581	93.8	-5,531
Wholesale trade	20,894	25,281	121.0	21,185	83.8	-4,096
Telecommunications	16,027	21,615	134.9	20,532	95.0	-1,083
IT services and software	18,288	42,216	230.9	41,864	99.2	-352
Total ICT sector	81,643	117,057	143.4	108,080	92.3	-8,977

Source: Based on data from Statistics Denmark

As can be seen from Table 3, both segments of the ICT sector were hit by the crisis. Manufacturing experienced the largest decline (12.3%), but ICT services employment also shrunk (6.2%). However, the IT services and software employment only went through a minor change, -352 persons, despite that the crises in ICT started with the burst of the dotcom bubble. This discrepancy may be due to the lack of success in developing the Danish dotcom segment compared to especially Sweden (see Chapter 3), and an increasing assignment of software firms to these activity codes[4].

The number of ICT firms also grew rapidly from 1992 to 2001. It increased from approximately 5,000 in 1992 to 8,800 in 2001 (75% increase)[5]. This growth is due to new IT service firms. The number of IT service firms increased with 140%. These data are not directly compatible with the employment data, but electronics is almost identical to the ICT manufacturing (NACE 30-33) and IT service (NACE 72) is almost equal to IT services and software. Data on wholesale trade and telecommunication services are not available. Table 4 shows the development of the number of ICT firms from 1992 to 2001.

[4] See the previous footnote.

[5] Based on Statistics Denmark's 53 industries classification. The ICT sector is here defined as 30009 Electronics and 72000 IT service.

Table 4 Number of ICT firms from 1992 to 2001

	1992 firms	2000 firms	Development 1992-2000 (1992 =100)	2001 firms	Development 2000-2001 (2000 =100)	Change 2000-2001 (firms)
Electronics	2,196	1,992	90.7	2,013	100.6	21
IT service	2,858	6,204	217.1	6,863	110.6	659
ICT sector	5,054	8,196	162.2	8,876	101.9	680
Total number of Danish firms	315,355	298,704	94.4	297,706	98.5	-998

Source: Based on data from Statistics Denmark

3.1 Geographical specialisation and evolution

Seemingly unaffected by the rapid growth in employees and new firms, the geographical employment specialisation pattern in Denmark has been rather stable from 1992 to 2002. In 1992 five counties were specialised in the ICT sector as a whole: Copenhagen Municipality, Copenhagen County, Frederiksborg County, Roskilde County, and Aarhus County. The first four are covering the greater Copenhagen area (missing Frederiksberg Municipality), while Aarhus County includes the second largest Danish city. In 2002 the pattern was unchanged. North Jutland County has been catching up, and the specialisation indicator has increased from 0.70 to 0.85. An urban or metropolis effect seems to exist in the ICT sector. Especially the service segments are located in the greater Copenhagen area and Aarhus, while other regions are specialised in ICT manufacturing. Table 5 shows the regional employment specialisations in the various ICT segments in 1992 and 2002.

The geographical specialisation pattern with specialisation and concentration in the metropolis regions at county level is also found on a more detailed geographical level. Figure 3 shows the ICT employment specialisation at municipality level in Denmark in 1992 and 2002, and Figure 4 shows the share of total ICT employment. These figures confirm the relative concentration of ICT in and around the cities of Copenhagen, Aarhus, and Aalborg, whereas Odense, the third largest city in Denmark, was not specialised in ICT in 2002. Aalborg municipality was not specialised in 1992, but became so during the 1990s. From 1992 to 2002 the specialisation pattern is fairly stable, but there are some changes[6]. The specialisation pattern in Figure 3 and Figure 4 are analysed in further details in Chapter 3.

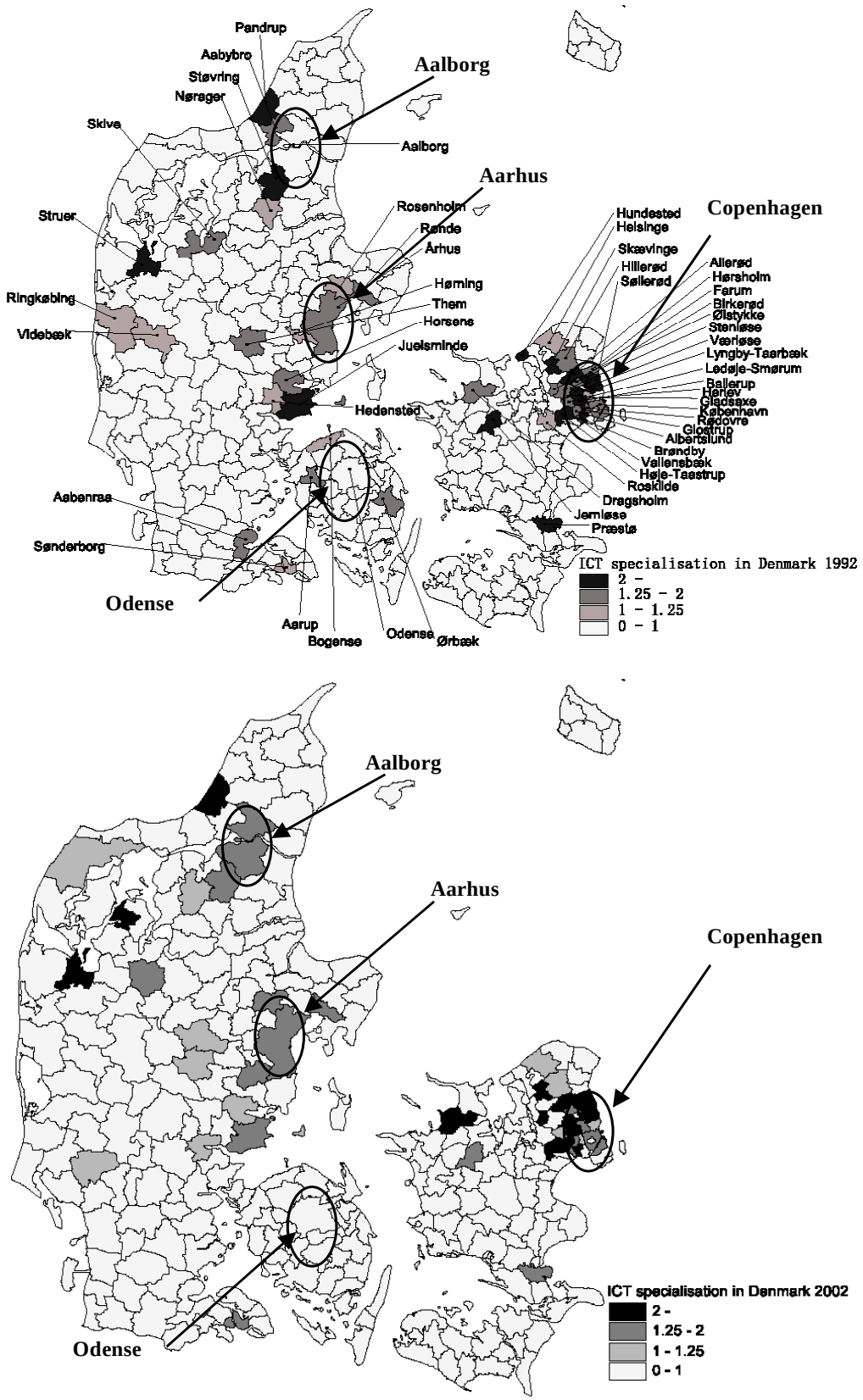
[6] Some of the municipalities with specialisation in ICT employment are specialised because of a more or less random location of a single large company and a small size of the municipality. This is one of the downsides of using a relative measure of this kind.

Table 5 Regional employment specialisations in different ICT segments in 1992 and 2002

	Copenhagen Municipality	Frederiksberg Municipality	Copenhagen County	Frederiksborg County	Roskilde County	Western Zealand County	Storstroems County	Bornholm County	Fuenen County	Southern Jutland County	Ribe County	Vejle County	Ringkoebing County	Aarhus County	Viborg County	North Jutland County
Manufacturing																
1992	0.76	0.23	**2.57**	**1.70**	**1.37**	0.69	0.73	0.02	0.40	0.39	0.20	**1.06**	**2.00**	0.66	0.81	**1.05**
2002	0.50	0.15	**1.33**	**1.75**	**1.37**	0.80	0.47	0.05	0.41	0.70	0.37	**1.25**	**1.40**	**1.03**	**1.60**	**1.28**
Office machinery																
1992	0.00	0.00	**7.88**	0.00	0.05	0.00	0.00	0.00	0.20	0.00	0.00	0.33	0.00	0.94	0.00	**4.33**
2002	0.00	0.00	0.00	0.48	**3.11**	0.00	0.00	0.00	**7.35**	0.00	0.00	0.25	0.00	0.57	0.00	0.00
Computers																
1992	0.37	0.39	**6.72**	**1.46**	**1.01**	0.01	**2.55**	0.00	0.32	0.06	0.09	**1.32**	0.05	0.47	0.33	0.70
2002	0.64	0.00	**1.31**	**1.72**	**1.23**	0.09	**1.42**	0.00	**1.54**	0.02	0.03	0.28	0.14	**2.96**	0.10	0.53
Electronic components and wire																
1992	0.05	0.12	**4.08**	0.92	**1.09**	**3.34**	0.91	0.00	0.52	0.07	0.02	**2.10**	0.42	0.32	0.13	**1.55**
2002	0.02	0.00	**1.31**	0.76	**1.54**	**3.62**	0.52	0.13	0.55	0.01	0.01	**4.00**	0.16	0.60	0.01	**1.45**
Telecommunications equipment																
1992	**1.33**	0.00	**1.97**	0.89	0.71	0.01	0.00	0.00	0.39	0.36	0.00	0.53	**1.50**	**1.31**	0.00	**3.13**
2002	0.04	0.00	0.39	**2.40**	0.60	0.00	0.00	0.00	0.00	0.65	0.30	0.88	**1.65**	0.28	0.05	**5.87**
Consumer electronics																
1992	0.27	0.03	0.25	0.17	0.91	0.05	0.82	0.00	0.03	0.77	0.47	**1.77**	**8.83**	0.42	**1.82**	0.27
2002	0.04	0.11	0.22	0.17	**1.13**	0.02	0.55	0.00	0.15	0.95	**1.41**	**1.83**	**5.68**	0.52	**3.30**	0.97
Electro medical																
1992	**1.28**	0.79	**2.37**	**1.79**	**2.43**	0.34	**1.06**	0.09	0.62	0.24	0.39	0.65	0.12	0.48	**1.39**	0.48
2002	0.69	0.55	**2.87**	**3.10**	**1.98**	0.43	0.84	0.16	0.54	0.25	0.18	0.28	0.07	0.47	**2.54**	0.20
Instruments etc.																
1992	**1.12**	0.07	**2.04**	**4.19**	**1.63**	0.16	0.17	0.00	0.47	0.59	0.12	0.32	0.32	0.96	0.66	0.41
2002	**1.09**	0.01	**1.34**	**2.01**	**1.30**	0.78	0.08	0.00	0.30	**1.42**	0.05	0.67	0.13	**1.98**	**1.37**	0.48
Services																
1992	**1.56**	**1.06**	**2.47**	**2.20**	**1.23**	0.30	0.28	0.31	0.61	0.45	0.22	0.66	0.40	**1.34**	0.22	0.53
2002	**1.80**	**1.09**	**2.63**	**1.81**	**1.13**	0.21	0.23	0.23	0.50	0.40	0.19	0.47	0.41	**1.28**	0.21	0.73
Wholesale trade																
1992	**1.07**	0.94	**4.01**	**3.00**	**1.35**	0.15	0.18	0.09	0.40	0.19	0.17	0.44	0.47	**1.14**	0.18	0.33
2002	0.76	0.36	**3.42**	**2.61**	**2.18**	0.23	0.21	0.25	0.29	0.46	0.25	0.46	0.77	0.82	0.26	0.49
Telecommunications																
1992	**2.13**	**1.30**	0.27	**1.48**	0.55	0.64	0.57	0.79	0.95	0.98	0.37	0.67	0.43	**1.85**	0.32	0.62
2002	**2.24**	**1.17**	**1.52**	**1.66**	0.41	0.19	0.34	0.48	0.74	0.61	0.18	0.43	0.27	**1.88**	0.09	0.78
IT services and software																
1992	**1.61**	**1.00**	**2.65**	**1.91**	**1.70**	0.16	0.15	0.13	0.56	0.27	0.15	0.89	0.28	**1.12**	0.17	0.67
2002	**2.11**	**1.42**	**2.79**	**1.48**	0.94	0.22	0.18	0.10	0.50	0.28	0.17	0.49	0.30	**1.22**	0.24	0.83
Total ICT sector																
1992	**1.30**	0.79	**2.50**	**2.03**	**1.28**	0.42	0.43	0.21	0.54	0.43	0.22	0.79	0.92	**1.12**	0.41	0.70
2002	**1.51**	0.88	**2.34**	**1.80**	**1.18**	0.35	0.28	0.19	0.48	0.47	0.23	0.64	0.64	**1.22**	0.53	0.85

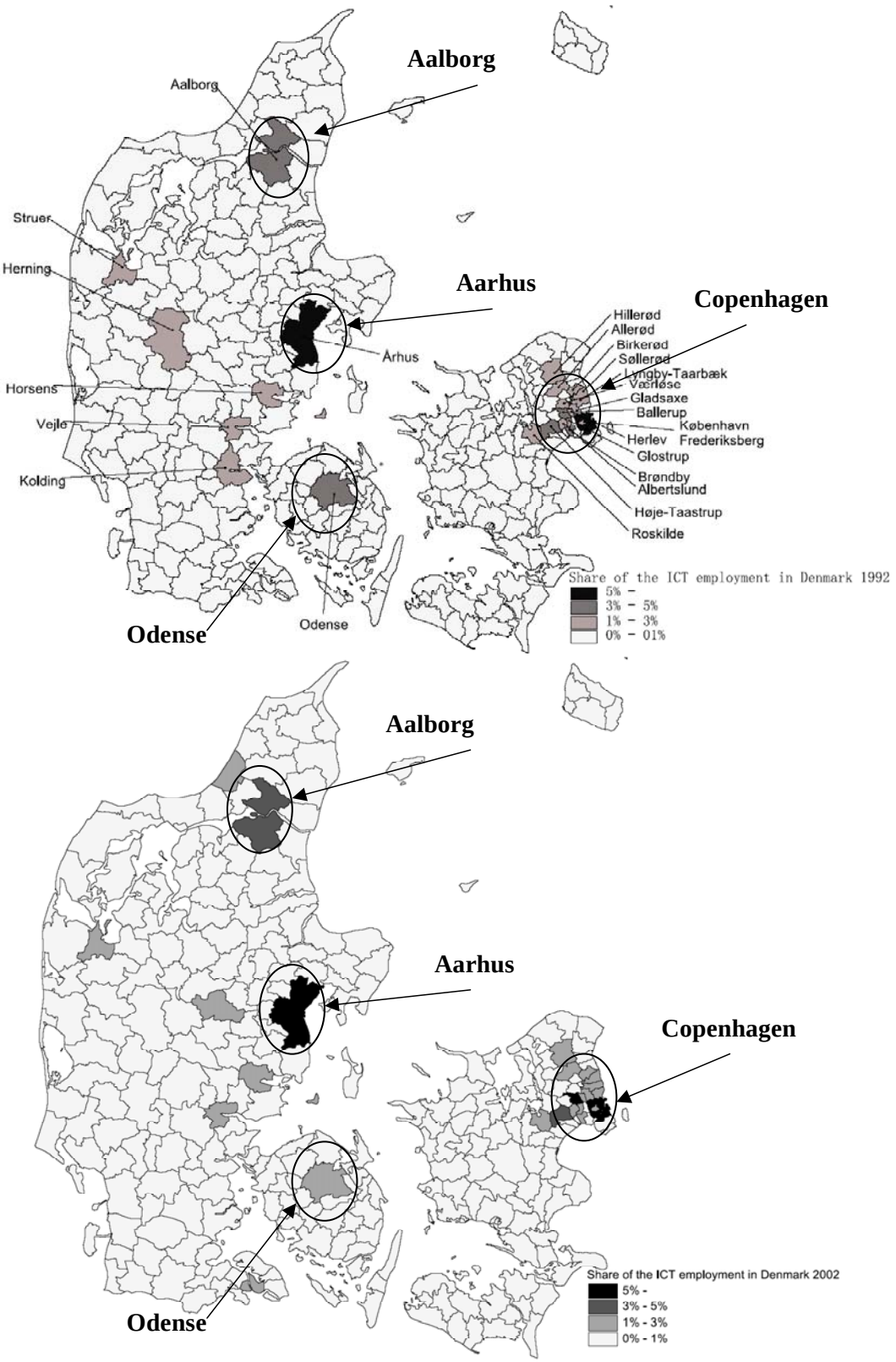
Note: The specialisation indicator is the share of ICT employment in every industry of the total employment of a given county compared with the national average. A value above 1 indicates an above average employment share - i.e. the county is specialised. Specialised industries in bold. Source: Based on data from Statistics Denmark

Figure 3 ICT employment specialisation at municipality level in Denmark 1992 and 2002



Source: Based on data from Statistics Denmark

Figure 4 Share of total ICT employment at municipality level in Denmark 1992 and 2002



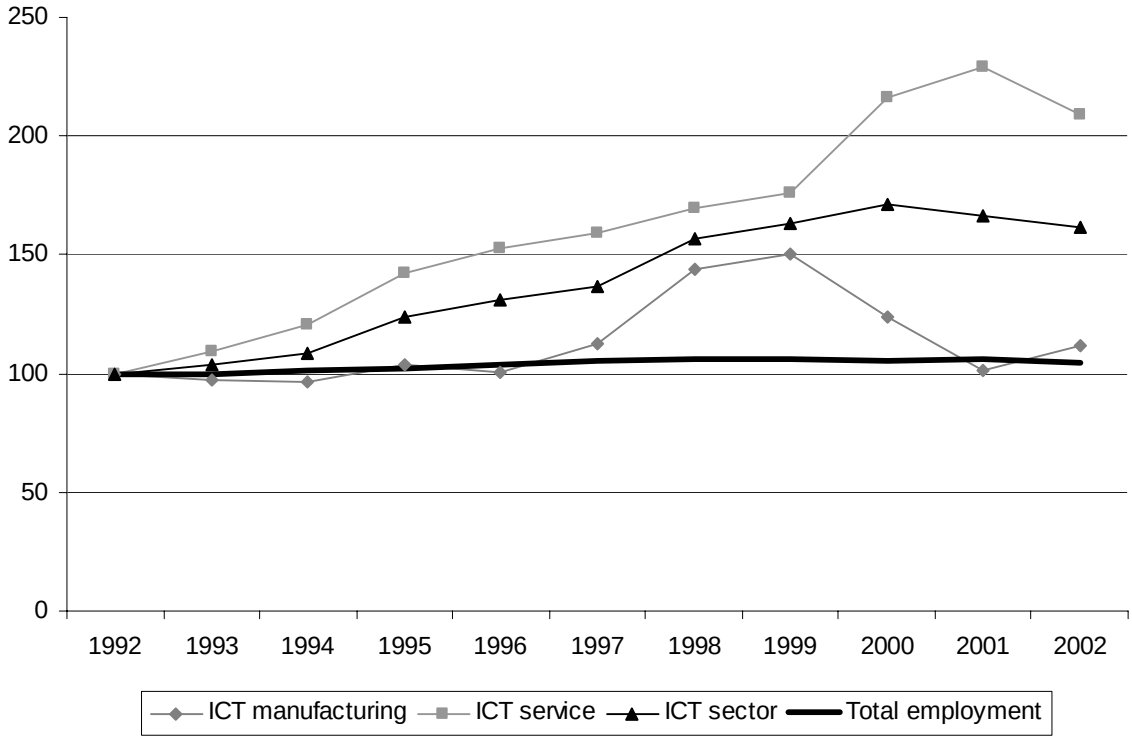
Note: 1% of the total ICT employment in Denmark was equal to 816 persons in 1992, and 1080 persons in 2002. Source: Based on data from Statistics Denmark

4 The development of the ICT sector in North Jutland

The ICT sector in North Jutland experienced high growth during the 1990s. Employment grew 61% from 1992 to 2002 compared with a growth of 32% at the national level and a 5% increase in total employment in North Jutland (see Figure 5). Total ICT employment was 8,192 in 2002, but the region is not specialised in ICT employment. The specialisation indicator increased from 0.70 to 0.85 i.e. it has somewhat been catching-up from a rather low level.

The structure of the sector is different from the overall Danish pattern, since 34% of the employment was in manufacturing compared to 23% for Denmark in 2002. During the 1990s specialisation in ICT manufacturing increased from 1.05 to 1.50 concentrated on two segments, telecommunications equipment and electronic components. The manufacturing employment peaked in 1999 with more than 3,700 employees, but decreased to 2,800 in 2002. However, North Jutland was still specialised in ICT manufacturing (1.28) in 2002. Table 5 reveals that especially the employment and increased specialisation in telecom hardware has been outstanding with an increase from a three to nearly six times larger employment share compared to the national average.

Figure 5 Development in employment in North Jutland from 1992 to 2002 (1992 = 100)



Source: Based on data from Statistics Denmark

The region has not been specialised in ICT services, but specialisation increased from 0.53 to 0.73 from 1992 to 2002. Employment in services increased 108% compared to 51% at the national level, but this segment was still rather poorly represented in North Jutland compared to the national average in 2002. Table 6 shows that IT service and software is the largest segment in North Jutland (37.5%), and the specialisation increased from 0.67 to 0.83. Employment in this segment peaked in 2001 (one year after the crisis had begun) at 3,251 employees, but decreased to 3,069 employees in 2002.

Table 6 The development of the ICT sector in North Jutland 1992 - 2002

	1992 Employment (persons)	1992 Share of ICT (%)	2000 Employment (persons)	Development 1992-2000 (1992 =100)	2002 Employment (persons)	2002 Share of ICT (%)	Development 2000-2002 (2000 =100)	Change 2000-2002 (persons)
Manufacturing	2,483	48.9	3,073	123.8	2,778	33.9	90.4	-295
Office machinery	248	4.9	133	53.6	0	0.0	0	-133
Computers	108	2.1	54	50.0	66	0.8	122.2	12
Electronic components and wire	629	12.3	457	72.7	418	5.1	91.5	-39
Telecommunications equipment	934	18.4	1,547	165.6	1,500	18.3	97.0	-47
Consumer electronics	119	2.3	317	266.4	416	5.1	131.2	99
Electro medical	229	4.5	208	90.8	97	1.2	46.6	-111
Instruments etc.	216	4.2	357	165.3	281	3.4	78.7	-76
Services	2,595	51.1	5,603	215.9	5,414	66.1	96.6	-189
Wholesale trade	615	12.1	1,062	172.7	924	11.3	87.0	-138
Telecommunications	885	17.4	1,808	204.3	1,421	17.3	78.6	-387
IT services and software	1,095	21.6	2,733	249.6	3,069	37.5	112.3	336
Total ICT sector	5,078	100	8,676	170.9	8,192	100	94.4	-484

Source: Based on data from Statistics Denmark

From 2000 to 2002 ICT employment in North Jutland decreased with 5.6% compared to 7.7% in Denmark. Therefore the effect of the crisis from 2000 to 2002 appears to have been less negative in North Jutland. However, this can also be partly explained by composition of the ICT sector in North Jutland. The major share of the region's ICT employment is within wireless communication that was hit later by the crisis. The mobile communication industry is experiencing a restructuring process that is not completely covered by the data from 2000 to 2002. Employment in manufacturing of telecommunications equipment and telecommunications services will decrease further in the 2003 and 2004 data.

Table 3 and 6 indicates a transition from manufacturing to services. North Jutland had a high growth (50%) in ICT manufacturing from 1992 to 1999 compared to the national level (4%) and a specialisation indicator on 1.5 in ICT manufacturing. But a transition from manufacturing to service in North Jutland started in 1999. More than a 1,000 employees moved away from the ICT manufacturing from 1999 to 2002, while the service segment increased employment with 900 in this period, although a part of this can be explained by the classification of Siemens Mobile Phones, see Footnote 2. The ICT sector still has a larger

share of manufacturing employment than at national level, but services is catching up. In 2002 the ICT sector in North Jutland had the highest specialisation indicator (0.85) outside the greater Copenhagen area and Aarhus.

5 Conclusion

The ICT sector has had a remarkable growth in employment and number of firms from 1992 to 2002. ICT services have experienced the largest employment growth, and IT services and software employment has more than doubled. The growth in ICT stopped in 2000 when the sector went from boom to burst and employment declined. Especially the ICT manufacturing was hit hard in this period while ICT services performed less badly, except for wholesale trade[7]. The crisis in the worldwide ICT sector does not appear to have hit Denmark as severely as other countries. The impressive growth in Danish ICT employment stagnated in 2000-2001 and decreased in 2002. The crisis has nonetheless, caused a wave of bankruptcies and made it difficult for start-ups. It has also changed the conditions for the ICT firms in terms of a dampened demand, growth and markets. The structure of the Danish ICT sector in an international context seems also to have mitigated the effects of the crisis in ICT, see Chapter 3.

[7] A curiosum for the ICT sector in Denmark and the other Nordic countries is the wholesale trade segment. Some of the firms in this segment are also developing and manufacturing ICT products, but are assigned to the wholesale trade category because their main value-added comes from wholesale of parent company products.

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Chapter 3

Knowledge Flows in the Danish ICT Sector: The Paradox of Advanced Demand and Mediocre Supply

Knowledge Flows in the Danish ICT Sector: The Paradox of Advanced Demand and Mediocre Supply[1]

1 Introduction

The point of departure of this chapter is part of the general worry about the rather weak Danish performance in the information and communication technology (ICT) sector (Begg et al., 1999; Dalum et al., 1999). The main focus is that, on the one hand, Denmark is one of the most advanced user nations, measured by conventional indicators for user penetration (such as number of personal computers (PCs), mobile phones and Internet access per capita). On the other hand, however, it is fairly obvious that the country is not one of the major players in the international ICT markets, even allowing for country size. The nearby and somewhat similar countries of Sweden, Finland and the Netherlands, are living proof that small countries can be very visible in this field. This chapter will focus on the role and character of knowledge flows in the ICT sector in a bid to find possible explanations for this apparent lack of match between the advanced demand, but rather weak supply side of the ICT sector in Denmark.

A tradition of analysing broad business sectors based on a cluster approach gradually evolved in Denmark during the 1990s[2]. The idea was to include important interactions, which may not be captured by traditional industrial classification schemes. The explicit goal was to promote discussion of the policy implications at national level of specific groups of related industries. The first round of studies of this type was conducted at the beginning of the 1990s. The entire spectrum of industries was divided into 'resource areas', more recently referred to as 'mega clusters' (Dalsgaard, 2001). More recently, the Danish Agency for Trade and Industry (EFS) has launched a second round of studies of a revised division of mega clusters, starting with a so-called 'benchmarking' report giving an overview of the basic statistical trends of the clusters[3]. This was followed by studies of some of the mega clusters, for example, construction and ICT (EFS, 2001). The aim was to incorporate the general structural characteristics of the mega cluster with a particular focus on the interactions

[1] This chapter is based on Pedersen, Dahl and Dalum (2005) "Knowledge Flows in the Danish ICT Sector: The Paradox of Advanced Demand and Mediocre Supply" forthcoming in Caloghirou, Constantelou and Vonortas (2005) "Knowledge Flows in European Industry" Routledge.

[2] For more detailed information on the mega clusters and the Danish cluster studies, see Drejer et al. (1999) and Dahl and Dalum (2001).

[3] Danish Agency for Trade and Industry referred to as EFS (2000). In 2002, this agency was renamed the National Agency for Enterprise and Housing. We have chosen to keep the old acronym EFS, which is the label on the publications referred to here.

between the use of new technologies, and their development and manufacture. Given that the application of new technologies very often is located in industries other than the one in which they were developed, the combination of the user and producer industries is emphasised. In the context of ICT it might be more difficult than for other mega clusters to draw the boundaries, taking into account the swift development of the underlying basic technologies.

The focus of Danish policy makers on the level of mega clusters changed during the production of the second round of studies when they introduced a new level of analysis. Now the focus is on small scale clusters. These are more narrowly defined as national or regional clusters that are current high performers or have considerable future potential. The overall aim is the same, but based on a narrower group of target industries. These public policy definitions of small-scale clusters and mega clusters on both national and regional levels, increase the confusion about how a cluster is actually defined. In this chapter, a sector definition rather than a cluster definition of the ICT area is chosen. When we talk about the Danish ICT sector, this is the industry in a national context. This equates to the ICT mega cluster in the public policy definition. The concept of clusters should not be used on the national level, but rather for regional or geographically limited concentrations of firms in a given location. Such firms have three common factors, which qualify them for this label: (i) they are coherent, that is, their activities evolve around limited segments of large industries (for example, wireless communication); (ii) they have a common technological knowledge base in a similarly limited area of these industries; (iii) They have a common pool of labour experienced in the specific technology, market and industry segment in question.

There are some problems in defining the ICT sector, since it differs from what are usually termed 'high tech' or R&D intensive industries, that is, industries developing and producing the ICTs (hardware), pharmaceuticals/biotechnology and aerospace. Originally the major focus in analyses of high-tech industries concentrated on the physical output (hardware). In the case of ICTs, however, it has become more and more evident that the hardware and software aspects are fundamentally intermingled - in many cases they can be regarded as two sides of the same coin. This has obviously led several analysts and researchers to use - rather than the electronics industry - the concept of an ICT sector, which comprises the electronics industry as well as software development and IT services. In a broader perspective, it may even include such industries as broadcasting, electronic and printed media, publishing, movie production and advertising, which, to an increasing degree, are converging with what traditionally has been conceived of as the 'core' ICT industries. The present chapter takes as its point of departure a more narrow definition, close to the statistical definition used by the OECD (2000)[4]. The EFS (2001)study contains a very broad

[4]More specifically the 'sector based' definition in OECD (2000)Annex 2, p. 249.

specification of the ICT industry (which includes publishing, media and printing). The present chapter has applied the narrower OECD specification in order to focus on the 'core' ICT activities. The OECD approach was used and further developed in a cooperative project by the Nordic Statistical Institutes (1998; 2000)[5], which produced inter-Nordic comparisons of, for example, ICT production and employment patterns (Nordic Statistical Institutes, 1998; 2000).

The purpose of this chapter is to investigate the apparent paradox of advanced demand from the Danish consumers, firms, and government agencies (regional administration, hospitals, schools, national government etc.) versus a rather weak supply in terms of production of ICT equipment and services in the country. This is examined by studying the structure, strengths and weaknesses of the industry in Denmark compared to the rest of western Europe and the U.S..

The remainder of this chapter is structured as follows. ICT is looked at within an innovation system perspective in Section 2. Section 3 investigates the structure and performance of the Danish ICT sector in an international perspective. Some features of the weak Danish position in ICT manufacturing are highlighted in Section 4. The consumption pattern is described in Section 5. Section 6 presents introductory case studies of two strong niches in the industry, which are geographically clustered. The final conclusions and discussion are presented in Section 7.

2 ICT within an innovation system perspective

Among the analytical ancestors of the innovation system literature are cluster studies, such as the Lundvall and colleague's (1984) analysis of the Danish 'agro-industrial complex'. The microeconomic foundations for this study were stated with explicit reference to the economics of innovation (Lundvall, 1985). This approach became one of the central foundations for the Danish contribution to Porter's major competitive advantage of nations project 1987-90, published as Moeller and Pade (1988). There was a clear Scandinavian influence behind two of the components in the 'diamond model' (Porter, 1990, Ch. 4) that is, 'demand' and 'related and supporting industries'.

In parallel with, but closely related to the proliferation of cluster studies during the 1990s surveyed by Porter (1998, Ch. 7), a stream of literature has emerged under the heading of 'systems of innovation'. Taking as its point of departure the concept of national systems of innovation (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Freeman, 1995), research has developed concerning sectoral systems (Breschi and Malerba, 1997; Malerba, 2002), technology systems (Carlsson and Jacobsson, 1997) and regional systems (Braczyk et al.,

[5]Table 11 in the appendix contains the definition in terms of a list of the 4-digit NACE codes.

1997)[6]. The common thrust of this work is an emphasis on interaction between actors leading to conceptualisation of innovation as a process, which often is highly embedded in a given social context.

The role of demand in the innovation system is closely related to user-producer interaction. Being connected to advanced users will form a competitive advantage for both producers and users. In small open economies many patterns of specialisation reflects advantages based on close user-producer interaction between advanced users and producers, such as dairy technology in Denmark or wood cutting in Sweden (Lundvall, 1992) (see also Dalum, 1992; Fagerberg, 1992). The effect of home markets on the evolution of a country's producers is not a new one. Vernon (1966) argued that the advanced demand in the U.S. allowed the domestic producers to gain advantage in the early stage of the product life cycle. This have been followed by a range of work emphasising that producers and users located within a nation, region, or a close network tend to interact and thereby strengthen their capabilities.

More emphasis is put on the quality of the demand opposed to the quantity because very competent and demanding users have provoked innovations even in areas with small volume. Innovation and production are interdependent and these innovation processes are one of the most important factors in shaping and restructuring systems of production. It introduces new sectors, breaks down old, and establishes new links in the system of production (Lundvall, 1988). In the studies of the competitive advantage of nations Porter (1990) found that home demand conditions had some effect in nearly all industries studied. The most important effect is dynamic and it shaped the rate and character of development and innovation of the domestic industry. He finds that quality is more important than quantity in determining competitive advantage. Advanced demand put pressure on domestic producers to innovate and the structure of the demand shape the development trajectory of the industry. If the domestic user needs anticipate those of other regions it creates an advantage to national producers (Porter, 1990; 1998). However, he downplay some of the important features of the advanced demand, such as user-producer interaction and the home market effect, by separating the two components of 'demand' and 'related and supporting industries'. But he does emphasise that the demand component should be seen in interplay with the other components of the diamond.

Lundvall (1985; 1988) links the role of demand with innovation. Demand is an important part in determining the rate and direction of the interactive innovation process. Lundvall (1985) argues that user-producer interaction is necessary to avoid unsatisfactory innovations. The producers depend on technological information and information about user needs as an input to the innovative process, while the users depend on the necessary information to

[6] Surveyed by Edquist (1997). For a recent overview, see Lundvall et al. (2002).

adopt and adapts products. In a recent article Lundvall and Vinding (2004) argues that innovation mainly is a result of meetings between technical opportunities and users needs. The innovation occurs where there are changes in technological opportunities, user needs, or both. This learning by interacting is a very fundamental form of learning in the economic system. It brings together insights from diverse users and combine them in new products that are then distributed widely by the producer. This makes it very important for the entire innovation system.

Related to the user-producer interaction is the concept of lead users. Von Hippel (1988) analyses the sources of innovation in many industries in U.S. and finds a concentrated innovative activity in a subset of users. These lead users are innovative and their innovations are preferred by all users. Von Hippel argues that users will innovate if it sees an in-house benefit and does not usually consider whether other users have similar needs. He claims that one of the problems in user-producer interaction is that the users are constrained by their experience. This limits their insight into new products, processes and services, which could lead to unsatisfactory innovations. The lead users are constrained by their old habits, but they are facing conditions and needs that are related to future conditions for other users. Von Hippel defines the lead users as users of novel or enhanced products, processes, or services that faces needs that are going to be general in the market place. Subsequently they are in position to benefit from obtaining a solution to those needs. Thus the producers could benefit greatly from engaging in user-producer interaction with them. The concept of lead users specifies that user-producer interaction is not straightforward and always beneficial for users and producers, but it also stresses the importance of advanced users.

However, Lundvall (1985; 1988; 1992) is rather narrowly focused on the positive effects of user-producer interaction on the producers' innovativeness, the users' utility, and on the innovations system as a whole. He finds that the interaction is a solution to many problems and downplays the possible negative effects of the interaction, but he does describes some. A lack of user-producer interaction and a lack of user competence could lead to producer innovations that are unsatisfactory for the users (Lundvall, 1988). The interdependence between users and producers therefore acts both ways. Users with a weak technological competence may have a negative effect on the system because it creates a disadvantage for the producers that the user needs are less advanced compared to users in other regions connected to competing producers. This interdependency changes the linear view of causality in the innovation process where producers innovate and diffuse to users. The user-producer interaction can create a distributed innovation process in which the lead users are the main source of innovation while the producers are mainly perfecting and diffusing. If the producers are falling behind the industry leaders, the problem could be caused by the users that are becoming less innovative (von Hippel, 1988). Even though Lundvall describes some of the negative effects of user-producer interaction, he somehow misses that a well-

functioning system can cause problems for the producers (and users). The car industry is an example. The oil shocks in the 1970s raised the price of fuel, which changed the consumer demand towards smaller cars with low fuel usage. However, the effects of the shock were reduced in U.S. keeping the fuel price low and the consumers kept demanding large and fuel consuming cars. As a result the American consumers continued on a trajectory different from the Japanese and European consumers, causing the American car industry problems in export markets and on the home market (with the increasing fuel prices in the recent years). The domestic user-producer interaction in the U.S. apparently worked fine, but still had some negative effects.

Recently Lundvall, however, adds to the assumptions for the successful user-producer interaction that innovators benefit from having access to feedback from and interaction with a diverse set of users. Because being locked in with a singe user provides a too narrow basis for interactive learning (Lundvall and Vinding, 2004). While the close user-producer interaction is beneficial in creating incremental innovations, it can also cause even great firms to fail. Based on numerous case studies Christensen (1997) and Utterback (1994) find that the emergence of new disruptive technologies that in the beginning are inferior to the existing technologies, but eventually outperforms it, often emerge outside the industry and its customers. The user-producer interaction thus leads the producers along a technological trajectory that might be outperformed later on of disruptive technologies, because the new technology does not attract the existing customers and cause the producers to miss it (This is described further in Chapter 8).

The user-producer interaction and the role of demand are dynamic and changing. Domestic demand for high quality goods force firms in this nation to innovate and the new products for the home market also finds market abroad (Mowery and Nelson, 1999). The advanced domestic demand can place the producers on a product trajectory that is different from other producers and can eventually turn out to be successful. Differences in domestic demand can also be a key factor in an industry where a changing pattern of industrial leadership prevails. Mowery and Nelson (1999) analyses the sources on industrial leadership based on studies of seven industries. They find that that the key role of users and international differences is the profile of domestic demand. This is central to the understanding of the evolution of many industries. An example of the role of demand and the evolution of an industry is the semiconductor industry[7]. An important factor in the rise to dominance of the American industry was the procurement and R&D policies of the U.S. Department of Defence (Langlois and Steinmueller, 1999). The primary factor during the early years of the transistor was the military adoption of the technology primarily because of performance and not costs. This demand affected the successful development of the

[7] See also the analysis of the machine tool industry that holds rather similar effects of demand (Mowery and Nelson, 1999).

American industry. Later on the pattern of end-user demand from consumer electronics also was crucial in shaping the capabilities of the Japanese semiconductor industry to enter a technological trajectory that made it very successful in the early 1980s. Langlois and Steinmueller (1999) concludes that the pattern for end-use demand for semiconductors had always a distinctly regional character. And the source of it has had an important role in shaping the industries in U.S., Western Europe and Japan.

The role of domestic demand clearly plays an important part in the evolution of industries. It can lead the producers on a development trajectory that could prove to be beneficial and create growth and innovation, but also lure the producers into unfavourable position. One of the prerequisites is close interaction between users and producers. A lack of interaction or less competent users can lead to unsatisfactory innovations, while advanced and competent users can lead to innovations and a competitive advantage. Advanced domestic users tend to demand higher quality goods and thereby forcing the producers to innovate and upgrade. Thus, it is not necessary just to have a home market of a certain size, the users also need to be advanced and demanding:

"A necessary condition for a positive impact of the home market on international competitiveness is that domestic users of the product or technology in question are technologically sophisticated and demanding" (Fagerberg, 1992, p.237)

In the present context a certain emphasis will be given to the phenomenon of regional clustering of pools of labour and knowledge, which plays a prominent role in the rather few success stories from the Danish ICT sector. In a knowledge flow context, these are intimately related to university-industry links.

3 Structure and performance of the Danish ICT sector in an international perspective

In the OECD's (2000) publication Measuring the ICT Sector Denmark is ranked high in terms of ICT employment in comparison with 24 other OECD countries. Based on 1997 employment data Denmark had more than 96,000 ICT employees in almost 12,000 firms. The share of ICT employment in the business sector was 5.1% compared to an OECD (24) average of 3.6% and a European Union[8] average of 3.9% (OECD, 2000). The only countries with a higher share were Sweden, Switzerland, Hungary, Finland and Norway. A comparison of the industrial distribution of ICT employment among the OECD countries

[8] Excluding Greece, Luxembourg and Spain.

reveals that Denmark has a low share of employment in manufacturing and telecommunications services and consequently a high share in other ICT services (OECD, 2000). A closer analysis of ICT employment in Denmark, based on a narrower definition using data from Statistics Denmark, reveals more of the structure of the ICT sector.

In Table 1 the 1997 data on employment and exports are assigned to six different ICT segments. Services account for approximately 80% of ICT employment and exports. However, the wholesale segment distorts the pattern. The large employment share of 41% reflects the problems of distinguishing sales and distribution activities for ICT equipment vis-à-vis other kinds of electrical equipment, such as various types of domestic electrical appliances. This may result in an overestimation of the ICT employment data. However, a large part of the wholesale segment is exports of ICT hardware, although registered as a service sector activity by Statistics Denmark. These features of the data make them hard to compare in a broader international context (than the Nordic countries).

Table 1 Segmentation of the ICT sector, 1997

Segment	Number of full time employees	Share of ICT employment	Share of total Danish employment	Exports (DKK 1 000)	Share of ICT exports	Share of total Danish Exports
Manufacturing						
Computers	2,725	3%	0.24%	1,007,853	3%	0.24%
Communication equipment	11,213	12%	1.01%	1,458,853	4%	0.34%
Instruments	5,420	6%	0.49%	3,252,103	10%	0.76%
Total ICT manufacturing	19,358	21%	1.74%	5,718,809	18%	1.34%
Services						
Wholesale	38,869	41%	3.49%	21,760,539	67%	5.09%
Telecommunications services	15,242	16%	1.37%	1,596,634	5%	0.37%
IT services and consulting	20,280	22%	1.82%	3,457,074	11%	0.81%
Total ICT services	74,391	79%	6.68%	26,814,247	82%	6.27%
Total ICT sector	93,749	100%	8.42%	32,533,056	100%	7.60%

Note: Definition of the segments is shown in the appendix in Table 12.
Source: Based on data from Statistics Denmark (The Danish Mega Cluster Statistics).

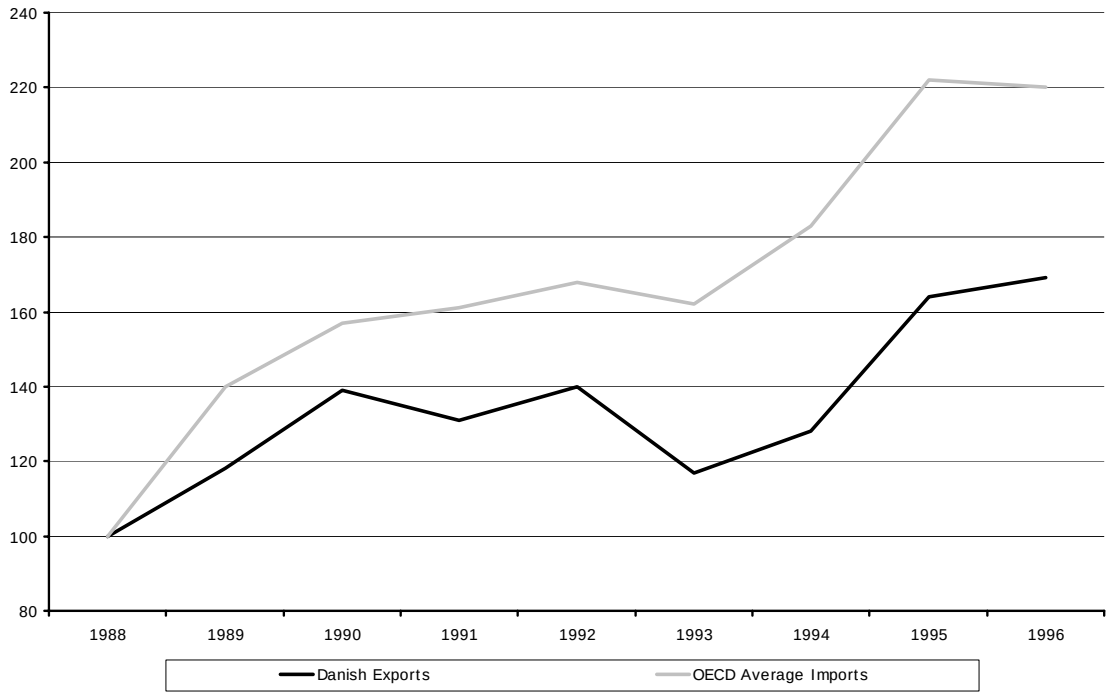
These problems with international statistical comparisons are familiar and are discussed in more detail in OECD (2000, Annex 2). The work in this chapter could be seen as a something of a 'patchwork' that tries to combine various indicators, which, to a reasonable extent, are internationally comparable. This is at the expense of a single coherent ICT definition applied throughout the chapter.

According to Table 1, ICT manufacturing accounts for less than 2% of total Danish private sector employment and an even smaller share of exports. Communication equipment accounts for more than half of ICT manufacturing employment and less than 25% of its exports. In comparison, the Finnish and Swedish employment shares are higher, 4% and 3% of total private sector employment, respectively, but the difference in total ICT employment shares between these three Nordic countries is not so great. In Sweden it is almost 10%,

while the Danish and Finnish shares are around 8.5% (Nordic Statistical Institutes, 2000). The service segment of Danish ICT is by far the largest measured by employment. The IT services and consulting segment is a subset of total ICT services. In terms of employment this segment is larger than the total ICT manufacturing activities, but in terms of exports it is less than two-thirds, which indicates that IT services and consulting are focused on the domestic market.

The Danish ICT sector experienced substantial growth in the period 1992 to 1998 in terms of turnover per employee (35%), employment (20%) and value added per employee (25%) - all in current prices. Generally, value added per employee has increased faster than employment, indicating increased productivity. The increase in employment can primarily be assigned to ICT services while ICT manufacturing has shown below average growth. However, the size and competitive performance of the aggregate ICT sector is weak in the international context. For a group of 15 OECD countries in 1997 only one, Iceland, had a GDP share of the ICT industries lower than Denmark's (OECD, 2000, Table 1)[9].

Figure 1 Danish ICT export performance of manufactured goods at the OECD market (1998 = 100)



Note: OECD Average Imports of ICT goods are a weighed average of 22 member countries.
Source: Based on EFS (2000).

[9] ICT has been defined as ISIC Rev. 2 classes 3825 (computers), 3832 (radio, TV and communications equipment) and 72 (communications services).

In terms of competitive performance, Danish ICT manufacturers have lost market share within the OECD market 1988-96, as indicated in Figure 1, OECD imports of ICT equipment have grown more than 120%, while Danish exports of ICT goods have increased by 68%.

3.1 International specialisation of ICT manufactured goods

The structure of Danish ICT manufacturing exports is shown in Table 2 which presents OECD trade statistics to compare the export structures of various industries across 12 OECD countries. Export specialisation is a convenient measure for analysing the relative export structure of a country vis-à-vis the average pattern of a relevant group of countries.

Table 2 Export specialisation, 1990-96 - Selected countries compared to OECD average.

	High-tech		Pharmaceuticals		Computers		Radio, TV & communic.		Low-tech		Food processing		Wood and furniture	
	'90	'96	'90	'96	'90	'96	'90	'96	'90	'96	'90	'96	'90	'96
Finland	0.5	0.9	0.4	0.2	0.3	0.5	0.9	1.4	2.3	1.9	0.3	0.4	3.8	3.3
Sweden	0.8	1.1	1.6	1.9	0.6	0.3	1.0	1.5	1.3	1.1	0.3	0.3	2.7	2.7
Netherlands	0.8	1.1	0.8	1.1	1.2	2.1	0.7	0.8	1.5	1.4	2.6	2.6	0.6	0.5
France	0.9	1.0	1.4	1.4	0.7	0.7	0.7	0.7	1.2	1.1	1.6	1.6	0.7	0.7
Germany[1]	0.6	0.7	0.9	1.0	0.6	0.5	0.7	0.6	0.7	0.7	0.6	0.7	0.8	0.6
Greece	0.1	0.2	0.6	0.4	0.0	0.1	0.1	0.1	3.0	2.9	3.0	3.4	0.3	0.2
Ireland	2.2	2.5	3.1	3.1	5.0	4.9	1.2	1.8	1.5	1.1	3.1	2.3	0.3	0.2
Italy	0.5	0.4	0.6	0.9	0.6	0.4	0.4	0.3	1.5	1.5	0.7	0.8	1.7	1.9
United Kingdom	1.4	1.4	1.6	1.7	1.5	1.6	0.9	1.1	0.8	0.8	0.9	0.9	0.3	0.3
United States	1.8	1.5	0.9	0.7	1.8	1.6	1.4	1.3	0.8	0.8	1.0	1.0	0.8	0.7
Japan	1.5	1.4	0.2	0.3	1.8	1.6	2.6	1.9	0.2	0.1	0.1	0.1	0.1	0.1
Denmark	**0.8**	**0.7**	**2.6**	**2.7**	**0.5**	**0.5**	**0.8**	**0.6**	**2.1**	**2.1**	**3.7**	**3.5**	**3.0**	**3.2**

[1]. Western Germany in 1990, unified Germany in 1996.

Note: The export data only contain manufactured goods (in current U.S.$). 'Specialisation' is the relative share of national exports from a given industry compared to the OECD average. If the indicator is above 1.0 the country has an above-average export share - i.e. is 'specialised'.

Source: Adapted from OECD (1999) appendix table 12.1.1.

Among the countries shown Ireland was the only small country to be specialised in high-technology export in 1990[10]. During the 1990s this pattern changed somewhat, to include Sweden and the Netherlands and Finland[11]. In the Swedish and Finnish cases two ICT companies, Ericsson and Nokia, were the major forces behind this pattern (particularly with production of mobile communications equipment). In Sweden, pharmaceuticals were also important in increasing the specialisation in high-tech. Exports from the Netherlands were specialised in pharmaceuticals and the computer industry. For the Dutch ICT industry export pattern this can be related directly to Philips in terms of non-Dutch production (and thus exports) of consumer electronics and lack of success in telecommunications hardware. Ireland stands out as by far the most high-tech export intensive OECD country in 1996 (44.3% of manufacturing exports)[12].

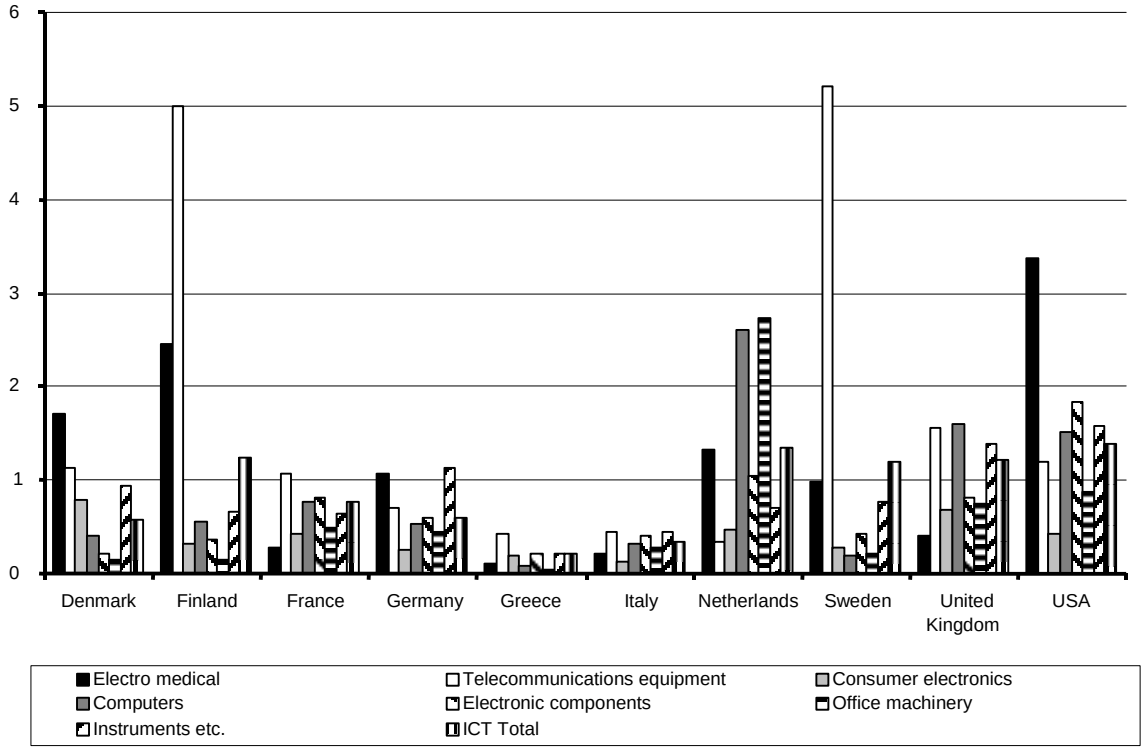
[10] Among the entire group of OECD countries only the U.S., Japan, Ireland and the UK were specialized in high-tech industries in 1990. For a definition of the categories of technology intensity, see OECD (1999, Annex 1).

[11] In 1996 also the newcomers Mexico and Korea joined the group of high-tech specialized exporters.

[12] See also Green *et al.* (2001)

At the same time, all of the small countries listed in Table 2 have the common characteristic of being specialised, though generally decreasingly so, in exports from the low-tech industries. However, the so-called low-tech industries in these countries are often based on very advanced process technologies. The technology intensities used in these standard OECD classifications are international averages that may hide substantial national differences.

Figure 2 Export specialisation in ICT and electro medical products, 1998.



Note: Table 13 in the appendix contains the specification of the various ICT products. Electro-medical equipment is not included in the ICT Total. 'Instruments etc.' refers to electronic equipment for testing and measurement.
Source: Based on data from OECD (2000) *International Trade by Commodities Statistics, No. 1.*

From Table 2 the lack of Danish specialisation in ICT hardware at the aggregate level is striking. Among the high-tech industries Denmark has only been specialised in pharmaceuticals in 1990-96. A more fine-grained analysis may, however, modify this picture slightly. Figure 2, based on OECD trade data according to the SITC classification, shows that Denmark was specialised in telecommunications equipment in 1998. Electro-medical equipment, also shown in Figure 2, is not included in the OECD and Nordic definitions of ICT. It is, however, closely connected to what is usually considered part of the electronics

industry and is shown here because it is the only segment of electronics in which Denmark has been specialised since the early 1960s (Dalum et al., 1988).

The 1998 snapshot depicted in Figure 2 is extended backwards for 1990-98 in Table 3. The general absence of export specialisation in ICT equipment is shown not to be confined only to Denmark: it also applies to Italy, France and Greece. Even Germany is shown only to have been specialised in the instruments group. The United Kingdom and more particularly the USA have been strong in ICT with specialisation in several segments.

Table 3 Export specialisation in ICT and electro medical products, 1990-1998.

	Germany									**Denmark**								
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1990	1991	1992	1993	1994	1995	1996	1997	1998
Electro medical	0.73	0.71	0.87	0.89	0.93	0.96	0.95	0.90	**1.06**	**2.20**	**1.90**	**1.82**	**1.74**	**1.81**	**1.87**	**1.68**	**2.06**	**1.70**
Telecom. equipment	0.74	0.83	0.83	0.84	0.86	0.81	0.78	0.81	0.70	**1.16**	0.93	0.95	0.78	0.79	0.72	0.83	0.95	**1.14**
Consumer	0.54	0.47	0.38	0.32	0.32	0.31	0.34	0.28	0.26	0.76	0.72	0.69	0.50	0.56	0.72	0.74	0.76	0.78
Computers	0.64	0.64	0.59	0.57	0.53	0.52	0.49	0.50	0.53	0.42	0.51	0.50	0.49	0.59	0.48	0.48	0.47	0.41
Electronic	0.59	0.63	0.57	0.55	0.60	0.63	0.61	0.63	0.59	0.16	0.15	0.15	0.20	0.18	0.16	0.17	0.20	0.21
Office machinery	0.55	0.47	0.51	0.44	0.45	0.50	0.50	0.46	0.46	0.42	0.21	0.19	0.22	0.20	0.21	0.17	0.19	0.15
Instruments etc.	**1.19**	**1.16**	**1.26**	**1.24**	**1.18**	**1.17**	**1.20**	**1.11**	**1.14**	**1.07**	0.96	0.98	0.98	0.98	0.94	0.85	0.89	0.94
ICT total	0.68	0.68	0.65	0.62	0.62	0.62	0.61	0.61	0.60	0.57	0.54	0.54	0.49	0.53	0.51	0.52	0.56	0.58
	Finland									**France**								
Electro medical	**1.57**	**1.91**	**1.93**	**1.96**	**2.08**	**1.93**	**2.35**	**2.73**	**2.46**	0.41	0.42	0.35	0.34	0.37	0.32	0.33	0.37	0.28
Telecom. equipment	**2.38**	**1.72**	**2.16**	**2.80**	**3.31**	**4.10**	**4.06**	**4.01**	**4.99**	0.94	0.93	0.84	0.80	0.76	0.80	0.81	0.92	**1.07**
Consumer	0.54	0.45	0.34	0.36	0.33	0.30	0.27	0.32	0.33	0.42	0.43	0.39	0.35	0.33	0.36	0.37	0.37	0.43
Computers	0.39	0.46	0.74	0.78	0.77	0.64	0.60	0.65	0.55	0.76	0.80	0.81	0.72	0.68	0.68	0.76	0.78	0.77
Electronic	0.26	0.24	0.25	0.24	0.26	0.23	0.26	0.29	0.37	0.56	0.54	0.54	0.61	0.63	0.74	0.83	0.85	0.81
Office machinery	0.05	0.07	0.07	0.11	0.13	0.09	0.11	0.11	0.16	0.54	0.60	0.59	0.57	0.55	0.64	0.68	0.61	0.50
Instruments etc.	0.74	0.76	0.69	0.68	0.63	0.64	0.58	0.65	0.65	0.77	0.74	0.72	0.71	0.67	0.69	0.69	0.70	0.64
ICT total	0.66	0.57	0.70	0.81	0.90	**1.00**	0.99	**1.06**	**1.24**	0.67	0.67	0.65	0.63	0.62	0.67	0.72	0.75	0.77
	United Kingdom									**Greece**								
Electro medical	0.72	0.62	0.69	0.47	0.42	0.43	0.40	0.41	0.41	0.08	0.03	0.03	0.10	0.03	0.15	0.11	0.07	0.10
Telecom. equipment	**1.09**	**1.07**	**1.05**	0.85	**1.02**	**1.22**	**1.39**	**1.39**	**1.57**	0.21	0.25	0.30	0.51	0.33	0.30	0.20	0.26	0.43
Consumer	0.70	0.77	0.61	0.61	0.68	0.71	0.81	0.72	0.67	0.01	0.01	0.01	0.03	0.03	0.03	0.10	0.16	0.19
Computers	**1.61**	**1.64**	**1.62**	**1.73**	**1.71**	**1.77**	**1.63**	**1.63**	**1.60**	0.02	0.04	0.05	0.06	0.04	0.04	0.04	0.07	0.09
Electronic	0.61	0.57	0.62	0.95	**1.02**	**1.15**	**1.06**	0.85	0.82	0.22	0.17	0.31	0.29	0.31	0.36	0.29	0.30	0.22
Office machinery	0.78	0.74	0.74	0.54	0.63	0.65	0.79	0.85	0.76	0.02	0.01	0.03	0.03	0.06	0.06	0.07	0.05	0.05
Instruments etc.	**1.49**	**1.44**	**1.37**	**1.32**	**1.32**	**1.34**	**1.35**	**1.43**	**1.40**	0.06	0.07	0.08	0.13	0.15	0.21	0.28	0.30	0.22
ICT total	**1.09**	**1.08**	**1.04**	**1.12**	**1.18**	**1.29**	**1.28**	**1.22**	**1.23**	0.10	0.10	0.15	0.18	0.16	0.18	0.16	0.19	0.21
	Italy									**Netherlands**								
Electro medical	0.13	0.17	0.20	0.21	0.27	0.27	0.26	0.24	0.22	0.58	0.82	0.77	0.77	**1.00**	**1.30**	**1.21**	**1.35**	**1.32**
Telecom. equipment	0.56	0.53	0.47	0.47	0.40	0.44	0.42	0.44	0.44	0.73	0.66	0.64	0.59	0.50	0.52	0.53	0.40	0.34
Consumer	0.24	0.19	0.19	0.18	0.17	0.17	0.17	0.12	0.12	0.44	0.40	0.39	0.39	0.37	0.40	0.52	0.47	0.47
Computers	0.75	0.72	0.66	0.66	0.57	0.51	0.44	0.35	0.32	**1.33**	**1.18**	**1.24**	**1.41**	**1.41**	**1.46**	**1.94**	**2.19**	**2.60**
Electronic	0.49	0.51	0.55	0.53	0.53	0.52	0.51	0.45	0.40	0.43	0.42	0.44	0.75	0.73	0.80	0.91	**1.04**	**1.04**
Office machinery	0.35	0.40	0.41	0.37	0.32	0.39	0.32	0.27	0.28	**2.27**	**2.27**	**2.40**	**2.25**	**2.72**	**2.73**	**2.75**	**2.85**	**2.73**
Instruments etc.	0.48	0.46	0.50	0.53	0.49	0.49	0.50	0.46	0.44	0.53	0.57	0.61	0.58	0.57	0.55	0.61	0.64	0.70
ICT total	0.53	0.51	0.50	0.49	0.45	0.45	0.41	0.37	0.34	0.85	0.79	0.81	0.91	0.91	0.95	**1.15**	**1.23**	**1.35**
	Sweden									**USA**								
Electro medical	0.69	0.58	0.59	0.63	0.49	0.66	0.51	0.46	0.98	**3.37**	**3.30**	**3.38**	**3.43**	**3.51**	**3.60**	**3.68**	**3.50**	**3.37**
Telecom. equipment	**3.08**	**3.15**	**3.12**	**3.48**	**3.75**	**4.23**	**5.12**	**5.39**	**5.21**	**1.40**	**1.39**	**1.41**	**1.49**	**1.47**	**1.46**	**1.30**	**1.26**	**1.19**
Consumer	0.16	0.14	0.12	0.12	0.16	0.18	0.19	0.17	0.28	0.37	0.35	0.35	0.33	0.36	0.35	0.38	0.38	0.40
Computers	0.70	0.66	0.59	0.39	0.28	0.23	0.23	0.21	0.20	**1.96**	**1.91**	**1.92**	**1.71**	**1.64**	**1.56**	**1.60**	**1.54**	**1.52**
Electronic	0.33	0.29	0.30	0.31	0.34	0.33	0.50	0.48	0.43	**1.38**	**1.25**	**1.27**	**1.32**	**1.48**	**1.62**	**1.66**	**1.71**	**1.84**
Office machinery	0.27	0.25	0.22	0.21	0.21	0.24	0.26	0.21	0.21	0.62	0.63	0.64	0.56	0.51	0.52	0.62	0.64	0.88
Instruments etc.	0.99	**1.05**	**1.02**	**1.00**	0.97	0.98	0.89	0.79	0.78	**1.55**	**1.58**	**1.56**	**1.57**	**1.56**	**1.55**	**1.55**	**1.57**	**1.58**
ICT total	0.83	0.82	0.80	0.80	0.85	0.93	1.11	1.20	1.19	**1.37**	**1.32**	**1.31**	**1.28**	**1.31**	**1.34**	**1.35**	**1.34**	**1.39**

Note: Electro medical is not included in the ICT total. Instruments etc. are instruments and equipment for detecting, measuring, checking and controlling physical phenomena or processes.
Source: Based on data from OECD (2000) *International Trade by Commodities Statistics, No. 1.*

It should be borne in mind that these results are sensitive to the methods used, such as level of aggregation, choice of year, etc., but that the specialisation patterns are generally fairly stable or 'sticky' over time (Dalum et al., 1998). The indicator is, for example, below one in the case of telecommunications for France, except for 1998 where it is above one (Table 3). The main feature of Danish telecommunications in the 1990s is that it was below

one apart from 19990 and 1998. However, the two examples from telecommunications indicate that further disaggregation of the data might reveal segments where these countries are specialised. Table 4 presents export figures for the large and rapidly growing mobile communications equipment segment of telecommunications in the 1990s. In this segment Denmark has been persistently specialised in the 1990s, while France and Germany entered a phase of specialisation only in the late 1990s.

Table 4 Export specialisation in mobile phones, 1990-1998.

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Denmark	**3.38**	**2.02**	**1.99**	**1.87**	**1.30**	**1.07**	**1.29**	**1.59**	**2.02**
Finland	**4.55**	**4.69**	**7.90**	**8.95**	**8.68**	**9.50**	**9.59**	**8.20**	**9.72**
France	0.62	0.67	0.35	0.53	0.48	0.65	0.85	**1.11**	**1.24**
Germany	0.68	0.64	0.55	0.60	0.95	**1.08**	**1.11**	**1.21**	**1.00**
Greece	0.03	0.05	0.03	0.05	0.11	0.11	0.19	0.26	0.48
Italy	0.57	0.67	0.65	0.49	0.25	0.27	0.20	0.19	0.20
Netherlands	0.08	0.06	0.09	0.11	0.10	0.11	0.08	0.11	0.08
Sweden	**3.83**	**4.45**	**4.96**	**6.17**	**6.08**	**7.23**	**7.75**	**8.05**	**7.50**
United Kingdom	**1.82**	**2.10**	**1.71**	0.90	**1.30**	**1.26**	**1.84**	**1.67**	**2.11**
USA	**1.99**	**2.07**	**2.36**	**2.45**	**2.00**	**1.68**	**1.26**	**1.16**	0.95

Note: Mobile phones are defined as SITC Rev. 3 code 764.32. The specialisation index is based on OECD (23).
Source: Based on data from OECD (2000) *International Trade by Commodities Statistics, No. 1.*

From this international comparison of the manufacturing segment of ICT it cannot be concluded that the relative weakness of Denmark is an isolated phenomenon in the EU. It also applies to such diverse countries as Germany (except for instruments), France, Italy and Greece. The cases of Sweden, Finland and the Netherlands illustrate that small country size is not an inhibiting factor in itself. What is important appears to be whether historical evolution of their respective national systems of innovation has led to the formation of large 'domestic' multinationals of the Ericsson-Nokia-Philips type. This was evidently not the case in Denmark.

Denmark has generally been characterised by a structure of small and medium sized ICT firms, as discussed in Dalum et al. (1988). In the mid-late 19th century and the early decades of the 20th century the Great Northern Telegraph Company was a large international player in telegraph technology, which might have become an embryo 'Danish Ericsson'. However, Great Northern never managed to enter telephone technology with the thrust that characterised Ericsson in Sweden and Siemens in Germany. In the early post World War II period Great Northern entered the emerging radio communications field through the acquisition of a small start-up, which was named Storno. This sector became the stronghold in Europe of Ericsson and Storno alongside Motorola and General Electric in the U.S. In the 1950s and 1960s Storno was the third largest producer world-wide, next to these two U.S. companies. Storno produced what is today known as 'closed' radio communications systems for police forces, airports, transport companies, etc. Storno and Ericsson were heavily involved in developing the path breaking Nordic Mobile Telephony (NMT) system launched

in 1981 as the worlds first cross international public (or 'open') mobile communications system, a predecessor of the successful GSM (Groupe Spéciale Mobile) system. While the early 1980s witnessed phenomenal growth of Nokia in Finland, originally based on mobile phone terminals, and later on entire systems, a 'counterfactual' discussion was ongoing in Denmark about whether or not, at a certain stage, a 'Danish Nokia' had been a real option.

There do not seem to be any 'basic laws' of economics that prevented another path of development for the Danish telecommunications industry. Although small, Storno was a world leading company, and a distinct research tradition in the wireless field had already emerged at the Danish Technical University in Copenhagen in the early decades of the 20th century. The Great Northern group sold Storno to General Electric (U.S.) in 1976, and the company was passed on to Motorola in 1986. Great Northern, like many other companies, could not in 1976 see the enormous market potential of mobile telephony. If it had the Danish ICT manufacturing landscape would have looked significantly different. Motorola used Storno as an entry port in order to become a more central player in the early stages of the GSM standardisation process, responsibility for which was assumed by a new European body, the European Telecommunications Standards Institute, ETSI, in 1987. To become a player in the ETSI context required a presence in Europe. As Motorola's European development arm, Storno managed to develop a GSM terminal in 1992 in line with Ericsson, Nokia and the north Denmark DC Development, a joint venture between two domestic mobile phone producers in the Aalborg region. Of the first four GSM phones developed two were developed in Denmark, one in Sweden and one in Finland. Motorola subsequently moved its GSM development activities to the U.S.; the two Aalborg firms were financially drained by the development effort, preventing them from entering a growth process of Ericsson-Nokia dimensions. However, mobile phone equipment has continued to be an area of specialisation in Denmark as can be seen from Table 4. The patterns for Sweden and Finland in the 1990s are remarkable, and Germany (Siemens) and France (Alcatel) have also become specialised. The USA, in spite of being home to one of the top three mobile phone producers, Motorola, had experienced a decreasing specialisation in mobile phones in the last half of the period. The lack of success of U.S. manufacturers in second generation (2G) mobile phone technology compared to European and Asian manufacturers would seem to explain this loss of specialisation.

In addition to mobile communications Denmark is specialised in the electro-medical equipment field, which is dominated by small and medium sized enterprises (SMEs), who have developed highly specialised niche products, often through intense collaboration with hospital doctors. This structure also characterises the instruments segment from the 1960s to the 1980s. The most important knowledge flows for these niche firms have generally been a combination of strong interaction with the users in the innovation process and strong links with university research.

While the trade data for ICT hardware can be used as a reasonable structural indicator in an international context, it is much more difficult to make international comparisons for the ICT service industries. During the 1980s and 1990s standardised - and machine independent - packages of software became very widespread. The U.S. (and Canada) have generally dominated this market through such companies as Microsoft (Windows, Word and Excel), Corel (WordPerfect), Lotus, SAS, SPSS and Oracle. At the less standardised end of the market U.S. companies such as EDS, Computer Associates (and the omnipresent IBM) have dominated the ICT services market through semi-standardised software packages, which have then undergone extensive modification by each company.

ICT services and consulting has been domestically oriented in most countries. Although software packages (and hardware) have become standardised, implementation and modification of large ICT service systems continued to be a bespoke business activity well into the 1990s. Packages such as Oracle and the German SAP have emerged as more standardised solutions for larger firms.

In the 1980s there were two main segments in ICT services and consulting. Mainframe-based service suppliers comprised a mix of affiliates of large U.S. hardware companies (especially IBM) and U.S. (such as EDS) and national consultancy companies. In the Danish case, the latter segment was composed either of large domestic companies (such as Maersk Data, ØK Data and LEC) or banks (PBS, Bankdata, SDC) and government organisations (Kommunedata and Datacentralen). Following the emergence of microcomputers an entire segment of PC distributors evolved.

Due to the typically rather centralised administrative procedures of government in Denmark, the mainframe-based service suppliers (whether private or government owned) tended to be dominant during the 1980s. But during the 1990s application of the first stand-alone PCs and then PC networks and the Internet gave rise to the emergence of a 'dotcom' segment. In Denmark, this segment never matched that of Sweden in the 1990s (represented by such high flyers as Framfab, Icon Media Lab, Cell Network and Adcore). The government-owned Kommunedata and Datacentralen in Denmark were privatised at the end of the 1990s. Kommunedata (IT solutions for the municipal administrations), now named KMD, underwent privatisation but without being changed fundamentally. Datacentralen was sold to CSC (a large U.S. IT consultancy company). These two companies are quite big, even in an international context, but very much oriented towards the domestic market.

A small segment of software applications emerged in the 1990s. Two firms, Navision and Damgaard Data, managed to develop total IT solutions for SMEs in terms of standardised packaged software with a certain international market presence. These two firms merged to become Navision-Damgaard, which became internationally known and was subsequently acquired by Microsoft, who wanted to enter this software segment.

The mainframe-based IT service firms experienced tremendous pressure during this period from PCs and network distributors. During the 1990s, by solutions based on PCs, to an increasing extent connected in networks, were substituted for mainframe based solutions. However, by the end of the 1990s and at the beginning of the 2000s, these two groups of actors increasingly converged. A trend towards IT solutions based on PCs in networks, with a centralised structure for servers and software, has changed the direction of development once again. Due to the heavy financial pressure on the sector from the beginning of 2000, substantial restructuring took place and this is still ongoing in 2004. The trend would appear to be towards a small group of firms capable of delivering, and even managing, total IT solutions for private firms as well as government authorities. The firms in the segment have been converging with the old mainframe-based IT consultants to become a group of 'complete service and network suppliers'. Many of these firms, for example, Aston Group, Eterra and WM Data, which all grew out of distribution of PCs and standardised (U.S.) software packages, have experienced severe economic problems and some have filed for bankruptcy. The dotcom segment has been shrinking rapidly due to the crisis in the IT sector and the cut in IT spending.

The structural change is still ongoing[13], but without reservation it can be concluded that the Danish IT service and consulting segment is not, and will not be, a major international player. This would hold even if the telecommunications service segment was included as assumed by the term ICT services. The telecom service sector accounts for 16% of total ICT employment in Denmark (Table 1), but is domestically oriented. The one-time government monopoly company, TDC, employed more than 16,000 persons, but was not a major international player. It was acquired by U.S. Ameritech in 1998, which itself was taken over by SBC.

The mobile communications segment has similar characteristics. The biggest company is TDC, followed by the Aalborg-based company, Sonofon, owned by Norwegian Telenor. The mobile service providers (including also affiliates of large foreign companies, such as Telia and Orange) are technically fairly advanced in an international context. But they are not large companies and they have basically become dominated by foreign multinationals.

To summarise: The general impression of an internationally rather weak Danish ICT sector appears well founded.

[13] Maersk Data and DM data has been taken over by IBM in late 2004.

4 What lies behind the relative weakness of the Danish ICT sector

What are the major factors behind this pattern? As a first step towards answering this, data on the ICT education structure will be analysed. The Danish higher education system and especially the system for training skilled workers, are generally considered to be high standard. Table 5 presents some basic data from the Education at a glance 2000 report (OECD, 2000).

Table 5 Percentage of population aged 25 to 64 by level of educational attainment, 1998.

	Primary and secondary education		Post-secondary tertiary education		Graduates in science and engineering (% of employment)
	Below upper	Upper	Education of at least two years, focusing on practical skills	Education of at least three years theoretical duration	
Finland[1]	32	39	17	13	0.08[2]
Sweden	24	48	15	13	0.07[3]
Denmark	**22**	**53**	**20**	**5**	**0.04[2]**
France	39	40	10	11	0.16[4]
Germany	16	61	9	14	0.09[2]
Greece[1]	54	30	4	11	0.06[4]
Ireland	49	30	10	11	0.25[3]
Netherlands	36	40	0	24	-
United Kingdom	19	57	8	15	0.19[2]
EU	46	57	10	12	0.12
OECD	38	44	8	14	0.09

[1] 1997. [2] 1995. [3]1996. [4] 1993.
Source: Adapted from OECD (2000) Appendix table 7, based on OECD (2000).

As can be seen from Table 5, Denmark has a high proportion of the population with upper secondary as well as post-secondary practically-oriented education. However, the shares of graduates with at least three years of study, and of graduates in science and engineering are rather low. But these data are somehow disputed. Education at a Glance 1998 used a different method of classification, categorising into non-university and university level education. In both these categories, Denmark performed better than the OECD average[14].

The Nordic Statistical Institutes (1998; 2000) efforts to produce comparable data on ICT activities represents a step towards international comparisons at the detailed level, as shown in Table 6. The high numbers of university educated employees in the Nordic ICT industries are striking. The close similarities in their education systems are probably the reason for this. However, Table 6 shows that Denmark is systematically ranked below its fellow Nordic countries. Finland has by far the largest proportion of higher educated employees in ICT among these four countries.

[14] See Appendix Table 2.6.1.in OECD (1999)

The relative small, and internationally weak, ICT sector in Denmark is explained in part by the small numbers of engineers and computer scientists being produced.

Table 6 Percentage of employees in ICT with tertiary education[1], 1998.

	Denmark[2]			Norway[3]			Finland	Sweden
	Non-university tertiary	University-level tertiary	Total tertiary	Non-university tertiary	University-level tertiary	Total tertiary	Non-university and university tertiary	Non-university and university tertiary
ICT manufacturing	8	17	25	14	24	38	45	37
ICT services	7	20	27	19	24	43	52	47
Wholesale of ICT products	8	16	24	16	13	29	51	35
Telecommunications	4	13	17	19	21	40	44	28
ICT Services and Consultancy	6	31	37	22	35	57	59	62
Total manufacturing[4]	5	8	13	7	7	14	24	18
Total services Activities[5]	4	11	15	12	11	23	31	24
Total private sector[6]	4	9	13	10	9	19	28	21

[1] Tertiary education is equal to ISCED level 5 (Non-university tertiary education) and ISCED Level 6 and 7 (University-level tertiary education). [2] 1996 level. [3] 1999 level. [4]Total manufacturing (NACE 15-37). [5] Total services activities (NACE 50-74, 92). [6] Total private sector (NACE 15-37, 45, 50-74, 92, 93).
Source: Based on Nordic Statistical Institutes (1998) and Nordic Statistical Institutes (2000).

There are two technical universities in Denmark producing engineers in electronics, at the bachelor (diploma engineers), masters and PhD levels: the Technical University in Copenhagen (DTU) and Aalborg University (AAU). DTU has been internationally known in electrical engineering for two centuries. AAU, founded in 1974, became quickly established in electronics, and was responsible for educating half of the Danish masters' students in electronics from the early 1990s. There is also a system of decentralised engineering schools, providing bachelors training in electrical engineering, which were originally set up to offer a higher education opportunity for skilled workers to follow a tailor made admissions programme. There are six such schools. Computer scientists are trained at the Copenhagen, Aarhus and Aalborg universities, and the University of Southern Denmark has recently started a programme in electrical engineering. The country is thus well provided with institutions capable of educating the relevant manpower; the problem is that too few students want to take these degrees - in spite of increased job opportunities in the second half of the 1990s[15].

The relative distribution of R&D expenditure within manufacturing industries is shown in Table 7 for a group of small advanced OECD countries, as well as for the entire OECD. The

[15] A phenomenon experienced in other western European countries as well in this period.

data also include a comparison according to four levels of R&D intensity.

Table 7 R&D specialisation in manufacturing for selected small OECD countries

	OECD-14[1]		Denmark[2]		Sweden		Netherlands		Finland	
	1990	1995	1990	1998	1990	1995	1990	1996	1990	1998
Food, beverages, tobacco	2.0	2.0	3.5	3.1	1.0	0.7	2.9	3.7	3.4	1.2
Textiles and clothing	0.6	0.6	1.0	0.2	0.6	0.4	0.8	0.8	1.6	1.2
Wood and furniture	0.2	0.4	1.8	0.8	0.5	1.0	0.0	1.4	5.1	2.3
Paper and printing	11.5	1.3	0.5	0.3	3.6	2.4	0.4	0.6	8.7	3.2
Chemicals	21.2	21.6	1.4	1.6	0.9	0.9	1.8	1.5	1.0	0.6
Pharmaceuticals	*7.6*	*9.6*	*3.1*	*3.1*	*1.8*	*1.7*	*1.1*	*1.2*	*0.7*	*0.4*
Non-metal mineral products	1.2	1.1	1.8	0.7	0.5	0.5	0.3	0.5	1.8	0.9
Basic metals	2.1	1.8	0.7	0.3	1.0	0.8	0.7	1.2	1.7	0.8
Metals and machinery[3]	71.1	70.7	0.7	0.7	1.0	1.0	0.7	0.8	0.8	1.1
Non-electrical mach.	*6.0*	*7.1*	*2.6*	*3.2*	*2.3*	*1.7*	*0.5*	*0.5*	*2.3*	*1.7*
Computers	***9.8***	***7.1***	***0.3***	***0.2***	***0.3***	***0.2***	***0.4***	***0.7***	***0.3***	***0.1***
Telecom & semiconductors	***14.5***	***16.3***	***0.7***	***0.6***	***1.9***	***1.4***	***1.1***	***0.9***	***1.3***	***3.1***
Shipbuilding	*0.1*	*0.2*	*21.5*	*13.0*	*2.9*	*0.5*	*1.0*	*1.1*	*10.2*	*1.4*
Motor vehicles	*12.6*	*14.4*	*0.0*	*0.0*	*1.3*	*1.3*	*0.4*	*0.5*	*0.1*	*0.0*
Aerospace	*14.4*	*10.7*	*0.0*	*0.0*	*0.4*	*0.5*	*0.1*	*0.2*	*0.0*	*0.0*
Scientific instruments	*4.9*	*7.3*	*2.4*	*1.2*	*0.2*	*1.1*	*0.2*	*0.2*	*1.1*	*0.6*
Other manufacturing	0.6	0.6	14.4	12.1	0.4	0.2	0.0	0.2	0.8	1.0
Total manufacturing	100.0	100.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
High-tech industries	46.5	43.8	0.8	0.9	1.1	1.1	0.7	0.8	0.6	1.3
Medium-high technology	40.7	44.1	0.9	0.9	1.0	1.0	1.4	1.1	1.0	0.6
Medium-low technology	9.0	8.0	1.9	1.8	0.6	0.6	0.8	1.0	1.7	1.1
Low technology	3.7	4.2	2.3	1.7	1.6	1.2	1.8	2.2	4.8	2.0
Total manufacturing	100.0	100.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

[1] Distribution of OECD R&D manufacturing expenditure. [2] The national distribution divided by the OECD distribution. The weighted average per country is equal to 1.0. If above 1 the countries is 'R&D specialised' in the given industry and vice versa if below 1. [3] Not all sub-groups are shown.

Note: Sub-groups are shown in italics.

Source: Adapted from OECD (2000) Appendix table 28.

The Danish (and Dutch) emphasis on food processing related R&D is outstanding with a share three times as large as the OECD average of 2%. The relative specialisation in pharmaceuticals R&D is also approximately 3, but this represents 30% of Danish R&D expenditure in manufacturing. Conversely, Danish R&D efforts in ICT manufacturing are generally very small in an international context. A more direct indicator is the OECD measure of ICT research in total business enterprise expenditure on R&D (OECD, 2000, Table 14). Denmark lagged behind the 14 most developed OECD countries in 1997 with a share of 7.2% and was also at the lower end in terms of business sector share of R&D for communications services (telecom services).

The high degree of concentration of R&D expenditure on a few industries for the small high-income OECD countries shown in Table 7 is quite clear. In Finland the increase in specialisation from 1.3 to 3.1 in telecommunications equipment & semiconductors reflects that this industry accounted for 50% of Finnish manufacturing R&D in 1998, basically due to

the very rapid growth of Nokia. For Sweden, the dominance of Ericsson is less outstanding, although this industry contributes with more than 20% of Swedish manufacturing R&D[16].

From the innovation data, the available evidence on Danish ICT patenting in the 1990s presented in Table 8 also indicates a rather low relative share vis-à-vis the OECD countries considered, as well at the entire group of OECD and EU countries. The share, as well as the average annual growth rate for 1992-98, are very low. However, comparison of the 1992-98 and 1992-99 growth rates indicates underlying data problems - probably small number problems - which may disturb the pattern substantially.

Table 8 ICT patents granted at the United States Patent Office.

	Share of ICT patents in total			Growth rate 1992-98	Growth rate 1992-99
	1992	1998	1999		
Finland	6.0	29.0	30.4	41.7	31.8
Sweden	7.3	16.8	16.9	28.2	23.2
United States	8.8	18.4	17.5	21.5	16.6
Ireland	14.2	24.4	16.5	17.3	11.7
Netherlands	10.2	16.6	14.4	15.2	10.3
Japan	14.1	21.0	18.5	13.2	8.9
Denmark	**6.4**	**3.1**	**6.3**	**0.0**	**13.0**
European Union	6.2	11.0	10.4	15.7	12.5
Total OECD	9.5	17.6	16.4	18.6	14.1

Source: Adapted from OECD (1999), Appendix Table 11.3.1 for 1992 and 1998; OECD (2000) Appendix Table 36 for 1999.

Finland has experienced the highest growth among the countries shown with 30% average annual growth in the 1990s. The ICT sector accounted for almost one-third of total patenting in 1999. The Swedish pattern has been somewhat similar, but not so pronounced. The reason is evident: there are no 'domestic' large ICT multinationals in Denmark. Nokia and Ericsson have been exceptionally aggressive in patenting activities in mobile communications related technologies, while the Danish ICT sector is dominated by small R&D oriented firms with a low propensity for patenting. Denmark could be described as a development 'hub' especially for terminals for wireless (mobile, cordless and satellite) communications, equipment for optical communications and highly specialised electronic measurement equipment. This type of equipment is typically developed by local R&D units of large multinationals, which probably result in patents being taken out by the headquarters outside Denmark. Alternatively, the innovations may come from small firms contracted by large multinationals. In this case the process does not typically result in a patent application.

However, innovation data based on a Danish questionnaire carried out in relation to the DISKO project (Lundvall, 1999) contain a data set on innovative activity, on which Table 9 is based, on a sample of 1910 firms. As a rough illustration of variations in propensities to

[16] The relation between the patterns of R&D versus export specialization (Figure 3 and Figure 7) is rather striking.

innovate across different clusters, firms reporting product innovations in the DISKO panel data have been aggregated into five of the EFS mega clusters.

Table 9 Relative number of product innovative firms in five EFS mega clusters, 1993-95.

N=1910	Product Innovation	No product innovation	Total	N
ICT MC	75.1%	24.9%	100%	249
Medico/health MC	57.8%	42.2%	100%	93
Agro-food MC	52.4%	47.6%	100%	248
Construction MC	38.3%	61.7%	100%	517
Total Economy	50.4%	49.6%	100%	1910

Note: The DISKO data set contains questionnaire data from a sample of 1910 firms, representative the private sector of the Danish economy.
Source: Based on data from the DISKO panel data 1993-1995.

According to this source the ICT mega cluster has by far the highest rate of product innovation, as more than 75% of the ICT firms have produced a product innovation. Only half of the DISKO firms have produced product innovations. The reported product innovations might not all have been patented. This indicates that the product innovation dynamics of the ICT sector are quite strong, at least compared with other parts of the Danish economy.

5 ICT consumption pattern

A substantial amount of data on the use of ICT equipment indicates that the markets of the small rich countries - as well as the U.S. market - represent the most advanced demand. This is typically illustrated by per capita penetration ratios in such fields as Internet connections, mobile phones, PCs in homes, etc. (see, for example, OECD, (1999; 2000, appendix tables 4-6)).

Among the small countries this especially applies to the Nordic area. The mobile communications field represents a now classic case of close interaction between advanced demand characteristics, institutional set up, regulation and international competitiveness of the supplier industries - that is, the very essence of the factors emphasised in cluster analysis.

The establishment of the Nordic Mobile Telephony System (NMT) in 1981, through a cooperation between the Nordic telecom service providers and the regulatory authorities, created the first ever cross-border market for public mobile telephony, based on a common standard. This was decisive in the Nordic firms (Ericsson, Nokia and the U.S.-Danish Storno) becoming world leaders in mobile communications equipment from the early 1980s. This strong competitive position was strengthened further when the pan-European GSM standard, now the dominant world standard, was implemented in 1992. In the late 1980s the Nordic companies and authorities, with Nokia and Ericsson acting as the leading architects to a substantial degree, influenced the GSM standardisation process. The largest producer of

mobile terminals at the time, Motorola, acquired Storno in Denmark to avoid being excluded from this important process.

The story has to a large extent been repeated in the 1997-98 specifications for the third generation (3G) mobile communications system, Universal Mobile Telecommunication System (UMTS), which also was dominated by Ericsson and Nokia. The development of the mobile communications industry is probably one of the most clear 'textbook' examples of cluster dynamics. Previously, the Nordic countries were the 'lead-users', which no longer will be the case. The allocation of UMTS licences in Europe in 2000 was very turbulent, resulting in rocketing costs to the telecom service providers to become licence holders. The ensuing financial crisis in the telecommunication services sector, accompanied by large scale redundancies and reduced expectations for 3G communications has marred the introduction of 3G in Europe. The massive investments required to build the 3G infrastructure combined with the deep financial problems of the telecommunications sector in general (the equipment hardware industry as well as telecommunications services) has caused the establishment of 3G networks and introduction of 3G phones to be delayed and postponed all over Europe. Nevertheless, in spite of these problems, 3G services have been introduced in several European countries: in Denmark services were introduced in October 2003 but it seems that the previous advantage of being an early advanced user has been lost.

Given the advanced nature of demand in the Nordic region concerning the use of ICT products and services, it might be expected that a similar position could emerge in relation to the new software development and IT service industries, including the dotcom segment. On the international scene, the Nordic area in this respect has been characterised as "...leading Europe in the technology revolution that will dominate the early years of the 21st century" (Financial Times, 2000) Besides the Nordic lead in mobile communications consumption, the Swedish Internet service segment grew very fast in the late 1990s, both on the consumption and the supply side. A large number of new dotcom firms emerged with some international visibility. The Swedish government encouraged the diffusion of high-speed Internet connections more than did the governments in other comparable countries. Subsequently, there has been a rather dramatic international downturn for the dotcom industry, which has hit Sweden especially hard. The general characteristics of the leading role of the Nordic countries may still persist, but they would appear to be basically founded on their strengths in the wireless segment.

Denmark has been lacking behind on the supply side, basically reflecting a 'lack-of-Ericsson-Nokia' effect, and also on the consumption side in relation to high-speed Internet access. However, during the last couple of years the diffusion of Internet connections has been very fast. Especially the number of Asymmetric Digital Subscriber Line (ADSL)

connections has grown from 26,000 in ultimo 2000 to 562,000 in medio 2004[17]. In international comparisons of penetration and availability ratios, Denmark is now usually found among the best in Europe (see e.g. Ministry of Research and Information Technology, 2004). ADSL connections are available in all Danish municipalities, and available to 96% of all households and firms (Ministry of Research and Information Technology, 2004)[18].

In international comparisons of ICT performance the supply and demand side indicators are often combined with general macroeconomic indicators. This may give rise to confusion concerning the competitiveness of the various sub-segments of the ICT sector per se. One example of this is in a consultancy report by PLS Ramboell and Boersens Nyhedsmagasin (2000). Ten western countries were benchmarked, using statistical data and the peer judgments of 170 experts in the 10 countries. Table 10 shows the benchmark of the statistical indicators. The data contain information on ICT applications as well as R&D efforts, expenditure on IT education, macroeconomic stability and performance, characteristics of the capital and labour markets, etc.[19] There is a group of clear 'front runners' (USA, Sweden and Finland); Denmark is among a group of 'followers' along with UK, Norway and the Netherlands, while the 'main group' is comprised of France, Germany and Spain.

[17] Based on data from http://www.itst.dk

[18] The numbers indicate that Denmark is doing well in respect to IT infrastructure, but this is only a partially correct picture, since the existing infrastructure is insufficient for the future demand. This is analyzed in Chapter 10.

[19] Specified in more detail in appendix Table 14.

Table 10 Overall performance of Danish ICT on a benchmark of statistical indicators.

	Total score	Un-weighted average	ICT labour force	ICT infrastructure	ICT education	Techno-commercialisation	Technology absorption	Globalisation	Capital markets	B2B e-commerce	Network culture	ICT consumers	Macro economy	Flexible labour market
U.S.	68.5	7.3	9.0	6.8	3.0	8.5	9.0	2.7	8.3	10.0	10.0	8.4	5.6	6.3
Sweden	67.4	7.2	3.3	8.0	6.5	8.5	8.0	9.7	4.5	9.0	7.0	8.8	7.1	5.7
Finland	63.2	6.7	7.3	5.4	7.5	8.0	6.0	6.3	6.5	7.0	5.0	7.4	7.3	6.7
Netherlands	58.8	6.2	5.0	6.8	8.5	6.5	5.0	6.7	6.3	3.0	9.0	5.4	5.9	6.7
Norway	53.2	5.6	6.3	6.2	4.5	3.5	10.0	5.0	3.3	6.0	6.0	6.2	5.7	5.0
UK	49.5	5.3	4.0	6.2	2.5	5.0	4.0	4.0	8.8	8.0	8.0	5.8	3.6	3.3
Denmark	**47.6**	**5.1**	**2.0**	**7.6**	**5.5**	**2.5**	**7.0**	**7.3**	**2.5**	**5.0**	**4.0**	**5.0**	**6.0**	**6.3**
France	45.7	4.8	7.8	3.0	7.0	6.0	3.0	6.7	6.3	2.0	3.0	1.8	4.9	6.0
Germany	38.1	4.0	5.3	4.2	6.0	2.5	1.0	3.7	4.8	4.0	2.0	4.6	5.6	5.0
Spain	28.0	2.9	5.3	1.0	4.0	4.0	2.0	3.0	4.0	1.0	1.0	1.6	3.9	4.7
Weight			0.83	0.82	0.82	0.77	0.77	0.76	0.75	0.70	0.68	0.66	0.64	0.62

Note: See appendix Table 14 for explanation of the benchmark indicators. Total scores weighted according to the global importance of the indicators.
Source: Adapted from PLS Ramboell Management & Boersens Nyhedsmagasin (2000), p. 31.

Bearing in mind the caveats that apply to this kind of methodology, it seems to fit the pattern described above. Denmark appears to be fairly well positioned to exploit the business opportunities in ICT from the point of view of demand, but not to the extent of, say, Sweden and Finland.

6 Regionally clustered strong niches in the ICT sector

Generally, there are two factors that determine the geographical distribution of the ICT sector. It should be expected that among the major location factors is a 'metropolis' effect. Many of the ICT service activities, such as software development, IT services and telecom services, are typically concentrated in cities. This also applies to the supply of skilled labour, such as engineers, computer scientists, business economists, etc., which again are expected to be a function of location of universities and business schools, often determined by government decisions.

The second factor is the somewhat 'random' location of firms, which is based on the preferences of their the original founders. This emphasises the combination of a 'random' initial triggering events (such as individual founder preferences) and subsequent cumulative causation effects (mainly via external economy effects on the labour market) leading to concentrations of related industries, that is, geographical clusters. As an indicator of relative specialisation, employment share of a given activity in a region may be compared with the

national average[20]. Measured in this way, only two regions are seen to be specialised in the ICT sector in 1992 and these are the regions around the two largest cities, Copenhagen and Aarhus[21]. At municipality level, the same specialisations appear in ICT around Aarhus, Copenhagen, and north of Copenhagen, but with additional single dots spread across the country, shown in Figure 3 in Chapter 2 as the grey and black regions. The third and fourth largest cities, Aalborg and Odense, are not specialised, but a map of share of total ICT employment, Figure 4 in Chapter 2, shows that ICT employment is concentrated in the larger cities[22].

During 1992-2002 employment in Danish ICT grew by 32% to 108,000. In comparison, total private sector employment grew by 5% in the period. Figure 3 in Chapter 2 depicts the regional ICT employment specialisation pattern for 2002. The picture is complex but there seems to be a grouping around three of the Danish university cities, Copenhagen, Aarhus and Aalborg, but not Odense. It also shows several localities with specialisation mainly based on single firms with individual strengths, for example, Bang & Olufsen (high end consumer electronics) in Struer, and Jamo (loudspeakers) in Sallingsund.

The development from 1992 to 2002 shows a fairly persistent geographical pattern of specialisation, but also a tendency towards higher specialisation in the larger cities. The concentration in the cities can also be seen in Figure 4 in chapter 2. It shows the share of total ICT employment at municipality level in 2002, which has been generally stable, located in the large cities. In 2002, the third largest city in Denmark, Aalborg was specialised in ICT employment, partly due to the emergence of a coherent telecommunications cluster in North Jutland, centred around wireless communications equipment, see Figure 3 in Chapter 2. The presence of the cluster can also be seen in Figure 4 and Figure 3 in Chapter 2 where the small municipality of Pandrup is marked with more than 1% of the total ICT employment due to the localisation of a large manufacturer of mobile phones. This strong specialisation emerged from the mid-1960s in maritime communications and diversified into mobile communications at the beginning of the Nordic Mobile Telephone System boom from 1981. The cluster accounts for more than half of the total ICT employment in the North Jutland County.[23]

[20] A value larger than 1 indicates an above average employment share - that is, the region is 'specialized' in that activity, and vice-versa.

[21] There are 16 counties in Denmark. Employment data (full time and part time) for 1992 are available from Statistics Denmark for 4-digit and 6-digit NACE codes. The 'Copenhagen Region' is interpreted here as the counties of Copenhagen, Frederiksborg and Roskilde as well as the municipalities of Copenhagen and Frederiksberg. The latter municipality was not specialized in ICT in 1992.

[22] The ICT sector in Figure 3 and Figure 4 in Chapter 2 is defined as NACE/DB (93): 3001, 3002, 3130, 3210, 3220, 3230, 331020, 331030, 331090, 3320, 3330, 514320, 516410, 516520, 6420, 713310 and 7200

[23] The Danish wireless communications equipment sector also consists of other large firms, such as Thrane & Thrane (maritime and satellite communication equipment) and Nokia Denmark (R&D in mobile phones). The latter employs more than 1,200 mainly working with R&D.

The figures and the development from 1992 to 2002 clearly point to ICT being mainly, but not exclusively, a 'city' industry. A closer look at the different ICT segments (see definition in Table 1 in Chapter 2.) reveals that both the Copenhagen and the Aarhus regions are specialised in IT services. Copenhagen, Roskilde, Frederiksborg and Aarhus counties are specialised in seven of the ten ICT segments, see Table 5 in Chapter 2. Further observations of high specialisation among the ICT segments points at the existence of other interesting concentrations of firms. In the county of Vejle (around the town of Horsens) there is strong specialisation in the manufacture of electronic components and wire. Further, Ringkoebing County is specialised in manufacture of consumer electronics with the location of the big (in a Danish context) consumer electronics firm, Bang & Olufsen. Lastly, there is a strong specialisation in Western Zealand in the manufacture of electronic components and wire, which mainly can be attributed to the location of the large producer, NKT.

Telecom service provision is concentrated in Copenhagen and Aarhus. This is a direct effect of the location of the major service providers (cable as well as wireless) - Tele Danmark, Sonofon, Telia and Orange, all with headquarters in Copenhagen, although most of Sonofon's employment is located in North Jutland.

Another cluster has emerged in the Copenhagen are in equipment for optical communications equipment. The optical communication cluster in Copenhagen is based on research at DTU. This led to the formation of NKT Elektronik, which - together with DTU - produced a group of firms and spin-offs. The largest company was Lucent Technologies Denmark, which was sold to a Japanese company in 2001, as a result of the financial crisis being experienced by the large international telecom companies, and which hit AT&T-Lucent rather hard. In spite of this, the Copenhagen cluster appears to have growth potential. This can be traced at the most detailed level of the OECD export specialisation pattern. Denmark was specialised in 'optical fibre cables' in 1990 (SITC Rev. 3 773.18, c.f. in the appendix), and then in 1993-98 in SITC 884.19.[24] Such patterns are hard to detect in the statistical sources, in this case because optical fibers have not traditionally been considered to be 'electronics'.

As can be seen a 'metropolis' effect is prevalent in the regional specialisation pattern of ICT activities. At the more detailed industry level, however, there is a certain degree of geographical diversification, which may be somehow related to the rather decentralised nature of the public education system.

There is, thus, a close correlation between the distributions of basically government financed R&D and higher education institutions in ICT and the regional distribution of private employment in Denmark. Engineers and computer scientists typically choose jobs close to these institutions. More specialised small-scale clusters usually emerge around these.

[24] The indicator was above 2 for 1997-98. A reclassification of the export data has apparently been made between 1992 and 1993.

This pattern has major implications for policy. To further encourage the development of ICT activities, a coordinated policy approach to such fields as research and higher education, specialised venture and seed capital, and regional development of the necessary infrastructure facilities (science parks, telecommunications networks, general transport facilities, etc.) are important.

7 Conclusion

The most obvious constraint on the future development of ICT in most western countries is the fundamental lack of qualified labour. During the early 1990s the intake of new students to engineering schools and business schools in Denmark decreased. However, between 1995 and 2000 the intake of students to IT-related university programmes increased from 1,750 to 5,500. In 1999 two new institutions, the IT-High School in Copenhagen and IT-West, started R&D and education with an enrolment in 2000 of more than 800 students. A dedicated science park and buildings for the IT-High School are part of the new Oerestad project in Copenhagen[25].

At the national level a major initiative has been launched by the Ministry under the label 'The Digital Denmark'. This initiative was first presented in a report in 1999 with five ambitious goals (Ministry of Research and Information Technology, 1999). One of these goals is the establishment of 'IT-lighthouses' in two different regions in Denmark. These types of initiatives are inspired by several major investments in regional growth centres in other countries[26]. Massive investments in ambitious projects in other countries have resulted in the establishment of special high growth regions for ICT businesses. These regions are now powerful magnets for high technology businesses, which agglomerate and cluster in these regional growth centres. A strong physical concentration of innovative environments of knowledge and education institutions has determined these developments.

The goal of the lighthouse projects is to stimulate the formation of ICT businesses in connection with knowledge and education institutions. The two Danish ICT lighthouses are located in North Jutland and the Copenhagen Oerestad region. The presence of the small-scale cluster in wireless communications in North Jutland is the main reason for the location of one of these projects; the major concentration of ICT activities in the Oeresund region and the deliberate, and high profiled, efforts to let this region become much more visible at the international scene, was decisive in the second case[27].

[25] For further details see Ministry of Research and Information Technology (2000). The science part has not been realized.
[26] Silicon Valley (U.S.), Information Age Town (Ennis, Ireland), Oulu Technopolis (Northern Finland) and Kista Science Park (Near Stockholm, Sweden).
[27] An indication of the success of these efforts is illustrated in a ranking of the Oeresund region among the high tech valleys worldwide in Wired Magazine (2000, pp.259-271).

Another striking feature of the ICT industry in Denmark the dominance of foreign ownership in a significant part of the Danish ICT sector, not least in those sub-industries displaying very fast technological development. This is apparently an indication of lack of investors willing to take the high risks, which are inevitable in the ICT field. The amount of seed and venture capital and the structure of their supply are issues that need to be influenced through policy, perhaps via government guarantees for high-risk investments in new technology start-ups[28].

However, among the governments of most of the well developed countries there has been an avowed intention to become 'the IT power house of the next millennium'. In the Danish context the Network Report (Ministry of Research and Information Technology, 2000) contains a rather extensive arsenal of already initiated activities as well as a series of proposals. The political intentions of government have been restated in two reports from the Ministry of Research and Telecommunications in 2001. However, this chapter has pointed to some serious handicaps to Denmark's achieving such a goal, basically in connection with the supply side. The problem appears to be rather fundamental: the lack of a large 'domestic' multinational ICT company is a serious problem for a small country. In some cases this might have been compensated for by the emergence of small and medium sized R&D oriented ICT firms, but too few have emerged during the 1990s - in spite of rather favourable economic conditions[29]. The challenges for Denmark appear to be great, given the present structure of the ICT sector.

[28] Two new major seed funds (organized as private companies) have been founded, financed jointly by government funds and private finance. One is based in the Copenhagen region and oriented towards biotechnology and pharmaceuticals. The other is part of the Aalborg University Science Park, NOVI with emphasis on ICT projects.

[29] In "Danmark.com" PLS Rambøll Management and Børsens Nyhedsmagasin (2000) have mapped a large amount of new Internet start up firms. The field appears to flourish, but nonetheless very few, if any, major international players have appeared.

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9 Appendix

Table 11 ICT definition

NACE	Description
3001	Manufacture of office machinery
3002	Manufacture of computers and other information processing equipment
3130	Manufacture of insulated wire and cable
3210	Manufacture of electronic valves and tubes and other electronic components
3220	Manufacture of radio and television transmitters & apparatus for line telephony/telegraphy
3230	Manufacture of radio and television receivers, sound/video recording or reproducing apparatus and associated goods
3320	Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes (except 3330)
3330	Manufacture of industrial process control equipment
5143+5164+5165	Wholesale of ICT equipment
6420	Telecommunications
7133	Rental and leasing of ICT equipment
7210	Hardware consultancy
7220	Software consultancy and supply
7230	Data processing.
7240	Database activities
7250	Maintenance and repair of office, accounting and computing machinery
7260	Other computer related activities

Source: Based on Nordic Statistical Institutes (1998).

Table 12 Segmentation of the ICT sector in NACE codes.

Activity	Segment	NACE	Description
Hardware manufacturing	Computers	3001	Manufacture of office machinery
		3002	Manufacture of computers and other information processing equipment
		3130	Manufacture of insulated wire and cable
	Communication Equipment	3210	Manufacture of electronic valves and tubes and other electronic components
		3220	Manufacture of radio and television transmitters and apparatus for line telephony/telegraphy
		3230	Manufacture of radio and television receivers, sound/video recording or reproducing apparatus and associated goods
	Instruments	3320	Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes (except 3330)
		3330	Manufacture of industrial process control equipment
Services	Wholesale	5143	Wholesale of electrical household equipment appliances and radio and television goods
		5164	Wholesale of office machinery and equipment
		5165	Wholesale of other machinery for use in industry, trade and navigation
	Telecommunications	6420	Telecommunications
	ICT Services and Consulting	7133	Rental and leasing of ICT equipment
		7210	Hardware consultancy
		7220	Software consultancy and supply
		7230	Data processing.
		7240	Database activities
		7250	Maintenance and repair of office, accounting and computing machinery
		7260	Other computer related activities

Source: Adapted from Dahl and Dalum (2001).

Table 13 ICT segments in SITC rev. 3 compared with NACE

NACE	SITC rev 3.	Product
Telecommunications equipment		
3130	773.18	Optical fiber cables
3220	764.11	Telephone sets
3220	764.13	Teleprinters
3220	764.15	Telephonic or telegraphic switching apparatus
3220	764.17	Other apparatus for carrier-current liner systems
3220	764.19	Other telephonic or telegraphic apparatus
3220	764.31	Transmission apparatus
3220	764.32	Transmission apparatus with reception apparatus
3220	764.82	Television cameras
3220	764.91	Parts and accessories for apparatus of heading 7641
3230	764.93	Parts and accessories of 761, 762, 7643, 7648
3320	764.83	Radar, radio-navigat. aid, remote control apparatus
3320	874.77	Other instrum. & apparatus for telecommunications
Consumer electronics		
3230	761.1	Televis. receivers, colour, whether or not combined
3230	761.2	Television receivers, monochrome, combined or not
3230	762.11	Radio, external source of power, vehicles, combined
3230	762.12	Radio, external source of power, vehicles, non-combi.
3230	762.21	Radio, without external source of power, combined
3230	762.22	Radio, without external source of power, non-combin.
3230	762.81	Other radio receivers, combined with sound reprodu.
3230	762.82	Other radio receivers, combined with a clock
3230	762.89	Other radio-broad-cast receivers, non-combined
3230	763.31	Record-players, coin- or disc-operated
3230	763.33	Other record players
3230	763.35	Turntables (record-desks)
3230	763.81	Video recording or reproducing apparatus
3230	763.82	Transcribing machines
3230	763.83	Other sound reproducing apparatus
3230	763.84	Sound recording apparatus
3230	764.21	Microphones and stands therefore
3230	764.22	Loudspeakers, mounted in their enclosures
3230	764.23	Loudspeakers, not mounted in their enclosures
3230	764.24	Headphones, earphones & combined microphone/speaker
3230	764.25	Audio-frequence electric amplifiers
3230	764.26	Electric sound amplifier sets
3230	764.81	Reception appar. for radio-teleph., -telegr., not elsewhere specified
3230	764.92	Parts and accessories for apparatus of heading 7642
3230	764.99	Parts and accessories for apparatus of group 763
Computers		
3002	752.1	Analog or hybrid data processing machines
3002	752.2	Dig. autom. data proces. machines, cent. proc. Unit
3002	752.3	Digital proces. units with: storage, input, output
3002	752.6	Input or output units, whether or not with storage
3002	752.7	Storage units, with the rest of a system or not
3002	752.9	Data processing equipment, not elsewhere specified
3002	759.97	Parts, accessories of the machines of group 752
Electronic components		
3130	773.11	Winding wire
3130	773.12	Co-axial cable & other co-axial conductors
3130	773.14	Other electric conductors, for a voltage <80 volts
3130	773.15	Other elect. conductors, 80 volts <voltage< 1000 v
3210	772.2	Printed circuits
3210	772.31	Fixed carbon resistors, composition or film types
3210	772.32	Other fixed resistors
3210	772.33	Wirewound variable resistors
3210	772.35	Other variable resistors
3210	776.11	Colour television picture tubes, cathode ray
3210	776.12	Monochrome television picture tubes, cathode ray
3210	776.21	Television camera tubes; image converters, intensi.
3210	776.23	Other cathode-ray tubes

Continued

Table 13 ICT segments in SITC rev. 3 compared with NACE

NACE	SITC rev 3.	Product
Electronic components (continued)		
3210	776.25	Microwaves tubes (excluding grid-controlled tubes)
3210	776.27	Other valves & tubes
3210	776.29	Parts of the tubes, valves of sub-groups 7761, 7762
3210	776.31	Diodes, not photosensiti. nor light emitting diodes
3210	776.32	Transistors, dissipation rate < 1 w
3210	776.33	Transistors, dissipation rate > 1 w
3210	776.35	Thyristors, diacs & triacs
3210	776.37	Photosensitive semi-conductor devices; light emitt.
3210	776.39	Other semi-conductor devices
3210	776.41	Digital monolithic integrated circuits
3210	776.43	Non-digital monolithiques integrated circuits
3210	776.45	Hybrid integrated circuits
3210	776.49	Other electro. integrated circuits, microassemblies
3210	776.81	Piezo-electric crystals, mounted
3210	778.61	Fixed capacitors for 50/60hz circuit, capa.>0, 5kvar
3210	778.62	Tantalum fixed capacitors
3210	778.63	Aluminum electrolytic fixed capacitors
3210	778.64	Ceramic dielectric fixed capacitors, single layer
3210	778.65	Ceramic dielectric fixed capacitors, multilayer
3210	778.66	Paper or plastic dielectric fixed capacitors
3210	778.67	Other fixed capacitors
3210	778.68	Variables or adjustable capacitors
Office machinery		
3001	751.13	Automatic typewriters; word processing machines
3001	751.21	Electronic without external source of power
3001	751.22	Other calculating machines
3001	751.24	Cash registers, incorporating a calculating device
3001	751.28	Postage-franking & similar mach., with calc. Device
3001	751.31	Electrostatic photo-copy. apparatus, direct process
3001	751.32	Electrostatic photo-copy. apparatus, indirect proc.
3001	751.33	Non-electrostatic photo-copying apparatus, optical
3001	751.34	Non-electrostatic photo-copying apparatus, contact
3001	751.35	Thermo-copying apparatus
3001	759.1	Parts, accessories of the apparatus of heading 7513
3001	759.91	Parts, accessories of the machines of sub-group 7511
3001	759.95	Parts, accessories of the machines of sub-group 7512
Instruments and equipment for detecting, measuring etc.		
3320	871.31	Microscopes other than optical & diffraction apparatus
3320	873.11	Gas meters
3320	873.13	Liquid meters
3320	873.15	Electricity meters
3320	873.21	Revolution counters, mileometers & the like
3320	873.25	Speed indicators & tachometers; stroboscopes
3320	874.11	Compasses; navigational instruments & appliances
3320	874.13	Surveying, hydrological, etc., instruments & appliances
3320	874.25	Measuring or checking instruments, machines, not elsewhere specified
3320	874.31	Apparatus for measuring the flow or level of liquid.
3320	874.35	Instruments & apparatus for measuring the pressure
3320	874.37	Other instruments & apparatus for measuring, check.
3320	874.41	Gas or smoke analysis apparatus
3320	874.42	Chromatographs & electrophoresis instruments
3320	874.43	Spectrometers, spectrographs using optical radiat.
3320	874.44	Exposure meters
3320	874.45	Other instruments & apparatus using optical radia.
3320	874.46	Apparatus for physical or chemical analysis, not elsewhere specified
3320	874.53	Machines & appliances for testing materials

Table 13 ICT segments in SITC rev. 3 compared with NACE

NACE	SITC rev 3.	Product
Instruments and equipment for detecting, measuring etc. (continued)		
3320	874.61	Thermostats
3320	874.63	Pressure regulators & controllers
3320	874.65	Other regulating or controlling instruments & apparatus
3320	874.71	Instruments & app. for measuring ionizing radiat.
3320	874.73	Cathode-ray oscilloscopes & oscillographs
3320	874.75	Other apparatus for measuring electr., without rec.
3320	874.78	Other apparatus for measuring electr. Quantities
3320	874.9	Parts & accessories for machines, appl., etc., not elsewhere specified
3340	871.91	Telescopic sight for 7, 87, 881, 884, 8996
3340	871.92	Lasers (other than laser diodes)
3340	871.93	Other optical devices, appliances & instruments
3340	881.21	Cinematographic cameras
3340	881.22	Cinematographic projectors
3340	884.19	Optical fibres, bundles, cables; polarising material
3340	884.39	Mounted optical elements, not elsewhere specified

Source: Based on OECD (2000) International Trade by Commodities Statistics, No. 1

Table 14 The used statistical indicators for the benchmark

Driver	Indicators
ICT labour force	Migration of highly educated labour
	Number of highly educated engineers
	Number of labour with ICT education
	Number and the quality of engineers and scientists
ICT infrastructure	Number of PCs per 100 inhabitants
	ICT expenditure per 100 inhabitants
	Internet hosts per 1000 inhabitants
	International Internet bandwidth, kbps per 100 inhabitants
	Business websites per 1000 inhabitants
ICT education	Government expenditure on education per capita
	Education quality in mathematics and natural science
Techno-commercialisation	Nation's share of the total ICT sector in OECD
	Nation's share of the total R&D expenditure
	The ICT sectors share of GDP
Technology absorption	Number of PCs per 100 white collar workers
Globalisation	High-technology trade ratio (exports/imports)
	International strategic alliances in percent of the total number of alliances (1990-1999)
	Exports per capita
Capital markets	Growth in venture capital per year per capita
	Venture capital per capita
	Growth in the financial assets of the institutional investors
	Financial assets of institutional investors in percent of GDP
B2B e-commerce	Secure servers per one million inhabitants
Network culture	Strategic alliances per one million inhabitants
ICT consumers	Value of Business-to-Consumer (B2C) trade per capita
	Number of consumers on the Internet in percent of total inhabitants
	Internet customers in percent of the total number of banking customers
	Penetration ratio in percent of the total retail sale
	Mobile phones per 100 inhabitants
Macro economy	Growth in GDP per capita
	Growth in exports (percent)
	Projected surplus of the balance of trade in 2001 compared with 1999
	GDP per capita
	Change in inflation rate in percent 1997-1999
	Labour productivity (GDP per employee per hour)
Flexible labour market	Growth of the labour force
	Frequency of employment
	Changes in real salaries 1995-1999

Source: Adapted from PLS Rambøll Management and Børsens Nyhedsmagasin (2000, p. 31).

Chapter 4

The Industry Structure in North Jutland from 1983 to 2002:

From Lagging Behind to Structural Catching-up

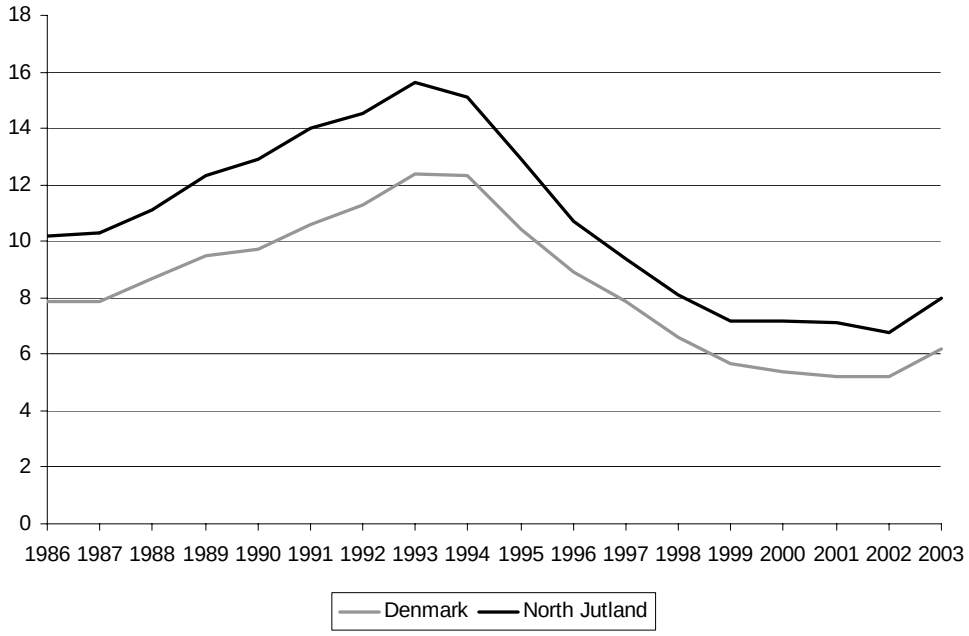
The Industry Structure in North Jutland from 1983 to 2002: From Lagging Behind to Structural Catching-up

1 Introduction

The purpose of this chapter is to introduce the North Jutland region by analysing the development in the industry structure during the last two decades. The period from 1983 to 2002 is divided into three sub-periods: The period from 1983 to 1992 was characterised by increasing unemployment and crisis in many of the traditional industries in North Jutland, while the period from 1992 to 1999 represented a golden growth phase compared with the 1980s. However, from 1999 the structural catching-up of North Jutland slowed down and the region continued on a growth path more similar to the other non-metropolitan regions in Denmark. The Danish economy was in a recession in 2000 and 2001.

North Jutland is the county at the northern tip of the peninsula of Jutland, which is the part of Denmark connected to the European continent. The population is around half a million people, slightly less than one tenth of the Danish total. The total employment was 243,100 persons in 2002, of which the private sector share was 160,100. The region has traditionally been characterised as peripheral with an unemployment rate among the highest in Denmark. The industry structure has previously been dominated by more traditional industries, such as agriculture and food processing, fishery, tourism, shipyards, textiles, tobacco and cement. However, during the late 1980s and the 1990s the region has experienced a process of structural change, which has transformed the structure of the private sector. In addition the gap between national and North Jutland unemployment rates were reduced during the late 1990s, see Figure 1.

Figure 1 Unemployment rate (%) of total employment



Source: Based on data from Statistics Denmark

2 The industry structure in North Jutland from 1983 to 1992

In 1983 the total employment in North Jutland was 226,400. The primary sector employment was almost 28,000 or 12.3% of total employment, while manufacturing employed 18.5% of total employment. From table 1 it can be seen that North Jutland was specialised in: the primary sectors, food, beverage and tobacco, other non-metallic mineral products, fabricated metal products, machinery and equipment, and construction. This specialisation pattern was comparable to many other Danish counties, such as Vejle, Viborg, Southern Denmark and Fuenen.

Table 1 Employment structure in North Jutland in 1983 and 1992

	North Jutland								Denmark	
	Specialisation 1983	Employment 1983 (persons)	Share of employment 1983 (%)	Specialisation 1992	Employment 1992 (persons)	Share of employment 1992 (%)	Development 1983 –92 (1983=100)	Change (persons)	Development 1983-93 (1983=100)	Share of employment 1992 (%)
Agriculture, fishing, hunting, and forestry	**1.66**	27,575	12.18	**1.58**	19,825	8.48	71.9	-7,750	74.9	5.37
Quarrying total	**1.35**	383	0.17	**1.36**	370	0.16	96.6	-13	95.3	0.12
Food, beverage and tobacco	**1.31**	11,218	4.95	**1.43**	11,609	4.96	103.5	391	93.8	3.46
Textiles and textile products	0.70	2,385	1.05	0.70	1,760	0.75	73.8	-625	74.4	1.08
Wood and furniture	0.77	2,035	0.90	0.88	2,707	1.16	133.0	672	114.7	1.31
Paper, publishing and printing	0.73	3,687	1.63	0.81	4,370	1.87	118.5	683	106.7	2.31
Chemicals	0.44	1,566	0.69	0.39	1,683	0.72	107.5	117	121.8	1.86
Other non-metallic mineral products	**1.89**	3,360	1.48	**2.16**	3,474	1.49	103.4	114	90.0	0.69
Basic metals	0.85	446	0.20	**1.24**	634	0.27	142.2	188	97.0	0.22
Fabricated metal products, machinery and equipment	**1.09**	16,846	7.44	**1.14**	18,803	8.04	111.6	1,957	106.7	7.07
Miscellaneous manufacturing	0.51	450	0.20	0.94	964	0.41	214.2	514	114.6	0.44
Construction	**1.08**	14,777	6.53	**1.02**	13,552	5.79	91.7	-1,225	96.1	5.67
Wholesale and retail trade, hotels and restaurants	0.94	34,573	15.27	0.99	38,417	16.43	111.1	3,844	104.4	16.58
Transport and storage	0.83	9,506	4.20	0.82	10,309	4.41	108.4	803	109.6	5.39
Post and telecommunications	0.74	3,445	1.52	0.84	3,454	1.48	100.3	9	88.7	1.77
Financial intermediation	0.92	4,798	2.12	0.92	5,357	2.29	111.7	559	111.3	2.49
Insurance	0.61	1,119	0.49	0.51	1,031	0.44	92.1	-88	109.5	0.86
Real estate activities business activities	0.84	8,350	3.69	0.77	10,079	4.31	120.7	1,729	130.2	5.59
Other service activities	0.90	10,232	4.52	0.89	10,956	4.68	107.1	724	107.8	5.27
Total private employment	**1.02**	158,279	69.9	**1.01**	161,234	68.94	101.9	2,955	102.5	68.4
Total employment	-	226,439	100	-	233,884	100	103.3	7,445	102.7	100

Note: Specialisation is the relative share of employment in a sector compared to the national average i.e. a number above 1.0 indicates that the municipality is specialised.
Source: Based on data from Statistics Denmark.

From 1983 to 1992 the total employment increased 3.3% in North Jutland compared to 2.7% at national level. The employment in agriculture, fishing, hunting and forestry decreased 28%, and its share of total employment was 8.5% in 1992. The shipyards in North Jutland went into crisis during the 1980s, and the employment decreased, but this is not seen in the aggregated data. The aggregated data shown in Table 1 reveals an 11.6% increase in fabricated metal products, machinery and equipment segment. This segment comprises a wide range of industries that had high growth, such as fabricated metal products, machinery and electronics. The service sector had a higher growth in employment (10.5%) compared to manufacturing (9.6%). The specialisation pattern was, however, quite stable in this period, and North Jutland remained specialised in the primary sector and manufacturing.

3 Structural catching-up in the 1990s[1]

During the late 1980s and the 1990s North Jutland experienced a process of structural change, which transformed the structure of the private sector. In 1999 the manufacturing industry was the largest segment employing 19% of total employment, followed by wholesale and retail trade, hotels and restaurants (17.9%). The development in the employment structure in North Jutland during the 1990s reveals a large decrease in employment in the primary sector, 27.5%, and a 32% increase in construction. Similar development trends could be found at national level, but it is more pronounced in North Jutland. In 1999 agriculture, fishing and forestry employed 14,300 (5.8% of total employment), which was a large drop in employment compared to 28,000 in 1983.

There are 16 counties in Denmark of which the greater Copenhagen area and Aarhus can be distinguished as having a more 'metropolitan' industry structure, specialised in knowledge intensive services, but not in the primary sector or manufacturing industry. North Jutland caught-up to the characteristics of the 'non-metropolitan' regions during the 1990s as indicated in Table 2, which shows the relative employment shares in the 1990s of the region vis-à-vis the national average. The 'non-metropolitan' regions are specialised in the primary sectors and manufacturing industry and not in the knowledge intensive services. North Jutland became specialised (i.e. got an above average employment share) in especially mechanical engineering as well as in electrical and optical equipment (only six Danish counties are specialised in electrical and optical equipment). The latter has been among the features, which point at the region not being peripheral any more. North Jutland was also specialised in telecommunications service from 1996 to 1998, but the specialisation indicator fell to 0.99 i.e. very close the average in 1999. Only Copenhagen Municipality, Copenhagen County, Frederiksborg County, and Aarhus County are specialised in this segment. The industry structure in Table 2 is in line with the average Danish 'non-metropolitan' counties.

[1] The data in this section is not strictly comparable with the previous section since the Danish activity code classification system was changed in 1993.

Table 2 Employment structure in North Jutland in 1992 and 1999 - the private sector

	North Jutland						Denmark
	Specialisation		Employment (persons)	Share of employ-ment (%)	Development 1992-99 (1992=100)	Change (persons)	Development 1992-99 (1992=100)
	1992	1999					
Agriculture, hunting and forestry	**1.59**	**1.48**	14,284	5.79	72.5	-5,417	77.3
Food, beverage and tobacco	**1.44**	**1.54**	11,227	4.55	94.6	-640	87.7
Textiles and textile products	0.73	**1.05**	1,477	0.60	81.9	-326	57.1
Wood and paper, publishing and printing	0.81	0.95	6,230	2.53	115.7	847	98.7
Refined petroleum products etc.	0.05	0.05	3	0.00	75.0	-1	82.8
Chemicals	0.30	0.19	460	0.19	73.8	-163	114.1
Rubber and plastic products	0.54	0.65	1,267	0.51	127.9	276	105.9
Other non-metallic mineral products	**2.15**	**1.81**	3,557	1.44	96.0	-149	113.1
Basic metals	**1.35**	**1.44**	1,293	0.52	138.6	360	128.9
Fabricated metal products	**1.26**	**1.33**	5,332	2.16	101.7	90	96.3
Machinery and equipment	0.91	**1.02**	6,282	2.55	109.8	561	97.7
Electrical and optical equipment	0.84	**1.19**	5,084	2.06	154.1	1,785	108.9
- Office machinery and computers	***1.22***	***1.80***	*340*	*0.14*	*106.6*	*21*	*71.5*
- Electrical machinery and apparatus	*0.60*	*0.74*	*1,198*	*0.49*	*148.6*	*392*	*121.2*
- Communication equipment and consumer electronics	***1.63***	***2.53***	*2,887*	*1.17*	*172.1*	*1,209*	*110.4*
- Medical equipment, instruments, watches etc.	*0.39*	*0.50*	*659*	*0.27*	*132.9*	*163*	*102.5*
Motor vehicles etc.	1.00	0.76	525	0.21	97.8	-12	127.9
Other transport equipment	**2.67**	**2.27**	2,017	0.82	54.1	-1,713	63.4
Furniture and miscellaneous	0.88	0.74	2,151	0.87	82.6	-453	97.8
Recycling	**1.32**	0.94	34	0.01	53.1	-30	73.9
Construction	1.00	**1.10**	16,436	6.67	132.0	3,988	119.4
Wholesale and retail trade, hotels and restaurants	0.99	0.98	44,115	17.89	110.8	4,296	111.7
Transport, storage and post	0.75	0.78	11,443	4.64	105.4	584	100.0
Telecommunications	0.63	0.99	1,777	0.72	197.9	879	124.3
Financial intermediation	0.80	0.76	5,160	2.09	84.0	-981	88.2
Real estate activities	0.91	0.92	2,767	1.12	104.6	122	102.5
Renting of machinery and equipment	0.58	0.72	425	0.17	154.5	150	124.4
IT service	0.72	0.63	1,942	0.79	171.4	809	194.2
Research and development	0.16	0.37	369	0.15	354.8	265	149.0
Other business activities	0.78	0.77	12,541	5.09	137.8	3,440	139.4
Recreational, cultural and sporting activities	0.71	0.76	3,374	1.37	128.0	739	119.4
Other service activities	**1.06**	**1.01**	1,962	0.80	94.5	-114	98.4
Total private employment	1.00	0.99	163,534	66.3	106.0	625	106.0
Total employment	-	-	246,546	100	106.3	9,192	106.2

Note: Specialisation is the relative share of employment in a sector compared to the national average i.e. a number above 1.0 indicates that the municipality is specialised. The sub-groups of the electrical and optical equipment industry are marked in italics. The definition can be found in Table 5.
Source: Based on data from Statistics Denmark.

The process of structural change has been speeded up by the relative fast economic growth in Denmark in the 1990s, where aggregate unemployment decreased from a level of 12% in 1992-93 to 6% at present. At the turn of the millennium the national rate of unemployment was 5.4%, but the rate was 7.2% in North Jutland, still the second highest among the 16 Danish counties. In an international context an unemployment rate slightly above 7% and a

per capita income of approximately US $23,000 (88% of the national average, based on 1998 GDP data) cannot qualify for being a poor region. But although the region has caught-up according to the structural dimension, the average annual GDP growth 1993-98 was 2.5% compared with the national growth rate of 3.3%. The North Jutland growth has been the third slowest among the 16 counties.

4 Development from 1999 to 2002

The development in employment in North Jutland in the period from 1999 to 2002 was more similar to the development in other non-metropolitan counties. Therefore it seems that North Jutland has stopped its structural catching-up and follows a more general growth trend. In 2002 the total employment in North Jutland was 243,100. From 1999 the total employment decreased 1.4%. A part of this decrease can be explained by a change in the data collection method by Statistics Denmark[2] and a change in the economic growth. The total employment decreased 0.6% at national level. Manufacturing is still the largest segment in North Jutland (18.2%) followed by wholesale and retail trade, hotels and restaurants (17.6%), and financial intermediation and business activities (10.7%). The latter segment was the only one of the three segments that had employment growth from 1999 to 2002.

Table 3 shows that most industries experienced decreasing employment. The agriculture, hunting and forestry segment continued the decreasing employment (8.6%) from 1999 to 2002, while the IT service (57.8%) and other business activities (12.8%) grew rapidly. North Jutland remained specialised in the primary sector, manufacturing and construction. At a more detailed level North Jutland remained specialised or increased the specialisation in agriculture, hunting and forestry (1.47), food, beverage and tobacco (1.66), textiles and textile products (1.20), other non-metallic mineral products (2.13), basic metals (1.93), fabricated metal products (1.45), machinery and equipment (1.06), other transport equipment (1.98), and construction (1.10). These industries accounted for almost 25% of the total employment in North Jutland.

However, North Jutland lost its specialisation in electrical and optical equipment (0.97), but increased specialisation in communication equipment and consumer electronics (2.70). The telecommunications specialisation indicator decreased from 0.99 in 1999 to 0.78 in 2002, because the main employer Sonofon (mobile communication service provider) outsourced[3] and downsized. The specialisation indicator for IT service increased to 0.83 (not specialised) which is the highest number outside the metropolitan regions, but the business structure in North Jutland is still in line with other non-metropolitan regions (see table 4).

[2] Approximately 18,000 out of a 40,000 persons decrease in total employment can be explained by this change. Total employment in Denmark was 2,741,386 in 2002. Http://www.dst.dk

[3] Outsourcing moves employment from one activity code to another. Outsourcing of the canteen or cleaning services will reduce employment in telecommunications service even though the activities remains unchanged.

During the 1980s North Jutland went into crisis fuelled by a recession in the Danish economy and many of the traditional large industries, such as fishing, agriculture and shipbuilding, downsized. From 1993 to 1999 represents a growth phase for the Danish economy and for North Jutland. In this period North Jutland experienced a structural catching-up that made its industry structure more in line with other non-metropolitan regions. But during 1999 to 2002 it seems that North Jutland has stopped the catching-up that occurred during the 1990s and continued on a growth path more similar to the other Danish non-metropolitan regions.

Table 3 Employment structure in North Jutland in 1999 and 2002 - the private sector

	North Jutland						Denmark
	Specialisation		Employment (persons)	Share of employ-ment (%)	Development 1999-02 (1999=100)	Change (persons)	Development 1999-02 (1999=100)
	1999	2002					
Agriculture, hunting and forestry	**1.48**	**1.47**	13,058	5.37	91.4	-1,226	93.0
Food, beverage and tobacco	**1.54**	**1.66**	11,825	4.86	105.3	598	98.9
Textiles and textile products	**1.05**	**1.20**	1,276	0.52	86.4	-201	75.7
Wood and paper, publishing and printing	0.95	0.90	5,144	2.12	82.6	-1,086	88.1
Refined petroleum products etc.	0.05	0.05	3	0.00	100.0	0	89.3
Chemicals	0.19	0.23	605	0.25	131.5	145	110.0
Rubber and plastic products	0.65	0.66	1,263	0.52	99.7	-4	98.1
Other non-metallic mineral products	**1.81**	**2.13**	3,239	1.33	91.1	-318	78.2
Basic metals	**1.44**	**1.93**	1,029	0.42	79.6	-264	60.1
Fabricated metal products	**1.33**	**1.45**	5,839	2.40	109.5	507	101.3
Machinery and equipment	**1.02**	**1.06**	6,120	2.52	97.4	-162	94.9
Electrical and optical equipment	**1.19**	0.97	4,430	1.82	87.1	-654	107.9
- Office machinery and computers	***1.80***	*0.51*	*66*	*0.03*	*19.4*	*-274*	*69.8*
- Electrical machinery and apparatus	*0.74*	*0.74*	*1,567*	*0.64*	*130.8*	*369*	*131.7*
- Communication equipment and consumer electronics	***2.53***	***2.70***	*2,334*	*0.96*	*80.8*	*-553*	*76.2*
- Medical equipment, instruments, watches etc.	*0.50*	*0.32*	*463*	*0.19*	*70.3*	*-196*	*111.7*
Motor vehicles etc.	0.76	0.75	465	0.19	88.6	-60	90.9
Other transport equipment	**2.27**	**1.98**	1,429	0.59	70.8	-588	81.9
Furniture and miscellaneous	0.74	0.62	1,615	0.66	75.1	-536	89.8
Recycling	0.94	0.79	22	0.01	64.7	-12	77.7
Construction	**1.10**	**1.10**	16,337	6.72	99.4	-99	100.3
Wholesale and retail trade, hotels and restaurants	0.98	0.98	42,739	17.58	96.9	-1,376	98.0
Transport, storage, and post	0.78	0.78	10,703	4.40	93.5	-740	94.2
Telecommunications	0.99	0.78	1,421	0.58	80.0	-356	102.4
Financial intermediation	0.76	0.73	4,920	2.02	95.3	-240	99.7
Real estate activities	0.92	0.97	3,110	1.28	112.4	343	107.5
Renting of machinery and equipment	0.72	0.74	511	0.21	120.2	86	117.9
IT service	0.63	0.83	3,065	1.26	157.8	1,123	120.6
Research and development	0.37	0.35	377	0.16	102.2	8	108.7
Other business activities	0.77	0.80	14,149	5.82	112.8	1,608	110.1
Recreational, cultural, and sporting activities	0.76	0.75	3,517	1.45	104.2	143	105.8
Other service activities	**1.01**	0.98	1,930	0.79	98.4	-32	102.2
Total private employment	0.99	0.99	160,141	65.9	97.9	-3,393	99.0
Total employment	-	-	243,101	100	98.6	-3,445	99.4

Note: Specialisation is the relative share of employment in a sector compared to the national average i.e. a number above 1.0 indicates that the municipality is specialised. The sub-groups of the electrical and optical equipment industry are marked in italics. The definition can be found in Table 5.
Source: Based on data from Statistics Denmark.

Table 4 Regional employment specialisations in Denmark 2002

	Copenhagen Municipality	Frederiksberg Municipality	Copenhagen County	Frederiksborg County	Roskilde County	Western Zealand County	Storstroems County	Bornholm County	Fuenen County	Southern Jutland County	Ribe County	Vejle County	Ringkoebing County	Aarhus County	Viborg County	North Jutland County	Denmark Employment
Agriculture, hunting and forestry	0.06	0.03	0.07	0.14	0.58	**1.34**	**1.62**	**1.88**	**1.59**	**1.73**	**1.96**	**1.01**	**1.96**	0.84	**2.04**	**1.47**	100,329
Food, beverage and tobacco	0.34	0.22	0.45	0.43	0.44	**1.39**	**1.15**	**2.35**	**1.02**	**1.52**	**1.52**	**1.73**	**1.59**	0.83	**1.45**	**1.66**	80,541
Textiles and textile products	0.31	0.30	0.17	0.18	0.43	0.77	0.47	0.41	0.72	0.63	0.83	0.99	**6.97**	**1.13**	0.66	**1.20**	11,976
Wood and paper, publishing and printing	**1.08**	0.44	0.69	0.83	0.67	0.93	1.00	0.88	0.76	0.88	0.80	**1.42**	**1.69**	**1.24**	**1.39**	0.90	64,779
Refined petroleum products etc.	0.11	0.00	0.10	0.02	0.91	**12.02**	0.04	0.00	0.02	0.00	0.00	**4.42**	0.09	0.08	0.11	0.05	632
Chemicals	0.81	**1.44**	**4.66**	0.88	**1.87**	**2.20**	0.13	0.00	0.23	0.18	0.91	0.79	0.64	0.52	0.10	0.23	29,198
Rubber and plastic products	0.03	0.13	0.33	0.59	**2.97**	**1.01**	**1.21**	0.02	**1.20**	0.39	**1.73**	**1.45**	**1.01**	0.99	0.99	0.66	21,507
Other non-metallic mineral products	0.10	**2.23**	0.32	0.78	0.70	0.91	**1.80**	**2.08**	0.62	**1.34**	**1.39**	**1.77**	0.97	0.62	**1.81**	**2.13**	17,172
Basic metals	0.04	0.00	0.36	0.44	**1.24**	0.98	0.50	0.00	0.77	**2.81**	0.28	**2.13**	**2.14**	0.61	**1.29**	**1.93**	6,017
Fabricated metal products	0.08	0.04	0.54	0.62	0.87	**1.16**	0.81	0.52	**1.85**	**1.24**	**1.35**	**1.35**	**1.81**	0.87	**1.29**	**1.45**	45,541
Machinery and equipment	0.20	0.01	0.65	0.39	0.52	0.84	0.98	0.84	**1.34**	**2.72**	**1.19**	**1.48**	0.80	**1.15**	**2.71**	**1.06**	65,258
Electrical and optical equipment	0.32	0.18	**1.05**	0.93	**1.24**	0.76	0.88	0.08	0.58	**1.66**	0.71	**1.38**	**2.60**	**1.02**	**1.08**	0.97	51,642
- Office machinery and computers	*0.62*	*0.00*	***1.08***	***1.67***	***1.31***	*0.09*	***1.36***	*0.00*	***1.77***	*0.02*	*0.03*	*0.28*	*0.14*	***2.86***	*0.09*	*0.51*	*1,473*
- Electrical machinery and apparatus	*0.16*	*0.04*	*0.68*	*0.20*	*0.48*	*0.82*	***1.12***	*0.10*	*0.74*	***2.86***	***1.14***	***1.84***	***3.99***	***1.01***	*0.68*	*0.74*	*23,945*
- Communication equipment and consumer electronics	*0.03*	*0.05*	*0.50*	***1.04***	***1.18***	*0.20*	*0.44*	*0.04*	*0.17*	*0.67*	*0.79*	***2.01***	***3.36***	*0.37*	***1.66***	***2.70***	*9,740*
- Medical equipment, instruments, watches etc.	*0.68*	*0.47*	***1.90***	***1.86***	***2.38***	***1.06***	*0.73*	*0.08*	*0.48*	*0.65*	*0.08*	*0.43*	*0.36*	***1.25***	***1.41***	*0.32*	*16,484*
Motor vehicles etc.	0.02	0.01	0.02	0.22	0.37	0.35	0.23	0.00	**2.41**	**3.11**	0.40	**3.38**	**2.60**	0.70	**1.16**	0.75	7,003
Other transport equipment	0.05	0.00	0.09	0.37	0.24	0.16	0.16	**1.18**	**4.90**	0.27	**2.14**	0.87	0.74	0.99	0.58	**1.98**	8,155
Furniture and miscellaneous	0.16	0.60	0.27	0.22	0.41	0.62	0.64	0.10	0.95	0.54	**4.93**	0.86	**2.04**	**1.19**	**3.77**	0.62	29,385
Recycling	**3.04**	0.00	0.40	0.09	0.41	0.13	0.00	0.00	**4.77**	0.14	**1.70**	0.00	0.06	0.08	0.21	0.79	314
Construction	0.39	0.59	**1.09**	**1.41**	**1.14**	**1.30**	**1.24**	**1.02**	**1.03**	0.92	**1.10**	**1.11**	0.93	0.97	0.98	**1.10**	168,055
Wholesale and retail trade. hotels and restaurants	0.88	0.78	**1.06**	**1.20**	**1.15**	0.92	0.95	**1.04**	**1.00**	**1.00**	0.94	**1.04**	0.96	**1.04**	0.84	0.98	493,025
Transport. storage and post	**1.28**	0.44	0.77	**2.08**	0.75	0.86	0.81	**1.14**	0.69	**1.02**	**1.12**	**1.03**	0.72	0.90	0.63	0.78	153,905
Telecommunications	**2.24**	**1.17**	**1.52**	**1.66**	0.41	0.19	0.34	0.48	0.74	0.61	0.18	0.43	0.27	**1.88**	0.09	0.78	20,532
Financial intermediation	**2.08**	**1.91**	**1.87**	**1.61**	0.63	0.51	0.62	0.48	0.64	0.73	0.53	0.65	0.77	0.78	0.67	0.73	75,946
Real estate activities	**1.43**	**1.72**	**1.09**	0.97	1.00	0.97	0.94	0.79	0.89	0.89	0.90	0.77	0.87	0.98	0.75	0.97	36,056
Renting of machinery and equipment	**1.05**	**1.54**	0.89	**1.63**	**1.04**	0.86	0.80	0.55	**1.24**	0.67	0.63	0.94	0.51	**1.37**	0.68	0.74	7,788
IT service	**2.11**	**1.37**	**2.78**	**1.48**	0.95	0.22	0.18	0.10	0.50	0.27	0.17	0.48	0.30	**1.22**	0.24	0.83	41,729
Research and development	**2.83**	**2.23**	0.90	**1.19**	**2.37**	0.39	0.34	0.39	0.30	0.12	0.14	0.46	0.04	0.66	**1.19**	0.35	12,147
Other business activities	**1.76**	**1.72**	**1.21**	**1.20**	1.00	0.73	0.71	0.47	0.90	0.66	0.67	0.86	0.64	**1.04**	0.57	0.80	200,561
Recreational, cultural and sporting activities	**1.98**	**2.21**	**1.56**	0.95	0.86	0.54	0.83	**1.25**	0.92	0.59	0.75	0.63	0.71	0.90	0.61	0.75	52,573
Other service activities	**1.13**	**1.54**	**1.03**	0.91	**1.11**	**1.09**	**1.12**	**1.11**	0.91	0.92	0.92	0.91	0.86	0.95	0.95	0.98	22,192
Total private employment	0.95	0.84	**1.04**	**1.10**	0.96	0.93	0.92	0.93	0.98	**1.03**	**1.05**	**1.06**	**1.09**	0.99	**1.02**	0.99	1,823,958
Total employment	329,725	41,482	173,591	192,098	253,712	129,882	106,406	19,335	221,271	121,903	118,005	185,557	148,343	327,731	122,248	243,101	2,741,386

Note: Specialisation is the relative share of employment in a sector compared to the national average i.e. a number above 1.0 indicates that the municipality is specialised. The sub-groups of the electrical and optical equipment industry are marked in italics. The definition can be found in Table 5. Source: Based on data from Statistics Denmark.

Table 5 Definition of employment structure

Description	NACE/DB(93)
Agriculture, hunting and forestry	01, 02, 05, 10, 11, 14
Food, beverage and tobacco	15, 16
Textiles and textile products	17, 18, 19
Wood and paper, publishing and printing	20, 21, 22
Refined petroleum products etc.	23
Chemicals	24
Rubber and plastic products	25
Other non-metallic mineral products	26
Basic metals	27
Fabricated metal products	28
Machinery and equipment	29
Electrical and optical equipment	30, 31, 32, 33
- Office machinery and computers	30
- Electrical machinery and apparatus	31
- Communication equipment and consumer electronics	32
- Medical equipment, instruments, watches etc.	33
Motor vehicles etc.	34
Other transport equipment	35
Furniture and miscellaneous	36
Recycling	37
Construction	45
Wholesale and retail trade, hotels and restaurants	50, 51, 52, 55
Transport, storage, and post	60, 61, 62, 63, 641
Telecommunications	642
Financial intermediation	65, 66, 67
Real estate activities	70
Renting of machinery and equipment	71
IT service	72
Research and development	73
Other business activities	74
Recreational, cultural, and sporting activities	92
Other service activities	93
Total private employment	01-37, 45, 50-74, 92, 93
Total employment	-

Note: The sub-groups of the electrical and optical equipment industry are marked in italics.

Part Two

Cluster Analysis

Chapter 5

Entry by Spinoff in a High-tech Cluster

Entry by Spinoff in a High-tech Cluster[1]

1 Introduction

Do new firm formations and their organisational background determine geographical clustering of economic activity? Recent studies have shown how capabilities of new entering firms are important for the evolution of industries over time. However, surprisingly little attention has been paid to the background of the entrants. The few available studies all conclude that the histories of entrants have substantial effects on the survival and performance of firms (widely cited in the present chapter). The main mechanism at work is that the capabilities of new firms are fundamentally shaped by the pre-entry experience of the founders (Helfat and Lieberman, 2002). Further, in some of the cases studies reported, the industries have been geographically concentrated. The degree of geographical concentration may have increased or decreased over time. Both features may be traced back to the background of the founders of new entrants combined with the degree of mobility of the labour force. In the literature, these two elements provide powerful contributions to explaining success as well as failure of industrial clusters.

In the present chapter, this approach is used to study the emergence and growth over the past four decades of a wireless telecommunications cluster around Aalborg in the region of North Jutland, northern Denmark (NorCOM). The aim is to analyse the dominating forces behind the growth of NorCOM using detailed information about the founding events and organisational background of every individual entrant in the cluster.

The next section presents the general theories the role of spinoffs for the evolution of industries and geographical concentrations of firms. Section 3 contains a mapping of the genealogical evolution of NorCOM, followed by a more 'quantitative' analysis of evolution. The implications of this study are discussed in Section 4 and concluded in Section 5.

2 Entry and pre-entry organisational capabilities

Schumpeter (1934) has more than anyone highlighted the economic importance of the entrepreneur. His arguments have contributed to the generally accepted view that entrepreneurial activity is a wellspring of economic change and technical innovation. In the last twenty years or so, more and more empirical studies have emerged concentrating on

[1] This chapter is based on Dahl, Pedersen and Dalum (2003) "Entry by Spinoff in a High-tech Cluster", DRUID Working paper series 2003 no. 11

entrepreneurial activities in primarily high-tech industries. However, mainly the recent studies have focused specifically on the importance of pre-entry experiences for new firms (see e.g. Klepper, 2001). This link between pre-entry capabilities and entrepreneurial activity is potentially very important for the survival and performance of the new firms and thereby the evolution of clusters.

Organisational sociologists have considered the effects of the transfer of routines and experience between a new firms and its founder's previous employer (Phillips, 2002). The argument that blueprints of a parent firm are passed on to new organisations through the offspring's founders (Carroll, 1984; Romanelli, 1985; Brittain and Freeman, 1986; Hannan and Freeman, 1986; Romanelli, 1989). All entrepreneurs bring knowledge and skills from their past working and educational activities that may be valuable in searching for new business areas and opportunities as well as in the daily life of running a firm (Shane, 2000). Thus, all entrants in an industry carry skills and routines embodied in the founders that are very likely to influence the new firm's future development and success. Often new firms enter the same industry in which their founders were previously employed. These cases are labelled spinoffs. Founders are likely to bring specific knowledge about a wide range of issues to their new firm, e.g. customer demand, products, technologies, suppliers and competitors (Helfat and Lieberman, 2002). This may also include knowledge about how to exploit new knowledge and technological developments based on unmet supplier or customer demands (Shane, 2000) or prior scientific and technical training (Roberts, 1991). Consequently, more experienced founders, e.g. entrepreneurial spinoffs, with valuable industry specific knowledge should have a higher probability of success compared with less experienced entrants. So it is very likely that the success of a new entrant is based on the experience of the founder.

2.1 Types of entrants

There are different typologies of entrants based on their prior experience in the literature. In order to study the evolution of a particular case according to the different types of entrants, it is necessary to select a relevant typology for distinguishing between different types. Klepper (2001; 2003) identifies four different groups of entrants. First, firms diversifying from related industries. The second is called the experienced entrepreneurs. They are firms founded by the heads or founders of already existing firms in the same industry. The third group is spinoffs in Klepper's terminology, founded by high level and experienced employees of incumbent firms in the same industry. And the last consists of inexperienced entrants with little or no experience relevant for the industry or founded by lower level employees from incumbent firms. However, there is an analytical overlap between some of the categories, such as between high-level employees and heads of incumbent firms. The separation of these two groups of people can cause some difficulties in

distinguishing between 'experienced entrepreneurs' and 'spinoffs' in an empirical case study and could be merged.

Helfat and Lieberman (2002) has presented another typology, which distinguishes between three main types of entrants: diversifying entrants, parent-company ventures and *de novo* entrants. (1) Diversifying entrants are firms entering new or established markets unknown to them, through acquisition or green field investment. (2) Parent-company ventures are new entities founded by established firms, either as joint ventures with other partners or as parent spinoffs.[2] (3) *De novo* entrants are divided into two different types based on their level of previous experience in the industry. This distinction between the various entrants is comparable to Klepper's approach. Entrepreneurial spinoffs are characterised as firms founded by experienced persons with previous employment in incumbent firms in the industry. Persons with no previous employment in the industry have, on the other hand, established the inexperienced start-ups. The typology used in this case is shown in Table 1.

Table 1 Typology of new firm entrants

Entrant type	Relation to established firm	Parent company Ownership
(1) Diversifying entrant	Same firm	Full
(2) Parent-company activity	New firm as a separate entity	
- Joint venture	Founded by multiple established firms	Partial
- Parent spinoff	Founded by established firm	Partial
(3) *De novo* entrant	New firm as a separate entity	
- Entrepreneurial spinoff	Founder(s) previously employed in the industry	None
- Inexperienced startup	Founder(s) no prior experience or contacts in the industry	None

Source: Adapted from Helfat and Lieberman (2002) and Klepper (2001).

2.2 An evolutionary account for spinoffs

Klepper (2001) exploits the metaphor of spinoffs as children and employers as parents in his evolutionary account for spinoffs. He proposes a model that combines the ideas of reproduction and inheritance with the notion of organisational routines. This notion is originally developed by Nelson and Winter (1982) assuming that firms are to a large extent governed by routines. A firm has separate routines for the different functions (R&D, marketing, management, etc.) and products involved in its operation. Either the founders or

[2] Helfat and Lieberman (2002) also included franchises as a parent-company venture. We have omitted this category, since it appears relevant mostly in retailing, which is not the focus of the present chapter. We are studying a cluster of manufactures and developers of wireless communication equipment in which it is highly unlikely to see franchises as a form of entry. However, the category has its value in typologies with a more general theory in mind.

the initial management team install these routines. Decision making at all levels will subsequently depend on them. When a new firm is born organisations will reproduce, because founders will rely on routines, which they are already familiar with from their previous employment experience. The quality of these routines will determine the future success and performance of the new firm. Entrepreneurial spinoffs may inherit more suitable routines than any other kind of startup, because of the experience of the founders. This may on average enable these spinoffs to outperform other startups. Eventually the longer survival and better performance of entrepreneurial spinoffs will one day turn them into parents, since employees with access to better routines will be more likely to found new organisations (Klepper, 2001). Capabilities of new firms are fundamentally shaped by the experiences of the founders (Helfat and Lieberman, 2002). Thus, better performing firms will spawn more spinoffs.

When a firm grows and takes on new technologies and products the organisational routines changes, which influences the performance. It will diverge further and further from its starting point and its parents. The firms will become less similar and so will their performance. Changing routines will change the choices made on product development and innovation. In other words, entrepreneurial spinoffs become a source of diversity as they develop more distinctive innovations over time – they will thus stimulate the rate of technological change in an industry. A common denominator of the research so far is that leading firms in industries may risk losing their dominant position to new entrants (especially entrepreneurial spinoffs) when faced with radical innovations. Given their past success, leading firms may not see critical deficiencies in their resource profile and routines necessary for changing markets (Helfat and Lieberman, 2002).

The average competences of diversifying firms are assumed to be greater than the average competences of the new firms given more comprehensive organisational experiences and complementary assets. But if the organisational challenges facing an industry are novel and sufficiently complex, the new firms may be able to reach or exceed the average competence level of the diversifiers, since new firms tend to have more flexible routines towards the demand challenges and changing conditions. Inexperienced firms will not be able to compete with any diversifier or spinoff, because they lack the sufficient experiences. If organisational challenges are not novel, diversifiers are more likely to be dominating the industry (Klepper, 2003).

To illustrate how the theories of spinoffs can contribute to a better understanding of geographical clustering, we look at the evolution of three industries studied in such a context. The evidence from the U.S. automobile, U.S. semiconductor, and U.S. television receiver industries reveals that pre-entry experiences and inherited firm capabilities can

explain the performance of firms over time.[3] The evolution of the three industries was fundamentally different with respect to which firms ended up dominating the industry as well as how the geographical structure evolved over time. However, three very distinct clusters emerged as a result of spinoffs in the evolution of these industries.

First, the *automobile industry* was characterised by a large rate of entry with more than 500 firms entering in its first 20 years (Carroll *et al.*, 1996). However, after 1909, the industry went through a tremendous shakeout until 1941. In this period the number of firms steadily decreased, dropping from 272 firms in 1909 to only 9 in 1941. The industry evolved to be a tight oligopoly dominated by three relatively late entering firms, Ford, General Motors and Chrysler. All of these came out of Detroit and their success can be explained by the pre-entry experiences and capabilities of the entrants. Many of these entrants were spinoffs and most of them, especially the most successful ones, can be traced back to the very successful early entrants that happened – somehow by chance - to locate in Detroit (Klepper, 2002). The new firms were able to rely on the superior performance of their parents to become successful themselves and dominate the entire industry. This cannot explain the initial location of the four large producers in Detroit and why they became successful, but given the chance of this occurrence, Klepper's theory can indeed explain why the firms founded in that area in the following years became so successful.

Second, many studies of the *semiconductor industry* have shown that entrepreneurial spinoffs and employee mobility have been important factors in the evolution of this field. As Dosi (1984) notes, founders of new firms in the early years very often worked as scientists or managers in existing semiconductor firms. Brittain and Freeman (1986) and Moore and Davis (2001) even argue that entrepreneurial spinoffs were the main engine behind the growth in Silicon Valley. The most well known case is the many firms that spun off from Fairchild Semiconductor, often called the 'Fairchildren'. Fairchild Semiconductor was in fact itself a spinoff of Shockley Transistor[4]. In general, engineers left established incumbent firms in large numbers and started new ventures that produced the capital goods and materials needed for semiconductor design and manufacturing. The majority of the new firms were founded in Silicon Valley where the technical expertise was already abundantly present, founders had the contacts to recruit talented employees, and an effective venture capital system was ready to provide the critical early financial support for founding a firm

[3] Helfat and Lieberman (2002) point to several similar studies, which all confirm this. Among these are Chatterjee and Wernerfelt's (1991) study of the U.S. manufacturing industries, Mitchell's (1989; 1991) study of the U.S. digital imaging industry, and Thompson's (2002) study of the U.S. iron and steel shipbuilding industry, which all conclude that pre-entry experiences of diversifying entrants, and sometimes entrepreneurial spinoffs, enhance post-entry performance. To these we might add that other industry studies also confirm this, e.g. the footwear industry (Sorenson and Audia, 2000), lasers (Klepper and Sleeper, 2002), tires (Klepper and Simons, 2000), and the disk drive industry (Christensen, 1993; Franco and Filson, 2000; King and Tucci, 2002).

[4] Shockley Transistor was also a spinoff. It was founded in 1955 by the co-inventor of the transistor William Shockley in 1955. He previously worked for Bell Telephone Laboratories.

(Romanelli and Schoonhoven, 2001). In the early years of the industry the technology itself was not well understood by most firms, and they basically also had to produce their own production equipment. As a result, semiconductor firms faced novel organisational challenges in aligning goals and designing the organisational structure that could establish and reach the technological demands of the industry. Working for incumbent firms was the best way to learn how to tackle those challenges. Consequently, entrepreneurial spinoffs were uniquely able to perform well in the industry (Moore and Davis, 2001)[5].

Third, Klepper and Simons (2000) study the prior experiences of potential of entrants - i.e. radio manufacturers - in the *TV receiver industry*. The radio manufacturers are interesting, because they came to dominate the evolution of the TV industry although they were only a minority among the entrants. Radio manufacturers entering early survived longer and gained, on average, larger market shares than non-radio producing entrants. In fact no non-radio producer ever gained a considerable share of the TV market. In the early years the U.S. television receiver industry was concentrated around three cities, Los Angeles, New York and Chicago, but further on Chicago firms became the leaders. Most of them had previous experiences in the radio industry and were founded as either parent or entrepreneurial spinoffs. During the shakeout in 1951-58 the Chicago region became the winner, as the New York and Los Angeles manufacturers gradually exited the industry (Klepper, 2003).

The evolution of the TV industry has been distinctly different from semiconductors and autos. In autos, even entrants from related industries (carriages, wagons, engines, etc.) were facing much more novel organisational challenges (Klepper, 2003). They could not rely on the knowledge and organisational routines from related activities, since the development and production of automobiles was very different from producing carriages, wagons or engines. It was a similar pattern in semiconductors. There were no related industries that semiconductor firms could have diversified or spun off from, taking their routines and organisational knowledge with them, because producing semiconductors was so inherently different from anything else at the time. Entrants in this industry had to develop the routines themselves coping with the novel organisational challenges facing them. The best way to learn how to do this was to work in an incumbent semiconductor firm.

These three cases illustrate that the evolution of industries is closely related to the challenges facing entrants. If an industry is closely related to an already existing one, the best firms from the latter are likely to end up dominating the new one. In such a case the geographical distribution of firms is likely to be the same. That happened in TVs. The best radio firms were located in Chicago and they were the ones able to perform in TVs as well and outperform the TV firms in Los Angeles and New York. In autos and semiconductors,

[5] They were often founded as a result of fundamental disagreements concerning strategic changes within in the incumbent firms (Brittain and Freeman, 1986).

entrants faced novel challenges very different from those facing other industries. Consequently, entrepreneurial spinoffs of early high performing entrants were the firms surviving in the longer run. Such spinoffs were much more capable of handling the new conditions. This determined the geographical distribution of these industries and creates clusters, since the successful early entrants located – basically randomly - in Detroit (autos) and in Silicon Valley (semiconductors).

2.3 The local and social dimension of entrepreneurial activity

The phenomenon of the most successful entrants having 'inherited' significant amounts of experience from existing firms implies that entrepreneurial activity has a considerable geographical aspect, since the majority of entrepreneurs may tend to found their new firms in close proximity to their previous employers (Sorenson, 2003). The local 'production' of new entrepreneurs, thus, plays a vital role for regional development. New jobs are not only created in incumbent firms but indeed also by the formation of new employers through local spinoff mechanisms.

This does not necessarily imply that founders will only base their new organisations in close proximity to their past employer. There are well known examples of founders, who search for the most proper location among many geographic regions, that either provide access to a large local market or, perhaps more important, offers the best selection of resources to the organisation.[6] Today, it is hard to argue that potential founders only have knowledge about their own local environment and the local entrepreneurial opportunities (Romanelli and Schoonhoven, 2001). But the current geographical distribution of an industry places important constraints on entrepreneurial activity (Sorenson, 2003). Important resources for new organisations, such as abundantly available technical personnel generally tend to be immobile and unevenly distributed across geographical space. Thus, founders tend to base their new organisations close to previous employers, since they have detailed knowledge about and social connections to available resources in that particular region.

According to Sorenson (2003), the process of founding a firm includes two stages. Each of these closely ties social networks to entrepreneurship. First, an entrepreneur has to be able to *identify the opportunities* for founding a new firm. In order to do this, the entrepreneur has to access knowledge about the conditions of the industry in question. Incumbent firms will naturally try to conceal their knowledge about strategic decisions and profitability of their operations, which may tempt others to enter their market segment. However, many

[6] For example, Jeff Bezos, the founder of Amazon.com, chose Seattle as the best location for founding the firm in 1995, because of the high concentration of local technical talent (Seattle being the home town of Microsoft and a growing number of spinoffs) and the close distance to the largest book warehouse in the world located in Roseberg, Oregon (Romanelli and Schoonhoven, 2001).

employees from the higher ranks in incumbent firms already have access to this knowledge. This enables them to become entrepreneurs themselves or disclose the information to others in their social network. In addition, if a region contains several firms in the same industry, entrepreneurs will tend to occupy positions in communication networks enabling them to access knowledge about market conditions and identify promising development opportunities more broadly (Sorenson, 2003). This will increase the likelihood that their firms succeed. A broad stream of empirical research confirms that social networks acts as communication channels for this type of knowledge (see e.g. Von Hippel, 1987; Rogers, 1995; Dahl and Pedersen, 2004).

The second stage is to actually *build the new organisation*. In order to complete this stage the entrepreneur needs to have access to three elements: industry-specific tacit knowledge, human capital, and financial capital (Sorenson, 2003). Social network relations can facilitate the acquisition of each of these elements. The new firms that are able to access industry-specific tacit knowledge have large advantages (Klepper, 2001; Klepper and Sleeper, 2002). This knowledge is an important source of prosperity to those that hold it, because it is extremely difficult to replicate. The entrepreneur must have strong social ties to the holders, since there are considerable issues of trust involved in accessing this knowledge. Furthermore, industry-specific tacit knowledge resides in incumbent firms as embodied knowledge in employees. Consequently, new firms virtually hail from the ranks of current employees in incumbent firms (Sorenson and Audia, 2000).

Another way to access this type of knowledge is to hire employees that hold it. Since the future of a newly founded firm is uncertain, it takes considerable persuasion to attract new labour from secure conditions in incumbent firms. Potential employees are not likely to move away from their secure positions, if they do not trust or have confidence in the abilities and judgment of the founder (Sorenson and Audia, 2000). In this process, social relations can facilitate the trust necessary in order to attract and obtain the human capital from the labour market.

Social connections also play a vital role when accessing financial capital for founding a firm. Founding a firm involves a series of risks and it is fundamentally an uncertain process. Even the magnitude of the risks is uncertain. Studies show that even risk-neutral investors exhibit ambiguity aversion, if they are unable to quantify the risk of an investment (Fox and Tversky, 1995). Hence, potential investors are likely to view the opportunities of new firms with considerable suspicion unless the investors are socially connected to the entrepreneur. An entrepreneur is more likely to find financial capital, if she has social ties to the investors, because they are more likely to trust her judgments of the risks and opportunities involved. Consequently, entrepreneurs are most likely to be tied to the region, where they have useful social relations, even if another region is otherwise more attractive (Sorenson and Stuart, 2001).

The benefits of social networks increase, as employees' gets more experienced and climb the occupational ladder. If this is the case, the likelihood of success for a new firm increases with the experience and social connections of its founder, because she has better opportunities to successfully complete the two stages of entrepreneurship. This means that entrepreneurial spinoffs are more likely to be successful than entrants with lower levels of experience and local industry knowledge. Since clusters inhabit more of these potential (successfully) entrants it would enhance cluster growth and development.

Successful and innovative firms with broader product lines are likely to spawn more spinoffs, since they form inspirational learning environments for their employees. Garvin (1983) and Cooper (1985) argues that since spinoffs usually are of a small size initially, small firms will have higher spinoff rates, because they act as the most valuable lessons for their employees on how to start their own firms. They also conjectures that regions, which have many firms in a particular industry, will also have higher spinoff rates, because of the high supply of qualified labour in that industry. Spinoffs are important for further evolution of a given industry. Cooper and Gimeno-Gascon (1992) argue that the heritage and background of a spinoff will have vital effects on its performance. Spinoffs with founders, who have experience from a parent organisation in a similar industry, are likely to have more valuable experiences to draw upon in the new firm. This will consequently lead to better performance. Also, employment in a growing and successful organisation will be an advantage for potential entrepreneurs, as they might be better able to attract financial and human resources for creating a new organisation. Therefore it can be expected that the majority of the new firms founded by former employees of growing companies will to a large extent replicate not only the primary work of the parent, but also the way the daily business and organisation is carried out. Because of the significant risks involved with founding a new firm, simple replication of a growing parent may be the best way to reduce the risk of early failure (Romanelli and Schoonhoven, 2001). Dyck (1997) claims that in some instances spinoffs are planned and supported by the parents. With this help from the parents, planned spinoffs will outperform unplanned and thus unsupported spinoffs.

Sometimes spinoffs evolve around the development of particular innovations (Anton and Yao, 1995; Wiggins, 1995; Bankman and Gilson, 1999). Innovations relate closely to the activities of parents and grow out of research undertaken by the parents. Spinoffs will occur, when employees pursue new technological discoveries made in his/her own firm. Wiggins (1995) and Anton and Yao (1995) add that the innovations are likely to be path-breaking and opening new sub-markets within the industry. The work of new firms and organisations is related to activities of parents and is in some cases innovative and introducing new products or services to the market.

Other social issues are also likely to play a part in the location decisions of founders of new firms. They have strong social ties to a specific location through the employment of their

spouse, the school of their children etc. This may also prevent them from leaving the region. So in general, we might expect that clusters of new firms in a particular industry continuously evolve in regions, where human and other resources are abundantly present and where entrepreneurs are produced at a large scale in the incumbent firms of the industry. If all of this is the case, the existing structural base of a region is a dominant source of the geographical concentration of industries and regional economic growth. But which factors determine where the initial activities of a new industry are located?

The initial activity is often seen as being located in a particular geographical location by chance (Arthur, 1990). This could be a single *de novo* entrepreneur (entrepreneurial spinoff) or a single diversifying local organisation. Arthur (1994) highlights the claims of Engländer (1926) and Palander (1935) that historical and chance events would have provided a location structure; and that inherited structure combined with agglomeration tendencies would determine the future settlements in a region. New industries will be laid down layer by layer upon inherited structures through the phases of development. In an evolutionary perspective, agglomeration can be interpreted as the mechanism by which existing organisations will breed the new ones founded by entrepreneurs.[7] New firms in a region will mainly emerge from the existing ones as entrepreneurial spinoffs. The immobility of labour as a result of social and economic forces will induce entrepreneurs to locate close to their origins, so they can maintain their social ties and continue exploiting their localised knowledge of capitalists, potential employees, and suppliers. As a consequence, the quality of the new organisations and the future development potential in a region at a given time, will be a function of the quality of the stock of existing firms and past entrants (Klepper, 2003). This is in line with Romanelli and Schoonhoven (2001), who argue that most new firms will be founded in the same geographical region, or very close to it, as that of the firm that produced the entrepreneur. Only few entrepreneurs will be attracted to another region because of available technical and market expertise and other resources. Entrepreneurs will more typically be produced within the region itself by existing organisations. This means that a region's future will be closely determined by its present structure and profile.

The spinoff process in a cluster also has a downside. Phillips (2002) argues that life chances of a parent organisation decrease, especially when higher ranked employees leave to found new firms. The transfer of knowledge and routines is larger from the parent to the entrepreneurial spinoff, the higher the founder was previously ranked. A 'parent-brain-drain' like this represents a disruption in the routines of the parent, which clearly affects the future of the firm. Furthermore, Rajan and Zingales (2001) argues that higher ranked employees are likely to take lower ranked employees with them to their new organisation. This is also likely to decrease the life chances of the parent. However, as time goes by after

[7] Arthur (1994) have argued that similar organisations with a somehow different background and from other regions will be attracted by the growing presence of activities. This tradition goes back to Weber (1928).

the separation of the progeny, life chances of the parent increase again, since the routines are rebuilt and stabilised. In his analysis of the Silicon Valley law firms, Phillips (2002) found that the transfer of resources and routines between parent and progeny decreased the life chances of the parent, but increased the new organisations' chances of survival[8].

3 The role of new firm entry in the history of the NorCOM cluster

The evolutionary approach outlined above is applied in the present section on the development of a fairly small cluster of high technology based firms in the field of wireless communications in the region of North Jutland, Denmark.[9] Defined narrowly, it consists of around 50 firms, a science park (NOVI) and Aalborg University (AAU), which contains one of the two major technical universities in Denmark as its Faculty of Engineering and Natural Sciences. The relative small size of the cluster has facilitated more easy information access and has made it possible to study an entire cluster over more than three decades.

3.1 The history

3.1.1 Early success of S.P. Radio

The success of S.P. Radio (established in Aalborg in the 1940s) in the 1960s and 1970s as one of the world's leading producers of maritime communications equipment gave the employees, who was the founders of the first spinoffs in the 1970s, the relevant capabilities and routines to become successful themselves. S.P. Radio is usually acknowledged as the main parent company in the NorCOM cluster. Simon Petersen, a newly graduated engineer, started a consumer radio retail business in Aalborg around 1930 and soon after he began manufacturing radio receivers himself. After World War II he started S.P Radio A/S, and increased the production of consumer electronics. In his spare time, Simon Petersen was a yachting enthusiast, and through this hobby he got the idea of producing radios for maritime use in yachts and small fishing vessels. S.P. Radio produced the first radio in 1949, but they did not start to produce radio communication equipment for maritime use (receivers and transmitters) until the early 1960s. The company had grown steadily since its establishment, but in the 1960s there were more than 30 producers of consumer electronics in Denmark and Simon Petersen saw that the industry was reaching a saturation point facing fierce

[8] Phillips also found that if a new organisation has founders from more than one parent, they were more likely to fail than otherwise. This result suggests that a mix of routines and experiences from different parents are likely to decrease the performance of the new organisation.

[9] For an account of the early development of this cluster, see Dalum (1995). More recently several studies have focused on various features of this cluster. Dahl and Pedersen (2004) (see Chapter 6) have studied the informal networks, Dahl (2003) has studied inter-firm mobility of labour, Dalum, Pedersen and Villumsen (2005) (see Chapter 8) have discussed the potential technological disruptions facing the cluster in a life-cycle context, and Lorenzen and Mahnke (2002) have studied the effects of acquisition activities by multinational companies.

competition. Large producers largely neglected the market for radio communication equipment to small vessels, so there was nearly no competition in this area. Consequently, S.P. Radio stopped producing consumer electronics and diversified into developing and producing maritime communication equipment in the mid-1960s. This became an almost immediate success. The equipment was technologically very advanced compared to its few competitors. The price was competitive, since there was not much use of mass production at the time in this industry. After a few years S.P. Radio was one of the world's leading producers of communication equipment to this segment. In 1966, the company had 150 employees, high exports and continued to expand its product line into the market for larger vessels.

S.P. Radio continued its success and grew in the 1970s and 1980s and was the largest communications firm in North Jutland in these years. In 1973 the first spinoff firm Dancom was founded by three engineers from S.P. Radio. One of them had been the head of R&D of S.P. Radio for four years. There is no record of why they started their own firm, but newspaper articles and literature indicate that Simon Petersen were very controlling and had a bad temper. This has definitely influenced the creation of the spinoff. Dancom was active in the same markets as S.P. Radio producing maritime communication equipment and later on also in closed mobile systems for onshore use.

A few years later in 1977 two experienced engineers working at Dancom decided to start Shipmate (named Rauff & Sorensen after the two founders in the first few years) in the washing room in Sorensen's basement. The first product was a radiophone for maritime use, which competed directly with both Dancom and S.P. Radio. Their product sold very well and funded the development of the next version, which was a large breakthrough for the company. In 1980, further success came after a boat exhibition, where they got the idea to develop a satellite navigation system. At that time the firm only had one employee besides the two founders. But they were still able to develop a complete navigation system at one third of the price of the competitors in only one year. Shipmate successfully developed and produced radiophones and navigation equipment for maritime use. Five years later the firm had reached 200 employees.

Dancom went into financial difficulties in 1980. The founders were suspended from their duties as managing directors. The firm was reconstructed under the management of Henrik Langkilde, who was brought in by the creditors. Before that he had written a 300-pages report as a consultant for Dancom. They wanted to explore the possibilities for using the firm's capabilities and advantages from maritime communication in an emerging market of onshore personal communication. The report was a complete overview of the worldwide wireless communication industry including an assessment of its future development and market potential. The reconstruction of Dancom was a turbulent period for the people in charge. The firm was located in the small community of Støvring, south of Aalborg, and they

were constantly followed and confronted by employees wanting to know more about their future. Consequently, they decided to move the firm to Pandrup, north of Aalborg, where a smaller components division of Dancom was already located.[10] Langkilde successfully reconstructed Dancom on a smaller scale focusing only on closed onshore mobile communication systems. Shortly after the firm started activities in producing personal mobile phones. In 1982-83, Dancom changed its name to Dancall Radio and shortly after it went public on the Danish Stock Exchange.

After the reconstruction, one of the original founders of Dancom, Svend Hansen, continued the maritime activities, when he founded Danish Marine Communication. He bought Dancom's old buildings in Støvring and hired some of the fired employees. [11]

3.1.2 The success in the first generation of mobile telephony

In the early 1980s some of the cluster firms and spinoffs (especially Dancall) diversified into an emerging technologically related area of personal mobile communication equipment. These new firms eventually started the second wave of success. They diversified into mobile communications as the market opened by the introduction of the common Nordic standard for mobile telephony (NMT). When the market boomed during the 1980s, these firms were successfully among the world leading producers of phones for this network. They were able to use the inherited and developed capabilities from the maritime radio communication equipment to diversify into mobile phones.

In this first generation of mobile communication, most countries had their own system based on different standards. Only the Nordic countries had a common standard. This is often argued to be one of the reasons for the success of the Nordic mobile phone producers. At the global level, the entrants of the mobile communication equipment industry in mobile communication technology came from many different technologies related to electronics. However, a major group of entrants were from either radio or network technology, of which the latter group has been the most successful (e.g. Nokia, Ericsson, and Motorola).

In 1985, Shipmate expanded into mobile communication with the new activities placed in a parent spinoff, Cetelco (with one of Shipmate's founders as technical manager). A year later they had developed and produced their first mobile phone. The reason for establishing Cetelco was to produce NMT phones, which had a fast growing market, but also to build up production capacity for mass production, that could reduce the costs of the maritime

[10] The component division was located in Pandrup, because of regional development subsidies.

[11] Other firms emerged in the early 1980s: Lasat (1982), an inexperienced entrant (founded by newly graduated engineers from Aalborg University), produced modems for wired telecommunications networks, and Niros Telecommunication Development (1985), a parent spinoff headed by engineers from Danish Marine Communication (1980-87), founded as a development department of a Danish firm, focused on radio communication. LH Agro was founded in 1976 as a parent spinoff of a local electronics firm focusing on communication systems for agricultural use.

products. After two years Cetelco had 25 engineers working with R&D. They developed and produced mobile phones for several European and East Asian countries. The tremendous success of NMT had made other countries adopt the system, albeit in slightly different versions. The NMT network was cheap to build in comparison with the more advanced systems, which was introduced in Western Europe in the beginning of the 1990s, so it continued to be the preferred system in particular in the Eastern European countries, the Middle East and Asian countries into the mid-1990s.

The cluster firms had high growth due to their successful diversification into mobile telephony and North Jutland became visible as a NMT region, but in the last half of the 1980s the market changed. The phones had undergone rapid technological development. From being relatively heavy, more or less portable (bag-like) terminals often installed in cars, the phones became much smaller and handheld. The small cluster firms were facing an international market with high development costs, production capacity demands and price competition, but they still managed to grow, since the local factor conditions were favourable. In newspaper articles from late 1980s, representatives of some firms stressed the importance of a large group of unskilled labour (the region had a 20% unemployment rate) with many possibilities for in-service training and the presence of a local university as particularly favourable conditions. However, there were severe problems attracting qualified and experienced engineers from other parts of the country. An engineer, who moved from Storno, a wireless communications firm in Copenhagen and later founded a spinoff, confirms this. He claims that it was not attractive to move to North Jutland to get a job at Dancall in the early 1980s, because there were only a few firms to work for.

In 1987, seven experienced engineers from Dancall founded T-Com. The engineers disagreed with Dancall's overall market strategy and decided that they could do it better themselves. T-Com's strategy was to develop NMT mobile phones just like its parent company, but differed by only focusing on R&D as a subcontractor. Other companies would then produce and market the phones under their own brands. In the same year, they developed their first mobile phone (produced and marketed by the French firm Alcatel). The firm focused on developing small, light, and advanced terminals. T-Com was very successful and after two years it had developed versions for all the different standards in the world. The company was first sold to British C-Com in 1990, but only one year later Maxon acquired it. Maxon from South Korea wanted to enter the market for mobile phones. The new Danish division of Maxon continued to develop NMT phones until 1995, because the NMT market continued to be large in Northern and Eastern Europe, the Middle East, and Far East Asia.

In the last half of the 1980s, there were a total of 15 firms in the industry in Northern Denmark. One of the entrant firms had been closed, but new firms had continued to enter. The majority of these were spinoffs.[12]

3.1.3 The success in the second generation of mobile telephony

The third phase of success started when the common European standard for mobile telephony (Groupe Spéciale Mobile, GSM) was introduced as a new standard. The success of NMT inspired the European telecommunications operators to create a European system based on digital technology. A race began between the leading producers in the world to be the first to be able to produce a complete terminal for this network.

The challenge of building a GSM mobile phone was seen to be a major economical and technical challenge for the mobile communication firms, since it was based on new digital technology. To cope with this, the two competitors Dancall and Cetelco formed a pre-competitive joint venture company, DC Development, with the purpose of building the basic modules of a GSM mobile phone in close cooperation with the Department for Electronic Systems at Aalborg University. The companies should develop the rest of the phone (display, design etc.) themselves. T-Com/Maxon was also a part of the planning process, but decided not to join and continued to focus on the NMT phones. DC Development was founded in 1988 and located at a new science park, NOVI, close to Aalborg University. They participated in the international GSM standardisation and specification process, since the specifications were determined in parallel with the development of the terminals. In 1990 the cooperation was increased to also include setting up the first production lines. Dancall focusing on the radio print and Cetelco on the digital part, which combined are basic elements in a GSM phone. This was a large technical challenge, since they had to develop and design their own automatic test equipment. DC Development succeeded in the development of basic modules and the parent companies were among the first to produce a GSM mobile phone in 1992. In spite of the achievement and talks during this period of making DC Development a permanent establishment, the companies decided to end their cooperation. DC Development employed at the peak almost 30 engineers and the group was divided equally between the two firms after the closing. The success increased the international visibility of the cluster and strengthened the region's reputation in wireless communication technologies.

The market changed as multinationals entered the GSM market with increased competition, falling prices, rapid development and increased demand for volume production as a consequence. The high development costs of NMT and GSM phones put Dancall and

[12] These were: Ammcom (a Dancall spinoff in 1986), BD Consult (a Cetelco spinoff in 1988), and Spacecom (a Thrane & Thrane (Copenhagen) spinoff in 1989). There were also two inexperienced entrants, Digianswer (who first was successful in developing a digital answering machine for the mobile phone and later a combined telephone and fax. Founded in 1986) and Force Electronics (developing and producing communication analysis and satellite equipment. Founded in 1989).

Cetelco into severe financial problems in the early 1990s, because they did not have enough financial backup to harvest their discoveries.

As a consequence, Cetelco was gradually taken over by Hagenuk (Germany) in 1988-90. Hagenuk wanted to enter the GSM market. Cetelco continued to grow afterwards (from 100 to 250 employees), but had too high development costs compared to its income. This became a problem already in 1993 with their first GSM phones, which were expected to last 15 months in the market, but only lasted 9 months. In 1995 when Cetelco launched the second version GSM phone, the development period was miscalculated, the phone was too big and expensive compared to competitors, and as a result the firm had to downsize the production and the number of employees dropped to 150. During the late 1990s, Cetelco stopped producing mobile phones and was only an R&D division of Hagenuk. In 1998, Telital (Italy) took over the division, but only three years later the problems were back. In December 2002, the firm was finally closed down. Some of the employees were immediately hired in bunches by other local firms and a new firm, Advanced Wireless Design (a parent spinoff of a Hong Kong based firm), was established with ten former employees.

Dancall had more than 600 employees in early 1993.[13] But the newly produced GSM phone was too expensive compared to competitors and at the same time the export of NMT phones suffered from declining markets. Consequently, Dancall had severe financial problems and the firm sold off their cordless telephony division as Cortech.[14] Now the only activity of the firm was mobile phones. But this was not enough and the firm still had to suspend its payments. Dancall was reconstructed with fewer employees and sold to Amstrad (United Kingdom). During the next couple of years, the firm grew larger than before the reconstruction. In 1997, Robert Bosch (Germany) acquired it. Bosch used the acquisition to enter the GSM market and continued the expansion to 1400 employees in 1999. In 2000, Bosch realised that it was too small a player in the industry and the firm decided to cut off its mobile phone activities. It ended up splitting the Danish division into two parts. Siemens (Germany) acquired the R&D department and Flextronics International (United States) bought the production facilities. During the transition period with changing ownerships many engineers moved to other local firms. Some of them also founded new firms.[15]

Several spinoff firms were founded throughout the 1990s. Gatehouse (founded in 1992 – spinoff from Dancall) began as an independent software company and worked as a

[13] In 1990, Dancall focused only on mobile and cordless phones. The production of closed mobile radio communication systems was separated as Danphone in a joint venture with a local electronics firm.
[14] DeTeWe from Germany bought this part. Cortech had success during the 1990s and continued to grow. In 2001, Rohde & Schwarz (Germany) acquired it with the focus of developing test equipment for wireless communication equipment.
[15] For instance TTPCom, which was founded in 2001 by three experienced engineers from Siemens. They wanted to startup themselves, but chose to start up a Danish branch of TTPCom (UK), developing e.g. software and games for mobile phones.

subcontractor for several other local firms from the beginning. It started out in GSM mobile phones, but gradually expanded into other technologies opening up the local market. The company has continued to grow and had 22 employees in 2002. In 2003 the expansion has continued through the acquisition of a small local competitor, PB Radio. PB Radio was founded in 2001, when a group of engineers spun off from Eurocom Industries (S.P. Radio).

Although mobile and maritime communication technologies were dominating activities in the local industries, other wireless technologies thrived as well. Among these were cordless telephones for regular wired telephony. Within this field, Danish DECT Development was founded in 1993 as a joint venture between nine communication companies (four of them were local). The purpose was to work on a further Danish development of the specification on the new European standard for cordless phones, Digital European Cordless Telephony (DECT). The standard was rather unspecified and further work was needed in order to actually produce phones from this standard. The purpose of the joint venture was to help the small Danish firms and to give them first mover advantages by providing them results from field experiments and test of prototypes. Although DECT mainly was supposed to be for speech it also included data transmission. After completing its task, L.M. Ericsson (Sweden) acquired Danish DECT Development in 1995 and renamed it L.M. Ericsson Danmark. The firm continued working with DECT cordless telephone technology. Later it expanded into mobile telephony and other wireless technologies. At its peak in 2000, there were 130 employees. In the late 1990s, the Danish division in Aalborg was appointed to be one of L. M. Ericsson's main development centres for the next generation of mobile phones. This increased the local expectations regarding the future employment potential, but then the telecommunications crisis hit. The firm was cut down in successive steps.[16]

In 1993 three experienced engineers from Maxon and four from Cortech decided to spin off.[17] They founded RTX as a turnkey solution development firm with the strategy to do R&D for other firms. RTX based their DECT design on chipsets from National Semiconductor and developed a very close cooperation with the U.S. company. Later, National Semiconductor also acquired a part of RTX. National Semiconductor had previously worked with Dancall and needed the knowledge on the future development of wireless devices to design their chipsets and RTX vice versa. RTX grew from seven employees in 1994 to more than 200 in 2003. The firm has never had a spinoff and very few engineers have left RTX to join other firms.

[16] In 2003, L.M. Ericsson downsized its division in Aalborg. Before that a group of engineers started Blip Systems, while another group was bought by SemCon Sweden, which located a division in Aalborg consisting of former Ericsson employees. SemCon was closed down in 2003.
[17] All seven had previously worked for Dancall.

During the last half of the 1990s a new bluetooth technology[18] became rooted in the cluster. RTX and Digianswer entered bluetooth very early and as a result Motorola acquired the latter in 1999. In early 2001 the UK-based Cambridge Silicon Radio (CSR) founded a parent spinoff in the region.[19] They hired a former Digianswer employee to start up the Aalborg department with the purpose of developing software for bluetooth devices.

During these years, several other experienced entrepreneurs decided to found spinoffs. Increasingly, other wireless technologies such as bluetooth became the main activities of these new firms and only one of them had activities directly in the area of mobile phones. This was ATL Research founded by engineers from Cetelco in 1996. While working at Cetelco they often got inquiries from other firms in the industry that wanted to buy development aid for mobile phones. But since Cetelco was a R&D department of Hagenuk, it was not possible to follow the potential market within Cetelco. The breakthrough of ATL Research was when they presented the world's smallest dual band mobile phone after six months of development work in 1997. ATL cooperated with several chipset manufactures until Texas Instruments (TI) acquired the firm in 1999. When this happened, a group of engineers headed by Ole Madsen left ATL/TI to found a local affiliate of Condat (Germany). This firm was acquired by TI and merged with TI's other activities in Aalborg. This enabled the American company to develop an entire mobile phone by itself in Aalborg.

At the global level, the mobile communications industry had high growth rates and mobile phone sales were skyrocketing in this period. The large multinational players in the industry were increasingly looking for new areas to base their activities in, in order to access local pools of development engineers. The Aalborg region had become very internationally visible within wireless communication and was an area where international firms could find the competencies they were searching for. As a result there were many parent spinoffs in the region from 1998 and onwards. Especially the big producers of chipsets and semiconductors entered the region. For example, Analog Devices (U.S.) hired one of DC Development's engineers to create a department for systems solutions in USA. In 1997, he was sent back to start up R&D activities for Analog Devices in Aalborg to improve the research activities and cooperation with customers.[20]

[18] Bluetooth is an industry standard for wireless data transmission over short distances between different types of devices.

[19] Other local firms also entered bluetooth (Penell and L.M. Ericsson). Also, a small group of relatively inexperienced engineers founded Bluetags in 2000 with the purpose of developing a bluetooth-based luggage tag.

[20] The NorCOM firms are not big buyers of components themselves, but they carry out R&D for many high volume manufacturers. In this phase, many very important strategic decisions are taken concerning choice of components, new trends, standards and norms, so it was increasingly important for chipset and semiconductor manufactures to have close connections to the R&D firms.

3.1.4 The burst of the dotcom bubble and the uncertain future of the industry

The period from 1999 to 2003 was a turbulent period for the cluster since the growth was quite rapid, but the cluster was affected unfavourably by the crisis in the telecommunication sector from the summer of 2001 with stagnating sales. The crises led multinationals to change strategies of which some collected their R&D units in larger units (in their home country) and other reduced the R&D expenses. Consequently, many of the Aalborg divisions of multinationals were downsized tremendously, e.g. Nokia, Ericsson, Lucent etc. However, many new firms were founded in these years. During the boom in 1999 internal disagreements let Maxon to dismiss the Danish management. Shortly after the former manager and marketing director founded Shima Communication. Many other Maxon employees followed them to the new company. They developed GSM phones for Chinese and Asian markets, and grew rapidly to 100 employees, when they were hit by the crises. Customers stopped payments, the expected revenues from royalties fell, and Shima was subsequently closed down. The employees primarily went to other cluster firms in groups. The old maritime communications firm ECI (S.P. Radio) had been in severe financial problems for some years and the manager and head of sales were dismissed in 2000. Shortly after they founded their own company, Polaris Electronics, competing with their former employer. Financial trouble also led to the formation of the parent spinoff Futarque Technologies in 2001. Force Electronics (development, marketing and distribution of satellite TV receiver equipment) went into suspension of payments and the R&D unit continued as Futarque. Force Electronics was later on acquired by Satellit Kompaniet (NO) and is competing with Futarque.

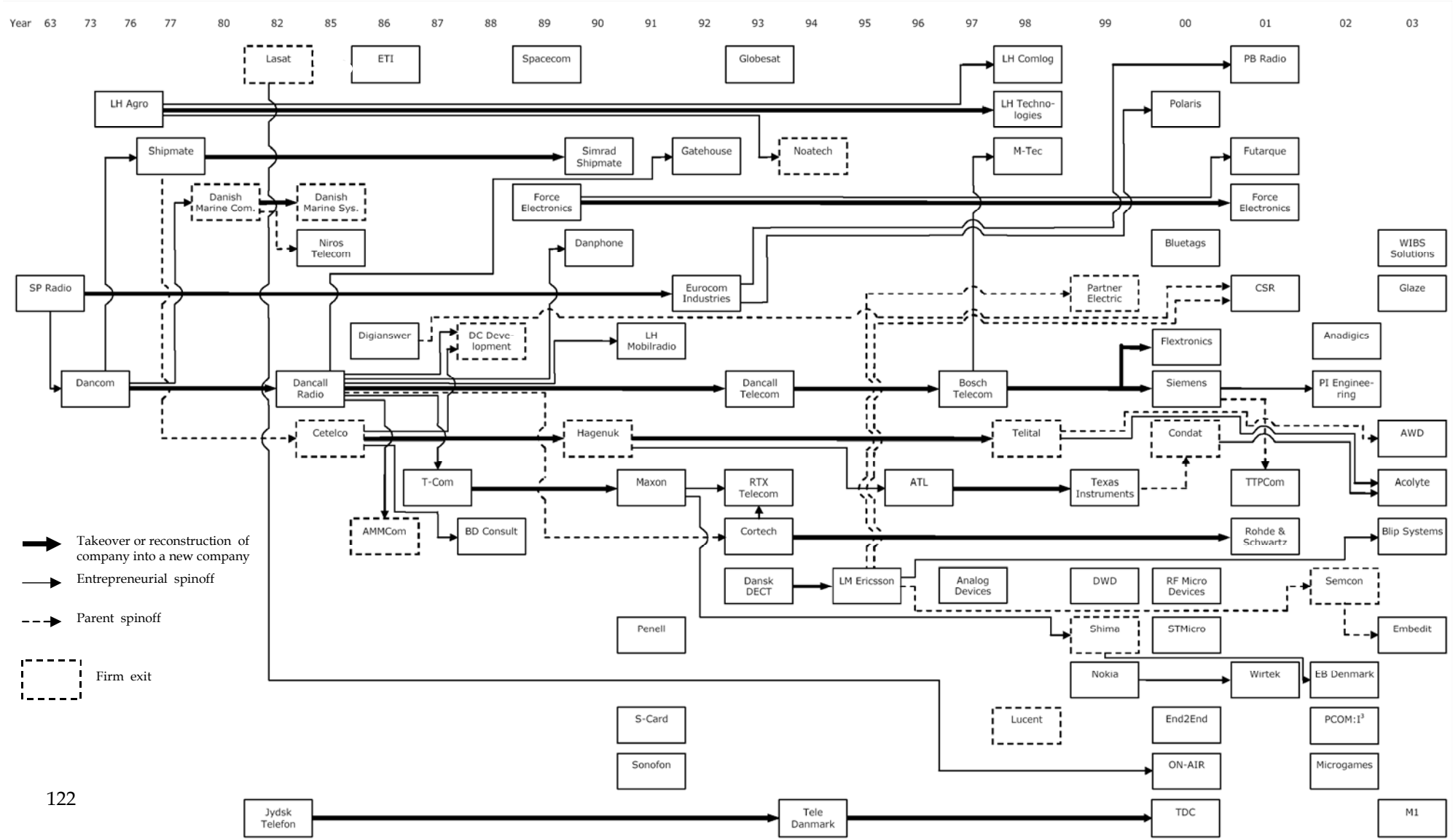
The crisis in the telecommunications sector in 1999 hit the service providers and the network infrastructure manufactures first, but in mid-2001 the terminal manufactures also had problems. The large multinationals sacked engineers, but the smaller local firms hired them. Others founded their own firm, e.g. Wirtek, Futarque, EB Denmark and PI Engineering. The crisis kept going in 2002, where four firms exited. Three of these went bankrupt, and one was acquired by the local Texas Instruments division. Despite these increases in exits, there was a still a growing number of firms in the cluster, because of higher entry rates.

3.2 The genealogical evolution

Figure 1 shows the genealogical evolution of the NorCOM firms. A bold full line between two firms represents a change in the original structure of the firm. This can either be a takeover by another firm or a reconstruction after financial troubles. Each arrow between firms indicates that one or more employees moved from the existing firm to found a new one – i.e. the entrepreneurial spinoffs (full arrow) or parent spinoffs (where founder or initial

management have come from a local firm – broken arrow). Firms with a broken box have closed and exited. In general, further information on individual firm events are found in Table 4 in the appendix.

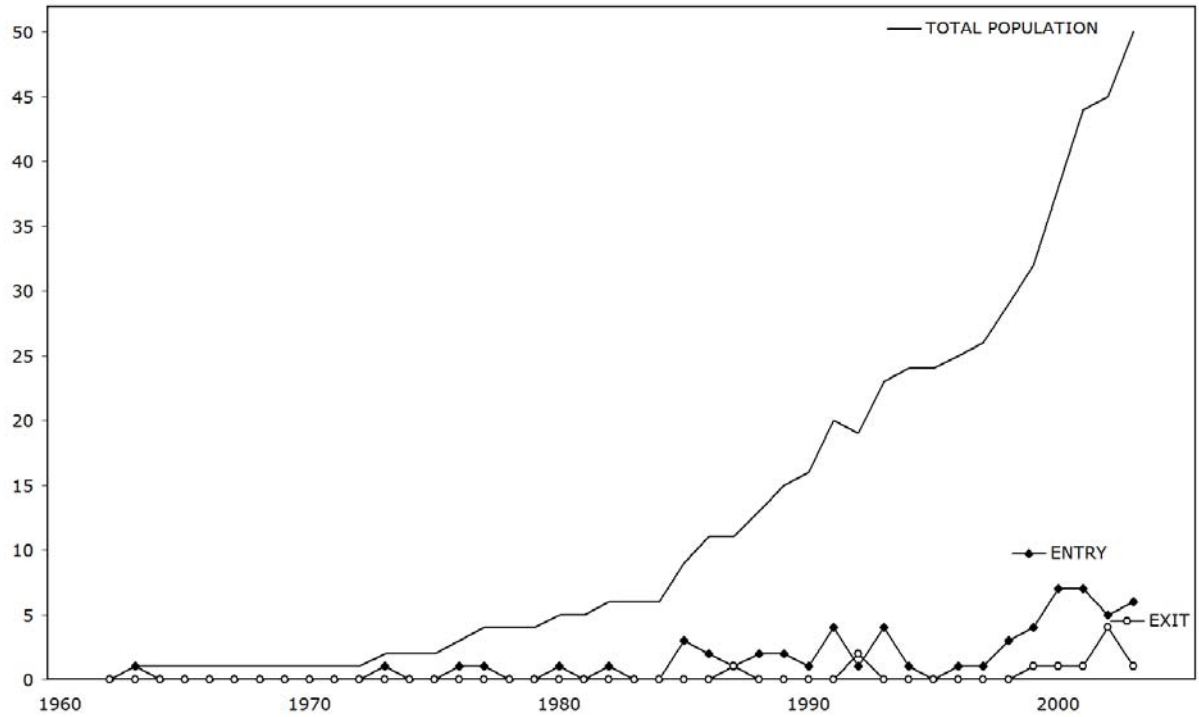
Figure 1 The Genealogy of the Wireless Communications Cluster in North Denmark (NorCOM) - 1963-2003



3.3 Types of entry and their employment impact

The overall evolution of the population of firms in the cluster is shown in Figure 2. There has been a steady, and even increasing, growth in the number of firms since the beginning.[1] Even after the turbulence caused by the burst of the dotcom bubble there has been a substantial entry. As a result the number of firms is higher than 50.

Figure 2 Entry and exit of firms in NorCOM



The number exits has until now been remarkably low. The year 2002 has been the only year where the number of exits has been above two in a single year. Only 11 firms have exited. Several firms have, however, been rescued from exit on the verge of bankruptcy after being taken over by other firms, typically multinational companies.

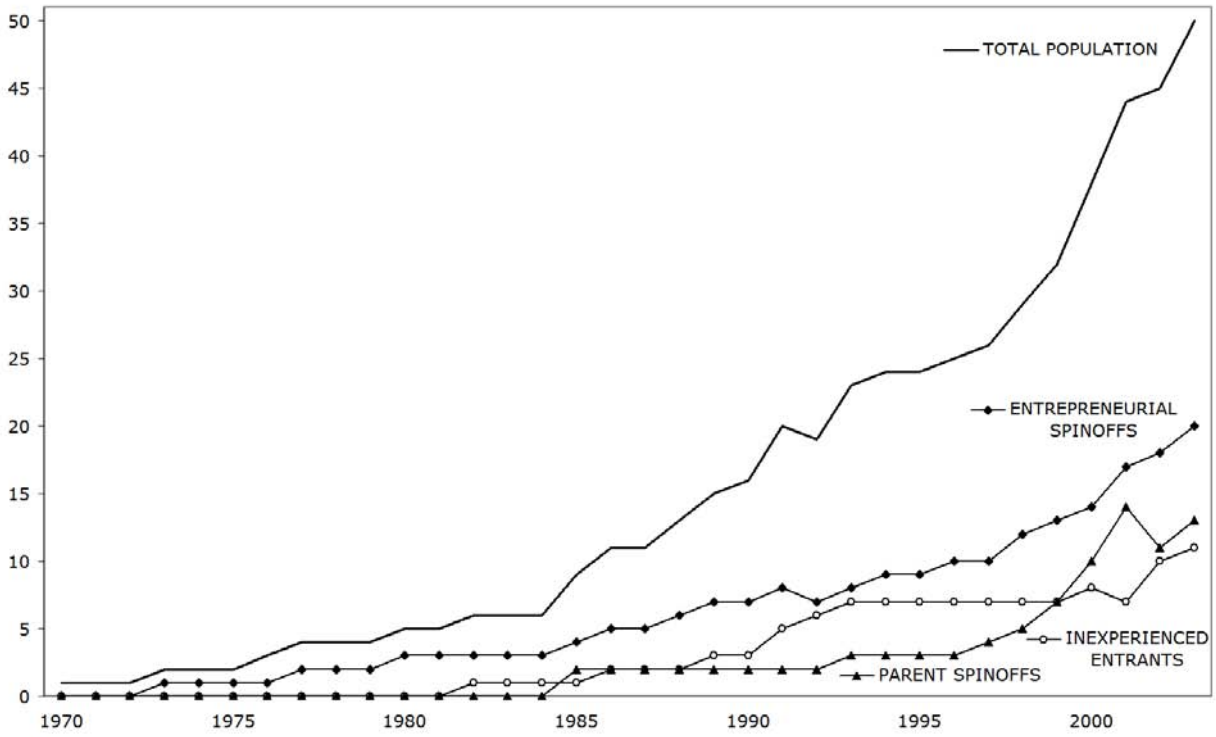
Three phases may visually be distinguished in Figure 2 in terms of different slopes of the total population curve. During 1973-84 the cluster grew from two to six firms, following the initial early success of the first parent, S.P. Radio. In the second phase 1984-95 the population

[1] Given the small number problem of this study, warnings should be given concerning interpretation of concepts like 'change of growth rates' etc.

of firms increased from 6 to 24 firms. In the third phase 1995-2003 the population increased from 24 to 51 firms.

In the process of constructing the genealogical tree in Figure 1, detailed information on every firm being active in the cluster since the 1960s has also been collected concerning the type of entry, cf. Table 1. The evolution of the cumulative number of the three most important types of entrants is shown in Figure 3.

Figure 3 Entry and exit of new firms in NorCOM by main category



The diagram indicates that the entrepreneurial spinoff firms have represented a large share of the increase of the population. They have been a driver of cluster growth during the entire period, but especially in the early years. Likewise, it has been the largest group of firms throughout the history of the cluster. The growth in the number of parent spinoffs since 1997 represents the increasing international visibility of the cluster. After the introduction of the GSM system, where local firms were at the front from the beginning, the international focus on North Jutland's wireless industry has increased the number of parent spinoffs from three in 1995 to 15 in 2001. Before 1995 there were mainly local or national based players behind the parent spinoffs. Later, it was foreign companies, such as L.M. Ericsson (SWE), Texas Instruments (U.S.), Motorola (U.S.), and National Semiconductors (U.S.), which entered through acquisition of or investments in already established local firms. Multinationals such

as Nokia (FIN), Lucent (U.S.), Analog Devices (U.S.), and Infineon (GER) located activities in the region through green field investments.

It should, however, be emphasised that the patterns shown in Figures 1 and 2 are based on counts of individual firms independent of their size. Table 3 indicates the general economic impact of the firms in terms of the top ten largest employment generators in 2003.

Table 2 Top ten employers in NorCOM in 2003.

No.	Name	Employees	Founded	Type[1]
1.	The old Dancall (Flextronics/Siemens)	1,520	1973	Entrepreneurial spinoff
2.	Sonofon	953	1991	Joint venture
3.	Eurocom Industries (SP Radio)	250	1948	Diversifier
4.	RTX Telecom	230	1993	Entrepreneurial spinoff
5.	Maxon Telecom (T-Com)	130	1987	Entrepreneurial spinoff
6.	Simrad Shipmate	120	1977	Entrepreneurial spinoff
7.	Texas Instruments (ATL + Condat)	105	1996	Entrepreneurial spinoff
8.	ETI	86	1985	Inexperienced startup
9.	Digianswer	83	1986	Inexperienced startup
10.	LH Technologies	80	1976	Diversifier
-	Remaining 40 firms (Avr. size: 15 empl.)	580	-	-
Total employment		**4,137**		

Employment data source: NorCOM Association (http://www.norcom.dk)
1. See Table 1.

The old Dancall firm is by far the largest employer due to the assembly plant now at Flextronics. The second largest is the mobile telephony operator Sonofon. Most of the remaining firms focus on development – and not manufacturing. Among the top ten firms, five firms are entrepreneurial spinoffs. This indicates that this type of entry can account for the majority of employees as well. To investigate this further, we have aggregated the employment figures for all the firms existing in 2003 for each type of entrant. This is shown in Table 3.

Table 3 Employment generation by different types of entry in 2003.

Type[1]	Employees	Number of Firms	Average size	Percentage
Diversifiers	330	2	165	8%
Parent-company activities:	1,270	17	75	31%
- Joint venture[2]	1,029	4	257	25%
- Parent spinoff	241	13	19	6%
De novo entrants:	2,537	31	135	61%
- Entrepreneurial spinoff	2,350	20	118	56%
- Inexperienced startup	187	11	17	5%
Total employment	**4,137**	**50**		**100%**

Employment data source: NorCOM Association (http://www.norcom.dk)
1. See Table 1 for further explanation.

The entrepreneurial spinoffs have generated the largest amount of jobs compared to the other types of entrants. In total, entrepreneurial spinoffs account for 56% of the total employment in the cluster. The second largest group in terms of this is the joint ventures accounting for 25% of the employment. Inside this group, Sonofon represents 953 out of 1,029 employees. Sonofon is a telecommunications service provider with a huge staff of supporters. It was located in Aalborg as a political decision to recognise the emergent cluster of firms in the industry. Firms founded by more inexperienced entrants do generally not grow as large as other firms. Part of the story is also that the restructuring of activities at the international level following the dotcom crash in 2000 has been more extensive in the multinational companies. As a result the parent spinoffs connected to these firms have been downsized to a larger extent than other firms. However, local spinoff firms acquired by multinationals but managed by locally brought up entrepreneurs have suffered somehow less from this.

These employment data are, however, very volatile, since the old Dancall (Flextronics and Siemens) and Sonofon accounts for the major share of the employment. If these were removed from the tables the main results remains rather stable with the dominance by entrepreneurial spinoffs. The heavy downsizing of Flextronics in 2004 also reveals the volatility of the employment data. The company accounts for approximately 1,300 employees, but this shock does not change the overall picture of the importance of entrepreneurial spinoff in the growth and evolution of the cluster.

4 Discussion

The most powerful finding of this study is that entrepreneurial spinoffs account for the majority of the firm growth in the cluster. Also in terms of employment no other type of entry accounted for a growth in the same magnitude (note the volatility of the data).

Spinoffs are theoretically argued to be a source of path-breaking innovations and opening new submarkets (Anton and Yao, 1995; Wiggins, 1995). This is confirmed by our study. We find that spinoffs are often sources of increased variety. Especially in the later period, where the variety among the local industry firms increases as new spinoffs create businesses in niches and markets, which are new to the region and occasionally also to the entire industry. Incumbents have generally been more reluctant to enter emerging submarkets of the wireless industry. Most of them have concentrated on their core activities through time. Only one of the large incumbents (Dancall) has been able to succeed technologically in several technologies. Dancall started as a maritime communications spinoff with activities very close to the parents, but quickly moved into other submarkets such as closed onshore communication systems, cordless wired telephones, and later personal mobile telephony. This is an interesting example of a firm, which has been able to flexibly adjust to emerging markets not only as a young spinoff, as argued by Klepper (2001), but also in the later stages of the history of the firm. However, the firm has also been the most turbulent firm in the cluster. It has been in financial troubled several times and reconstructed four times (three times with new owners/investors) on the verge of bankruptcy. The turbulent internal environment and uncertainty about the future has been a reason why Dancall has had the most spinoffs[2].

Another implication of this study is that local entrepreneurial spinoffs appear to have suffered less than the worldwide industry after the burst of the dotcom bubble. Parent spinoffs or divisions of large multination companies in the region have been closed down or downsized to a much larger extent than other types of entrants. Former high profile entrants, such as L.M. Ericsson and Nokia, have virtually closed down all the operations in Aalborg. So it appears that given the amount of new entrants after the burst, the cluster has not been influenced to a significant extent. An interesting aspect is also that the employees, which have been sacked in the downsizing of Ericsson and Nokia, have started new firms themselves in groups. A group of former employees from Ericsson started their own firm financed by SemCon from Sweden. One year later Semcon Sweden pulled the plug on their division in Aalborg, but the employees continued as a division of the Copenhagen-based

[2] A spinoff may be the result of organisational problems or inertia in the parent firm (Cooper, 1985). If the incumbent has difficulties of an organisational nature, the employee is likely to have less difficulties leaving the firm and taking advantage of the missed opportunities. Examples of such a crisis is when the incumbent is acquired by another firm, when a new CEO from outside has been appointed, or when a firm experiences decreasing economic performance (Brittain and Freeman, 1986). Another reason that Dancall has many spinoffs could be that firms with broader product lines are argued to spawn more spinoffs, since they form inspirational learning environments for their employees. Employee learning can also play an important role in spinoffs. This implies that spinoffs will exploit the opportunities of their parents by entering with a product similar to the one they worked with at the parent. Consequently they either compete directly with their parent or more narrowly with one of the parent's activities (Franco and Filson, 2000; Klepper and Sleeper, 2002). The entrepreneurs may be motivated to found a competing firm, when the growth of their current employer indicates a substantial demand for its products and services. Growth, especially very fast growth, can indicate the presence of an unmet demand and thus great market opportunities for additional competitors (Romanelli and Schoonhoven, 2001).

Embedit. Similarly, Nokia had a spinoff (Wirtek) during one of their downsizing operations. Both SemCon/Embedit and Wirtek now operate as suppliers to the multinational parents.

In a similar fashion, engineers have frequently changed employers in groups and project teams. When Shima and Telital had financial trouble in recent years, groups of ten to fifteen engineers left their employer together to join RTX and Texas Instruments, respectively. This enabled the project teams to stay together and continue their development activities. This type of inter-firm transfer of knowledge and capabilities has happened frequently throughout the history of the cluster. The movement of these coherent groups of people is likely to have immediate effects to the receiving firms. They are very likely to be well functioning and they have already built internal cooperation patterns and systems. This will enable them to have a relatively larger and more immediate impact compared with an establishment of the project groups from the bottom.

Since 1999, the business environment of the industry has been very turbulent. In this period, the number of exits has increased. However, at the same time entry has also increased substantially. Although it is small numbers and only a few years is this case, this development seems to be typical for industrial clusters. In a study of the U.S. footware industry, Sorenson and Audia (2000) found that both entry and exit increases as the local population of firms increases. The larger the population of firms, the larger is both entry and exit in the footware industry. This strongly suggests that traditional agglomeration economies could not account for the geographical distribution of the footware industry. It remains to be seen for the wireless communication industry, but there are several indications pointing in a similar direction as evidenced by the present case study. Instead Sorensen and Audia concluded that social networks are a valid explanation for the fact that entrepreneurs continue to found firms in concentrated areas, even when there does not appear to be any apparent benefits from such a location.

In the present case, founders confirm that social relationships are very important for founding a firm. A good example is again the founding of RTX. The six founders of the firm came from two different incumbents, Cortech and Maxon, and they knew each other from working together at Dancall in the past. After they had worked for the incumbents on the exact same technologies, they teamed up and founded RTX.

It is another characteristic of the cluster that venture capital (VC) has played a minor role historically. However, a few firms have been founded in more recent years backed by VCs, e.g. Bluetags and End-2-End. Even though the local science park (NOVI) was founded in the beginning of the 1990s, it has mainly acted as a supplier of office space to new firms and not directly as a VC. It has basically only supported Bluetags. This is probably the effect of a fairly underdeveloped VC-sector in Denmark, which are conservative towards these ventures.

There are several open questions concerning the spinoff process and the process of founding a firm, which are still unexplored in this context. Why do spinoffs occur? What triggers the separation process? What type of positions do future founders have in the parent organisation? How are spinoffs financed? These are the important unanswered questions, which can give us a much better knowledge about the process of spinning off. Several studies have already confirmed that this exact type of entry is an important source of economic growth and variety and technological change in industries. The background of founders can potentially explain the growth patterns of units at all levels – from individual firms, entire industries as well as geographical regions and clusters.

5 Conclusion

A key component in the growth of the cluster has been the early performance of the first entrant, SP Radio. Both technologically and economically the firm was very successful and provided a good example for the following entrants. Through the 1970s and 1980s a series of new firms was founded as spinoffs, which became among the world leaders in NMT and GSM technologies. In the 1990s the activities of parent spinoffs often founded by multinationals have added to the growth in number of firms. Often these have founded subsidiaries by hiring or headhunting experienced local employees to start the new firms.

In this process of industrial transformation, competencies from the past became highly relevant for the wireless industry from maritime to personal mobile communications through the NMT and later the GSM standard. The success of the maritime companies fuelled a series of confident entrepreneurial spinoffs often competing directly with the mother firm, SP Radio. The original and successful business design and organisational routines were inherited by the new organisations and then facilitated the overall basis for the formation of the cluster through rapid growth in the number of firms.

So far the dominating theories of economic geography and spatial agglomeration cannot sufficiently explain the emergence of clusters like the NorCOM case. The claims of the dominant theories about the initial factor conditions and overall regional attributes and institutional set-up as the explanations of the evolution of clusters in general do not appear to be satisfactory. In the NorCOM case, these factors cannot explain why this cluster of high-technology and research intensive firms all of a sudden grew up in a region, which had been lagging behind the remaining part of the country for decades - and dominated by farming, food processing, fishery and the process industries in mainly low growth manufacturing industries. Similarly the local market conditions did not support the formation of the cluster very well, since it has been oriented towards foreign markets from the very beginning with a high degree of exports.

The initial location of first firm in the cluster can at best be characterised as a chance event. The entrepreneur Simon Petersen returned to the region after studying at in another region. It could basically have been anywhere else in the country.[3] Later, when the cluster had entered its initial growth phase, the local university was founded, but even in the years after that the firms had to rely on internal competence building and 'imported' employees from other Danish regions. In this early phase the 'quality of the parents' played a major role as an early seedbed for innovation and growth. In 1980s and 1990s, the university clearly had an effect through its growing supply of qualified labour and top-level basic research in the wireless technologies of the cluster.

Clusters have become a desirable phenomenon in the minds of many public policy makers. Most of the efforts to obtain this are directed more generally at different levels. The main finding of this chapter is that spinoffs have been the central mechanism in the evolution of a high-tech cluster. Furthermore it also has some policy implications. Little attention is paid on the public policies on employee contracts, which can have a strong influence on how clusters develop through a spinoff process. The employee's future possibilities for founding a new firm can be very limited, if the employing organisations use non-compete covenants or clauses in their employment contracts. This type of adscription of employees will evidently limit the evolution of clusters and hinder employment growth through new firm formations.

Furthermore, a lot of attention and resources have recently been directed towards increasing the entrepreneurial activity of newly graduates from the universities. The idea is to get more of these from human science, social science, natural science, and engineering to found a firm based on ideas from their studies. This effort seems to exaggerated since it misses the lesson from the spinoff theories - the capabilities of new firms are shaped by the experiences of the founders and better performing firms will spawn better spinoffs. Entrepreneurial spinoffs (founders previously employed in the industry) are an important driver in the evolution of clusters[4].

[3] Two of Simon Petersen's classmates from Aarhus Teknikum, Peter Bang and Svend Olufsen, also went back to their home region (also a less favored region) and founded the still existing consumer electronics manufacturer Bang & Olufsen.

[4] In the NorCOM case only a single firm, Lasat (1982-2001), was founded by newly graduated engineers.

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7 Appendix

Table 4 Details the NorCOM firms

Name	Founded	Exit	Type[1]	Founder(s)	Events
SP Radio	1948	-	D	Simon Pedersen	- Diversified into maritime radio communications in 1963. - Renamed Eurocom Industries A/S in 1992 when acquired by SAIT-Radio Holland (BEL-NLD) and STN Atlas (GER)
Dancom	1973	-	S	P.E. Sørensen, Svend Hansen, Erik Sørensen (all SP Radio)	- Reconstructed in 1980 with Henrik Langkilde as manager. - It had 20-30 employees from the beginning and the Danish pension funds as major investors. - Renamed Dancall Radio in 1983 - Acquired by Amstrad (UK) in 1993 after bankruptcy and renamed Dancall Telecom - Acquired by Robert Bosch AG (GER) in 1997 and renamed Bosch Telecom A/S - Sold to Flextronics International (USA) (production division) and Siemens AG (GER) (R&D division) and split into two individual firms in 2000
LH Agro	1976	-	D	Per Larsen	- Renamed LH Technologies Denmark when acquired by InterAg Technology in 1998. Acquired by Spraying Systems Co. (Illinois, USA) in 2000
Shipmate	1977	-	S	Erik Sørensen and Erik Rauff (Dancom)	- Acquired by Simrad (NOR) in 1994 and renamed Simrad Shipmate.
Danish Marine Communication	1980	1987	S	Svend Hansen and Carl Eiler Carlsen (both Dancom).	- Reconstructed in 1985 as Danish Communication Systems (1985-87)
Lasat	1982	2001	I	Claus Christensen, Jens Christian Winther, Keld Nielsen (newly graduated engineers from Aalborg University)	- Acquired by Olicom A/S (DEN) in 1996 - Acquired by i-Data A/S (DEN) in 1999
ETI	1985	-	S	Mark Fitzhugh, Jesper Kaagaard (Lasat)	
Cetelco	1985	2002	P	Engineers from Shipmate	- Acquired by Hagenuk (GER) in 1990 - Acquired by Telital (ITA) in 1998, when Hagenuk went bankrupt and renamed Telital R&D Denmark A/S
Niros Telecommunications Development	1985	-	P	Gert Wolff and Preben Andersen (both Danish Marine Communication), Gorm Niros (Niros Telecommunication, Copenhagen) and Niros Telecommunication (DEN)	- Acquired by Hans Damm Research A/S (DEN) in 2003
Digianswer	1986	-	I	Ole Jensen	- Acquired by Motorola (U.S.) in 1999
Ammcom	1986	1992	S	Engineer from Dancall	Reconstructed as RRI (1991-1992)
T-Com	1987	-	S	Jørgen Elbæk, Villy Andersen, Mogens Westeraa, Jørgen Bregnhøj, Niels Christian Gjerrild, Flemming Buus Pedersen and Sigmar Gudbjørnson (all Dancall)	- Acquired by C-Com Group Ltd. (UK) in 1990. - Owner was acquired by Maxon Telecom Co. (KOR) in 1991. - Renamed Maxon Telecom in 1994.
BD Consult	1988	-	S	Bent Dahl (Cetelco)	
DC Development	1988	1992	J	Dancall and Cetelco	- Closed in 1992 due to financial difficulties in parent companies.
Force Electronics	1989	-	I	Jan Skaug Sørensen	- Went into suspension of payments in 2001 and was split into two firms: Futarque and Force Electronics - Force Electronics was acquired by Satellitt Companiet (NOR)
Spacecom	1989	-	S	Peter Nielsen (Thrane & Thrane, Copenhagen (DEN), former SP Radio)	
Danphone	1990	-	J	Dancall and Hans Jørgen Jensen	- Hans Jørgen Jensen acquired a part of the Dancall 4000 project from Dancall (development of closed landmobile radio communication systems). Dancall continued to be an owner, but the employees bought a part of the company. Manager was Ole Jensen. - In 2000 manager Ole Jensen and technical director Jens Lucassen acquired all shares.
Penell	1991	-	I	Martin Jensen and Bjarne Flou	- Acquired by RTX Telecom in 2001. Continued as a separate entity.
Sonofon	1991	-	J	GN Store Nord (DEN) and Bell South (USA)	- In 2001 GN Store Nord sold their shares to Telenor (NOR), who owns 52,5% and Bell South owns the remaining 47,5%.
S-Card	1991	-	I	Steen Rasmussen	
LH Mobilradio	1991	-	S	Kurt Poulsen (Dancall Radio)	
Gatehouse	1992	-	I	Michael Bondo Andersen	

1. Types: D=Diversifier, J=Joint Venture, P=Parent Spinoff, S=Entrepreneurial Spinoff, and I=Inexperienced Startup (see Table 1).

Table 4 Details the NorCOM firms (continued)

Name	Founded	Exit	Type[1]	Founder(s)	Events
Cortech	1993	-	P	DeTeWe (GER)	- Founded when DeTeWe (GER) bought the cordless development department from Dancall - Acquired by Rohde & Schwarz GmbH & Co. KG (GER) in 2001 and renamed Rohde & Schwarz Technology Centre A/S
Dansk DECT Udvikling	1993	-	J	Nine firms	- Founded as a joint venture between the incumbent telecommunications service provider Tele Danmark A/S (by the subsidiaries Jydsk Telefon A/S and Telecom A/S), Bang & Olufsen Technology A/S, Dancall Radio A/S, Diax Telecommunications A/S, Kirk Telecom A/S, L.M.Ericsson A/S, Lasat Communications A/S, Partner Electric A/S and Radartronic A/S. The employees came from Mannesmann, Aalborg University, Bang & Olufsen, Diax Telecommunications and Tele Danmark. The managing director was Niels-Christian Gjerrild (Sonofon, former T-COM). - Acquired by L.M. Ericsson in 1995 and renamed L.M. Ericsson Danmark
RTX Telecom	1993	-	S	Jørgen Elbæk, Mogens Westeraa, Villy Andersen (all T-COM, and former Dancall), Jens Hansen, Jens Toftegaard Pedersen, and John Nissen Lund (all Cortech and former Dancall)	
Globesat	1993	-	I	Jens Gram, Karl Johan Damgaard, and Erik Christensen	
Noatech	1994	2000	S	Niels Ole Andersen (LH Agro)	
ATL Research	1996	-	S	Finn Andersen, Jan Thomsen and Jens Christian Lindof (all Cetelco)	- Acquired by Texas Instruments (U.S.) in 1999 and renamed Texas Instruments Denmark
Analog Devices	1997	-	P	Esben Randers (Analog Devices (U.S.), former DC Development, Cetelco) and Analog Devices (U.S.)	
M-Tec	1998	-	S	Svend Mousten Hansen (Bosch)	- Jesper Fjeldsø Jensen buys a part of the company in 1998
LH Comlog	1998	-	S	Per Larsen (founder of LH Agro)	
Lucent	1998	1999	P	Lucent (U.S.)	
Danish Wireless Design	1999	-	P	Infineon Technologies AG (GER) and Per Hartmann Christensen (Sony, München (GER), former DC Development and Dancall)	
Nokia	1999	-	P	Nokia (FIN) and Alan Jacobsen (Nokia Copenhagen)	
Shima Communication	1999	2002	S	Jørgen Bregnhøj and Peer Lohmann (both Maxon)	
Partner Electric	1999	2002	P	Jens Christian Winther (L.M. Ericsson, former Lasat) and Partner Electric (DEN)	- Reconstructed/renamed in 2001 as Partner Voxtream (2001-2002) - Reconstructed in 2003 as Partner Voxtream of 2003 in Vojens, Denmark
Polaris Electronics	2000	-	S	Sven Egelund Rasmussen and Klaus Torp (both SP Radio)	
Condat	2000	2002	P	Ole Madsen (ATL Research, former Dancall) and Condat AG (GER)	- Acquired by Texas Instruments (USA) in 2002 and merged with ATL Research (Texas Instruments Denmark)
RF Micro Devices Design Center Denmark	2000	-	P	RF Micro Devices (USA) and Niels Jørgen Jensen, managing director (former Dancall)	
STMicroelectronics	2000	-	P	STMicroelectronics (FRA/ITA)	
Bluetags	2000	-	I	Niels Klitsgaard and Carlos H. Østby	
End-2-End	2000	-	P	Niels Peter Langkilde and Deutche Bank (GER) Hewlett-Packard (U.S.), and Cisco (U.S.)	- Also named Pre-Tel Wireless.
Futarque Technologies	2001	-	S	Jacob Pedersen, Jesper Kaagaard (former ETI, Lasat), John Tveit and other former Force employees	- Futarque was founded as a R&D unit when Force went into suspension of payments. - Futarque was acquired by former employees, Novi A/S and Erhvervsinvest Nord
WirTek ApS	2001	-	S	Michael Aaen and others (all Nokia)	- When Nokia Mobile Phones decided to move the Aalborg research and development department to Copenhagen 13 employees decided to go their own way. WirTek ApS entered into a framework agreement with Nokia for the delivery of consultant services in the mobile browser technology area.
SemCon	2002	2003	P	SemCon (SWE)	- Founded by acquisition of parts of activities and employees in L.M. Ericsson. Head of department John Kristensen (former L.M. Ericsson)

1. Types: D=Diversifier, J=Joint Venture, P=Parent Spinoff, S=Entrepreneurial Spinoff, and I=Inexperienced Startup (see Table 1).

Table 4 Details the NorCOM firms (continued)

Name	Founded	Exit	Type[1]	Founder(s)	Events
Cambridge Silicon Radio (CSR)	2001	-	P	Michael Bak (Digianswer, former L.M. Ericsson), Carsten B. Andersen (L.M. Ericsson) and Cambridge Silicon Radio (CSR) (UK)	
TTPCom	2001	-	P	TTPCom (UK) with Morten Iversen, Brian Møller and Gäel Rosset (all Siemens Mobile Phones)	
On-Air	2000	-	S	Per Frost Jensen (Lasat, former Sonofon and Maxon) and IPM Management.	
P.B. Radio	2001	-	S	Peter Bak (Eurocom Industries)	- Acquired by Gatehouse in 2003
PI Engineering	2002	-	S	Carsten Pedersen (Siemens Mobile Phones)	
Anadigics	2002	-	P	Anadigics (U.S.)	- Manager Rahim Torfi
EB Denmark	2002	-	S	Jan Lausten (Shima) and Hans K. Kofod (Siemens)	
PCOM:I[3]	2002	-	I	Jyoti Prasad	
MicroGames	2002	-	I	Henrik Hansen, Morten Jørgensen and Theis Olesen (newly graduated engineers from Aalborg University)	
Advanced Wireless Design	2003	-	P	10 former employees of Telital (Cetelco) and a Hong Kong based company	- The company was founded a few months after Telital went bankrupt. Torben Amtoft (Telital) is the managing director. He took 10 employees and all the production equipment with him.
Acolyte Denmark	2003	-	S	Michael Vistisen (Condat, former Telital), Søren Rønnest (Telital) and Claudio Freti	- The company was founded in 2002 in Switzerland, but in 2003 it started a division in Aalborg.
Blip Systems	2003	-	S	10 former L.M. Ericsson employees.	- The company was founded by 10 former employees of L.M. Ericsson Aalborg with Peter Knudsen as manager.
Embedit	2003	-	P	Embedit (DEN) and John Kristensen (Semcon)	
M1	2003	-	I	Mads Peter Veiby and Thomas Johan Havemann	
Glaze	2003	-	P	Glaze System Tech (SWE)	
WIBS Solutions	2003	-	I	Rajeev R. Prasad	

1. Types: D=Diversifier, J=Joint Venture, P=Parent Spinoff, S=Entrepreneurial Spinoff, and I=Inexperienced Startup (see Table 1).

Chapter 6

Knowledge Flows through Informal Contacts in Industrial Clusters: Myth or Reality?

Knowledge Flows through Informal Contacts in Industrial Clusters: Myth or Reality?[1]

1 Introduction

Many researchers have provided detailed studies of clusters with high performing innovative capabilities over the last ten years or so. Often, clusters have been closely connected to leading-edge universities in the business area of the cluster. Researchers who have studied Italian industrial districts (Russo, 1985; Brusco, 1990; Pyke et al., 1990) have argued that one of the explanations for the geographical concentration of innovative activities is that knowledge developed in a cluster or industrial district flows more easily within it, but more slowly outside and across its borders. One of the explanatory factors cited is that informal networks of contacts emerge between individuals across firm boundaries, and act as channels of knowledge flow. These channels of communication, it is argued, facilitate knowledge diffusion, giving firms located in clusters certain advantages regarding innovative performance. Numerous studies have highlighted the importance of these channels for the existence of clusters, with Saxenian (1994) being one of the most cited examples. Similarly, authors of econometric studies of the geography of innovation (many of which are reviewed by Feldman (1999)), have frequently claimed that localised knowledge spillovers (LKS) of this kind are the main reason for the geographical concentration of innovative activity.

Knowledge spillover through informal contacts is just one of the externalities that are argued to be the main forces behind industrial clustering. From the classical work of Alfred Marshall (1890), Krugman (1991) derives three kinds of externality that are important for clustering: (i) economies of specialisation caused by a concentration of firms being able to attract and support specialised suppliers, (ii) economies of labour pooling, where the existence of a labour force with particular knowledge and skills attracts firms, which in turn attract and create more specialised labour, and (iii) technological externalities or knowledge spillover (LKS), where knowledge and information flow more easily between actors located in a cluster than over long distances.

In his effort to integrate the geographical dimension into mainstream economic theory, Krugman (1991) dismissed the role of LKS by claiming that although they may exist in some high-tech industries, they are not an important force for agglomeration. Instead, our focus

[1] This chapter is based on Dahl and Pedersen (2004) "Knowledge Flows through Informal Contacts in Industrial Clusters: Myth or Reality?" Research Policy 33, pp. 1973-1686.

should be directed towards more measurable externalities, such as economies of specialisation and labour pooling. Krugman's claim has fuelled an intense, and sometimes heated, discussion within the community of economic and industrial geographers (see Martin and Sunley (1996) and Martin (1999) for examples of this debate) and among other scholars, as illustrated by the critical quotations in Jaffe et al. (1993) and Audretsch and Feldman (1996). In an effort to dismiss Krugman on this point, Martin (1999) claims that empirical studies of the geography of innovation provide clear evidence that LKS plays an important role in the clustering of economic activity. However, these studies have been criticised by Breschi and Lissoni (2001), who argue that the concept of LKS is no more than a 'black-box' with ambiguous content. In particular, they argue that this literature fails to distinguish between local knowledge flows that take the form of public goods and those that do not. They suggest that in order to shed light on this issue, it is necessary to study in detail how knowledge is actually transferred between individuals and firms located in the same geographical area.

The next section of the chapter presents a review of the theoretical ideas that have been dominant in the debate about the role of informal knowledge exchange through personal contacts. Informal knowledge exchange is an example of a channel of knowledge spillover or Marshallian technological externalities. Consequently, we look only at those contributions that have considered this as an isolated empirical and theoretical phenomenon. These theories may possibly have contributed to the creation of the myth that clusters are driven by intense disclosure of detailed knowledge between firms. This myth has spread to the above-mentioned literature on clusters and the geography of innovation. In this chapter, the dominant theories are confronted with an alternative view, which has criticised the proposed role of informal contacts in clusters by arguing that they are used to disclose only very general information and ideas of minor importance. The role of the present chapter is to confront these two views in an empirical investigation of the extent of informal networks and their role as channels of knowledge diffusion.

To study the importance and extent of informal networks in clusters, we use the results from a questionnaire study of the communications cluster in Northern Denmark (NorCOM). The discovery of NorCOM by Gelsing and Brændgaard (1988) relied on the same arguments for the existence of this cluster as are found in the dominant literature. They argued that informal personal networks are intensive between the employees, who carry knowledge through the cluster. Later, Dalum (1993) stated that the employees have strong personal relations and that there are many relations of a cooperative, as well as a competitive, nature. This helped to establish the dominant local view that the informal networks within the cluster were one of the main reasons for its fast growth in the 1990s.

This chapter examines informal networks of contacts between employees in NorCOM and assesses whether these networks act as channels of valuable and specific knowledge

exchange between firms. Unlike previous studies (also of NorCOM), the present analysis is carried out at the micro level, in this case focusing on the engineer. Such a focus provides a better picture of the informal network of contacts, which constitutes one advantage of the present chapter. Previous studies have, for example, been based on interviews with the managers of the firms, and such studies cannot reveal completely the extent and importance of networks. The manager then becomes the only representative for matters inside the firm and in relation to the behaviour of the employees. The results are likely to be biased towards the manager's personal opinion and organisational policy.

The remainder of the chapter is structured as follows. The next section presents theories of the importance of knowledge diffusion through informal contacts in general and in clusters specifically. Section 3 builds testable propositions from the theoretical framework and describes the NorCOM Questionnaire Survey, on which our analysis is based. The results are presented in Section 4. Conclusions are presented in Section 5.

2 Knowledge diffusion and informal contacts

The ideas of collective invention (Allen, 1983) are convenient for describing the dynamics of knowledge diffusion through networks and clusters. Collective invention is characterised by high invention rates and fast knowledge accumulation created by disclosure of information between competing agents. It is driven by exchange and circulation of knowledge and information within networks formed by groups of socially connected individuals.

Allen's ideas were based on case studies of the blast furnace industry in Cleveland (UK) in the middle of the 19th century, where producers shared knowledge about their furnaces that enabled them to discover, collectively, the positive relationship between productivity and the height of the furnace (Allen, 1983). Since then, other historical case studies have confirmed Allen's ideas, for instance McGaw's (1987) study of the mechanisation of chapter manufacture in the Berkshire area (New England) from the beginning of the 19th century. Another example is Lamoreaux and Sokoloff's (2000) study of the American glass industry from 1870 to 1925. These cases seem to be geographically bounded and thus relevant for general cluster theory. More recent developments of regional clusters, such as Silicon Valley, where rapid technological development is combined with a relatively open diffusion of knowledge (Saxenian, 1994), and the Italian examples of industrial districts (Russo, 1985), provide modern examples of collective invention.

Two aspects of collective invention are worthy of particular note (Cowan and Jonard, 2000). First, participation in the type of community mentioned requires a high level of technical knowledge and skill, which is needed to contribute to, and to take advantage of,

developments within the communities. Second, reputation is very important, because the provision of information is motivated primarily by an expectation of reciprocity.

Although the idea of collective invention is appealing, it is primarily relevant to industries where firms do not spend substantial amounts on the development of new knowledge. In these cases it is profitable to release technical information and knowledge, since it is expensive and almost impossible to exclude others from the developments (Allen, 1983).

When similar firms are located in clusters (or industrial district-like environments), firms share a common set of values and knowledge so important that they form a cultural environment. In this environment, firms are linked by specific informal relations in a complex mix of cooperation and competition (Brusco, 1990). Saxenian (1994), when comparing the regional agglomerations in Silicon Valley and Route 128, points to certain disparities with regard to the creation and character of networks. In Silicon Valley, informal contact between individuals is important, mutually beneficial, and widely observed. With a culture that supports informal relationships and a variety of regional institutions that provide network services by arranging trade fairs, conferences, seminars, and social activities, the individuals (co-workers, competitors, former co-workers, suppliers, customers etc.) meet each other often, which results in the formation of relationships and informal contacts. These are maintained and strengthened by ongoing activities. Technical and market information is exchanged, because the Silicon Valley culture allows them to discuss details of their work. In the Route 128 case, informal contacts are few and the culture discourages networking, and the exchange of knowledge and problems. The extent of informal activity in Silicon Valley is perhaps unusual, but the level of interaction and information flow in combination with a rapid technological development is important for theories of clusters in general.

The existing literature (e.g. Rogers, 1982; Von Hippel, 1987; Schrader, 1991) suggests that knowledge diffusion through informal channels occurs in the form of information trading. This type of informal exchange of knowledge between firms is a frequently observed phenomenon in product development, production, and the diffusion of technological innovations (see Martilla, 1971; Czepiel, 1974; Allen, 1984). Information trading refers to the informal exchange of information between employees working for different, and sometimes competing, firms (Von Hippel, 1987). Colleagues in different firms provide each other with technical advice, expecting that the provision of information will be reciprocated in the future. For instance, an employee in the production process might solve unforeseen technical problems by communicating with a colleague in a competing firm that uses the same production equipment. The colleague in the other firm has to decide whether to provide him with the information. If it creates disadvantages for his firm, he might want to keep it. Otherwise, he would disclose it with a future reciprocity in mind (Schrader, 1991).

The transfer of knowledge represents a potential cost for the transferring firm. Competitive advantage decreases as the value of the knowledge transferred increases (Allen, 1984). In other words, the transfer of knowledge influences the firm's valuation of a particular piece of information. Schrader (1991) points to three factors influencing these expectations. First, the rents that the firm can expect to gain from a given piece of information are influenced by the degree of competition. If the firm transfers to a non-competing firm, the change in rent is likely to be zero, unless the other firm transfers this information to another competing firm. In addition, if the two firms have different competitive goals, the receiving firm might gain the benefit without the transferring firm losing rent (see also Hamel et al., 1989). Second, the availability of alternative sources of information has an effect on rent expectations, which depend on the time span for which the owner has an advantage relative to the acquirer of the information. Similar knowledge and information can often be acquired from other sources, such as suppliers or competitors. Consequently, the competitive advantage of a piece of information can be lost even if the transferring firm refuses to transfer it to the receiver. Third, rents are affected by whether the information relates to a domain in which the two firms compete. Firms are likely to compete along many dimensions, such as price, quality and consumer services. The decrease in rent expectations may differ between these.

On the other hand, firms might also receive rent benefits from transmitting information or knowledge. Studies by Von Hippel (1987) and Rogers (1982) show that the transfer of knowledge is part of a relationship based on mutual exchange. Schrader (1991) points to two different approaches. One approach assumes that the partners are interested in continuing the relationship. A firm would weaken the relationship if it did not return a favour, which would prevent it from gaining rents from knowledge received in the future. The other approach builds on the possible social aspects of exchange relationships. The lack of willingness to return a favour may induce feelings of guilt and a poor reputation. It is generally agreed that receiving a benefit will increase the chances of the favour being returned with a similar transmission of knowledge. This depends on the value of the knowledge or information. The higher the benefit, the greater is the chance that it will be returned. Obviously, even if the receiver is eager to return the favour, the initial transmitting firm gains nothing from the relationship if the receiver is unable to provide any beneficial knowledge. Therefore, Carter (1989) suggests that firms that trade information tend to favour partners that promise the most useful knowledge in return. Clearly, a firm is more interested in establishing relationships with another firm that is at the forefront of technological development.

According to Maskell et al. (1998), the creation of informal networks of contacts goes through several phases, from relations between two individuals to entire networks. The transformation starts with transfer of knowledge between two individuals. Repeated

interactions between the two lead to falling costs of future interactions through the development of routines and conventions, which decrease costs. This makes the relationship stable. Both vertically and horizontally, related firms may benefit from a climate of trust and mutual understanding. This will facilitate more informal contacts and interaction, at the levels of both the firm and the employee (Maskell, 2001). Maskell also stresses the importance of experimenting and testing different technological paths in clusters of horizontally related firms. They learn from the success and failure of others and are able to monitor, discuss, and compare other firms' solutions. In this way, they participate in a continuous learning process by comparing different solutions, selecting, imitating, and adding their own ideas.

Breschi and Lissoni (2001) are critical of some of the ideas presented above. Building on detailed studies, they make two main points (our emphasis). First, knowledge sharing through informal contacts is not likely to involve more than the sharing of relatively small ideas, which will not jeopardize the originators' rights to more strategic knowledge. Second, interpersonal communication is relatively more important for sharing knowledge with customers than with competitors (Lissoni, 2001). Moreover, Schrader (1991) finds that friendships have no significant impact on the probability that information is traded. However, he also claims that friendship might define the extent of the network. Furthermore, physical proximity does not imply the existence of social proximity, since such epistemic communities (see Cowan et al. (2000) and Steinmueller (2000)) never include all members of the local community. Knowledge may be far from accessible to most of those located nearby (Breschi and Lissoni, 2001). Knowledge circulates in small epistemic communities, which are centred around single firms, rather than flowing freely within clusters (Lissoni, 2001).

In analysing the Brescia mechanical cluster, Lissoni (2001) finds that the communities consist of individual engineers linked by personal ties of trust and reputation. Although they arise from successful commercial partnerships and deals, the communities are not based on inter-firm arrangements, but respect the appropriation strategies of each firm. Accordingly, Breschi and Lissoni (2001) argue that there might be several competing networks of firms in a regional cluster. The networks are built over time with the cooperation of partners, suppliers and customers. As a result of long lasting inter-firm cooperation, engineers have created their own 'codebook' and specific knowledge, which cannot easily be understood by competitors. Even in epistemic communities that contain members from competing networks, the engineers retain their loyalty to the firm or network to which they belong. They exchange general, rather than specific, knowledge. Although regional clusters are seen as homogeneous knowledge communities, the firms still tend to specialise in narrow market niches with customised products. As a result, only a fraction of firm-specific knowledge can possibly be diffused through informal contacts within a cluster (Lissoni 2001).

In summary, earlier theoretical contributions argue that knowledge is diffused through informal contacts. Across firms, colleagues provide each other with advice and solutions to problems. They disclose even valuable firm-specific knowledge with future favours in mind, despite the fact that such disclosure could be a disadvantage to the firm. However, this view has been criticised recently by other scholars, who argue that agents will not disclose firm-specific knowledge to external agents because of loyalty to the firm. They will only exchange more general knowledge of low value. Based on these conflicting views, two groups of propositions are developed in the next section.

3 Propositions and survey data

The propositions are divided into two groups according to the aims of the chapter. The first deals with the type, extent and value of informal contacts, while the second focuses on their causes. The following propositions have as their basis the view that informal contacts between employees in different firms are an important source of knowledge for the firms.

Propositions group 1

When an engineer decides to share knowledge with an informal contact he/she should, ideally, consider whether it is in the economic interest of the firm. However, he/she will look past that sometimes and disclose important pieces of knowledge even if it is to the disadvantage of his/her firm. This type of transaction will take place because the engineers will expect to gain valuable knowledge in return. The higher are the benefits at the receiving end of the exchange, the larger is the chance of reciprocation.

Hypothesis 1a: *Firm-specific knowledge is exchanged through informal contacts.*

Hypothesis 1b: *Knowledge acquired through informal contacts is generally valuable to the receiver.*

The questionnaire deals with this by asking the engineer whether he/she had ever acquired knowledge through informal contacts that could be used in his/her own work. Afterwards the engineer is asked to place a value on that knowledge (high, medium or low) and to characterise it.

Propositions group 2

The contacts involve informal exchange relationships. They are stable over time, since the creation of informal contacts takes time and involves trust and frequent interaction. Over time, employees tend to keep in contact with former colleagues and classmates as they change jobs within a cluster. At first, only low-value knowledge is traded through a specific informal contact because of uncertainty about the relationship. However, as the number of successful transactions and the level of trust increase, it is possible that more valuable knowledge will be traded. Through long working experience, an engineer develops contacts with more people and works in different project groups and firms. He builds up trust and a reputation and therefore increases the number of his contacts. Perhaps more importantly, he increases his knowledge of who to approach for information. This increases the extent of informal contacts and leads to the following hypotheses:

Hypothesis 2a: *Relationships between engineers persist through time.*

Hypothesis 2b: *More knowledge will be shared as the employees gain experiences, because of stronger relationships and increased trust.*

In order to minimize the loss of competitive advantage from valuable knowledge, the firm wants to limit the possibility of employees disclosing information about their businesses to informal contacts. This leads to:

Hypothesis 2c: *Firms want to reduce the extent of knowledge sharing with employees in other firms through informal channels, to prevent competitors from gaining valuable knowledge and secrets.*

This chapter draws on data from a questionnaire survey conducted in November/December 2001. A questionnaire was sent to engineers in the NorCOM firms. NorCOM is the name of a formal organisation formed by some of the firms in the wireless communications cluster in North Denmark. During the last two decades this cluster has emerged in North Jutland focusing on wireless communications equipment. The cluster is defined by a joint knowledge base, which includes electronic signals transmitted by radio waves. At present, 25 out of the 35 firms in the cluster are members of NorCOM. The questionnaire was sent to the managers of the member firms. Nineteen of these managers agreed to recommend to those of their employees with engineering degrees (including computer scientists) that they answer the questionnaire.

The engineers are the single most important resource for research and development in the cluster. In almost all of the firms, they account for a high proportion of employment. After contacting the managers personally, we received information about the number of employees in this category. 791 questionnaires were sent to the 19 firms. 346 questionnaires were returned to us, which represents a 44 percent response rate.

After seeking some basic information and educational background, we asked about the following: (i) working experience in communication technology and in different locations, (ii) characteristics of their present job and important parameters in the process of selection for their present job, (iii) reasons for job changes, (iv) contact with other employees from other firms, (v) contact with departments and university staff, (vi) the need for, and use of, further educational opportunities, (vii) the importance of, and reason for, membership/non-membership of labour unions, and (viii) the entrepreneurial spirit and opportunities for the establishment of firms in the future.

In this chapter and in the questionnaire, we define an informal contact as a person working in another firm (in the same cluster) with whom the engineer has a social relationship that is not part of a formalised agreement between the two firms.

A survey of links in the electronics industry in North Jutland in 1988 revealed only a few formal links, but interviews revealed the existence of many informal links (Gelsing and Brændgaard, 1988). This study, the first to map the relations between the firms, found a high degree of mobility of employees between the firms. Based on interviews, Gelsing and Brændgaard concluded that although the management disapproved of informal contacts and external knowledge diffusion, there were well developed informal contacts between technical personnel, who knew each other's job shifts and stayed in contact. Dalum (1993) confirmed this through interviews at management level:

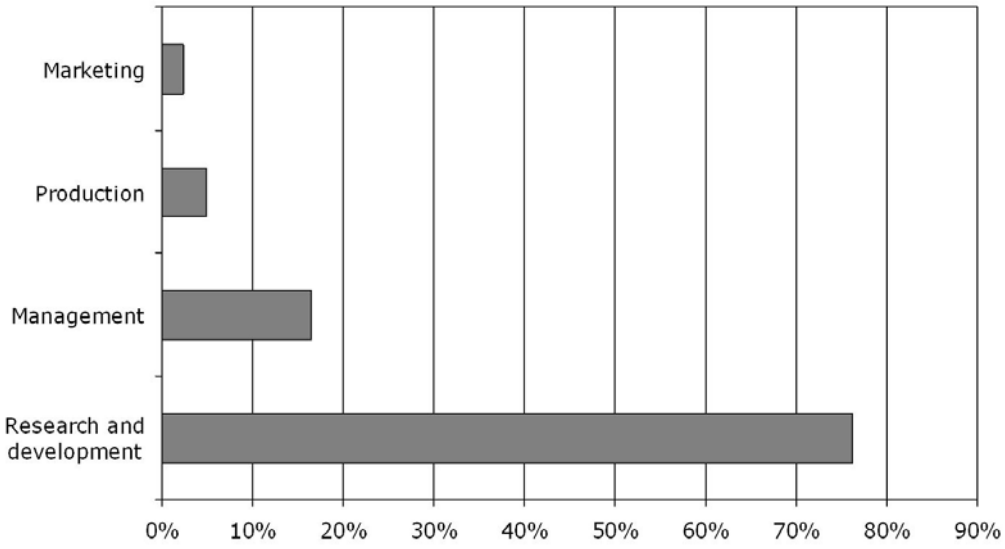
> *"… the informal personal networks (…) have been of significant importance. Below the level of top management there are intensive informal links between employees, even from firms who are competitors." (Dalum, 1993, p. 200)*

With no official cooperation between firms, technical personnel borrowed test equipment and spare parts from each other and small technical problems were solved by telephone calls to former colleagues or fellow students. The knowledge diffusion had the character of trade with some expected reciprocity. Gelsing and Brændgaard (1988) claim that the informal contacts and subsequent knowledge diffusion were very important for the emergence of the cluster.

4 Importance of informal contacts

In the questionnaire survey, the sample of engineers consisted mainly of men (94%) with an average age of 33 years. Almost half of them were graduates from Aalborg University and their average work experience in the cluster was between four and five years; 62% had worked in the cluster for four years or less. On average, they had worked a little more than 2½ years in their current job and less than 25% had done so for more than three years. Their function in the firms at the time of the survey is described in Figure 1. They were engaged primarily in research and development.

Figure 1 Most important job function in the firm



The important issue for this chapter is whether the engineers were members of informal personal networks. A majority (76%) answered that they had at least one informal contact with employees in other firms in the cluster. Informal contacts were, as expected, widespread, a phenomenon that is shown at the top of Table 1.

4.1 Value and specificity – Testing propositions group 1

To investigate whether the engineers acquire any useful knowledge through informal contacts with employees in other firms, we look at the acquisition of knowledge both in general and with respect to their specific job function. The engineers are divided into two groups: those who acquire, and those who do not acquire, knowledge through informal contacts that they can use in their current job. This is shown at the bottom of Table 1.

Table 1 Engineers with at least one informal contact and their acquisition of knowledge

Question	N	Yes	No	Total
"Do you have informal contact with at least one employee in another firm in the cluster?"	342[1]	76%	24%	100%
"Do you acquire knowledge through your informal contact(s) that you take advantage of in your current job?"	258[2]	41%	59%	100%

1. This is equal to the total sample excluding four missing observations. Percentages are shares of this number.
2. This is the number of respondents with at least one informal contact.

Of the engineers with informal contacts, 41% gained knowledge from them. This means that informal contacts do act as a channel of knowledge. Around 30% of the total sample acquired knowledge from their contacts that they found to be useful in their own job. In comparison, Schrader (1991) surveyed technical managers in the steel mill industry and found that 83% of his sample had provided specific technical information to a colleague in another firm at least once during the previous year. Schrader's study is of the entire US steel mill industry, which is not geographically clustered, but his results suggest that these informal relationships across firms are present even across significant geographical distances. Another noticeable difference between our study and Schrader's is that his questions are about whether the subjects of the study had provided information to a colleague in another firm, whereas we asked whether they had received information from contacts in other firms. This difference is potentially significant, especially when loyalty to one's firm is taken into account. It would be easier to state that one had received information, rather than state that one had provided a contact with information. However, it is difficult for the provider to value the usefulness of the information for the receiver. This difference in the construction of the questionnaire should be borne in mind when comparing our and Schrader's studies.

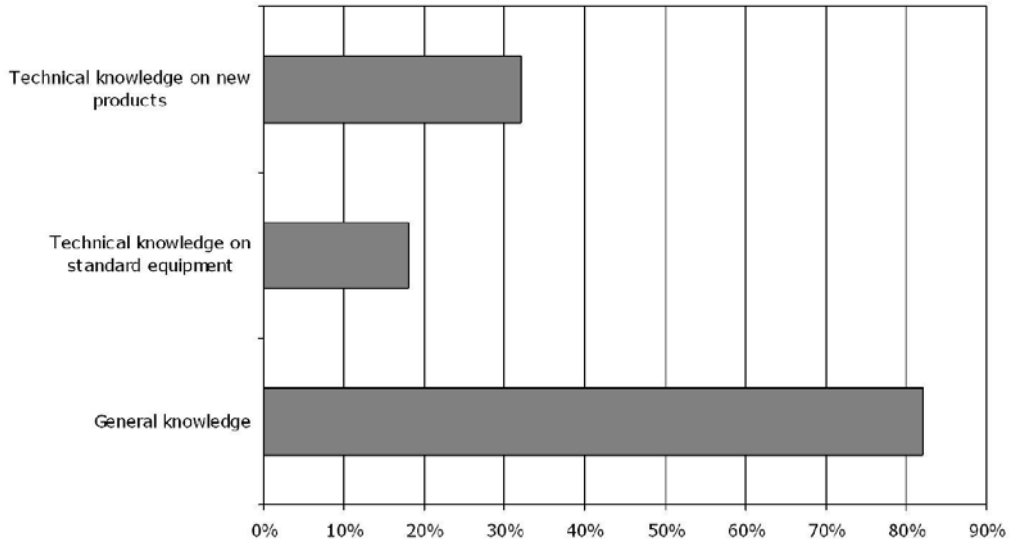
In a study of electronic and mechanical engineers working within four industries in the Brescia mechanical cluster, Lissoni (2001) found that 30% of the engineers had a relationship of some kind with engineers in other firms. 60% of these relationships involved technical discussions, which is equivalent to 18% of the total sample. This is clearly in conflict with our results, but may be due to differences in the two samples. The present study is of a small cluster located in a small geographical area, the Aalborg region, with a fairly limited number of firms with one common core technology, wireless communication. In contrast, Lissoni's study has a broader industrial specification and firms were located across a larger geographical area. This could be why there are higher shares of engineers with informal contacts and knowledge sharing in the NorCOM questionnaire. Another difference with similar implications concerns the characteristics of the two industries. There are rather large differences between the work practices and technological challenges in the more mature mechanical industry and the more unstable, but developing, wireless communication industry. The lower technological challenges could mean that engineers in the mechanical

industry are less likely to seek information about future developments outside the firm. Consequently, this could also be a source of differences between the results.

However, we still know little about what kinds of knowledge are shared through these contacts. The critical literature claims that this knowledge will be general and not very specific. Lissoni (2001) finds that 27% of the engineers' relationships involve only asking/giving suggestions of a general nature and only 15% discussed current projects. His results show a lower level of information trading, from which he concludes that informal contacts do not go beyond the exchange of general information. However, again, his study is broader, as discussed above.

Figure 2 shows how many engineers acquired different kinds of knowledge in our study.

Figure 2 Type of knowledge acquired through informal contact

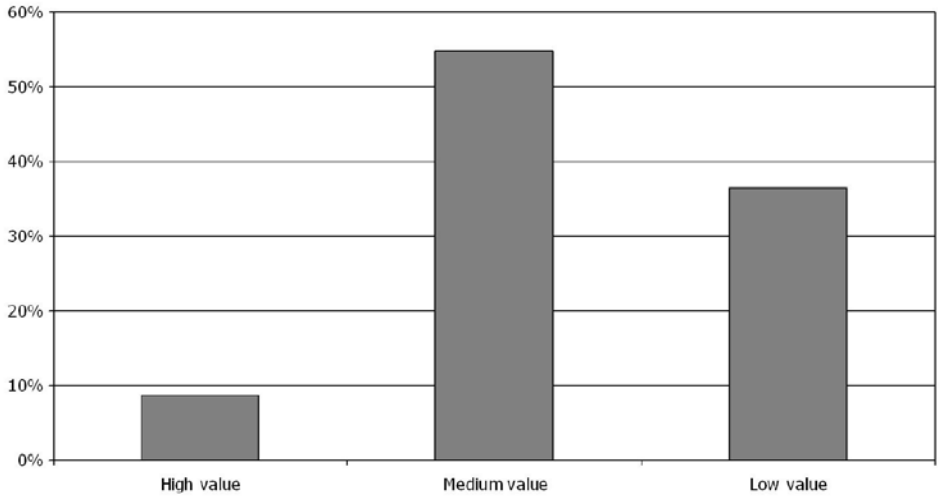


Note: The engineers were asked the following question: "Which type of knowledge do you acquire through your informal contact(s)?" and were given four options: general knowledge, technical knowledge on standard equipment, technical knowledge on new products, and other. The percentages reported are the total number of engineers acquiring the particular type of knowledge as a proportion of the total number of engineers who answered that he/she acquired knowledge from his/her contacts (104 respondents). Respondents could pick more than one type of knowledge in the questionnaire.

Engineers acquired all kinds of knowledge through their informal contacts. General knowledge was diffused through this channel, with more than 80% of respondents mentioning this. However, more specific knowledge was also diffused, shown by the fact that more than 30% of engineers who acquired knowledge gained access to technical information about new products. In the bigger picture, this shows that 32% of all the engineers with at least one informal contact gained access to general knowledge from that contact. More interestingly, 12% of those engineers also acquired more specific knowledge on new products. Clearly, this means that informal contacts in other local firms cannot be neglected as a source of specific knowledge. This confirms hypothesis 1a. In this context it is

interesting to see not only what type of knowledge is acquired, but also how this knowledge is of value to the receiving engineer.

Figure 3 Value of knowledge acquired through informal contact



Note: The engineers were asked the following question: "How do you rate the value of the knowledge that you receive from your informal contact?" and were given three options: high, medium, and low.

Figure 3 shows the distribution of the value of knowledge across the three categories. More than 60% of the respondents that gained access to knowledge rated the knowledge as being of medium or high value to their own work. All in all, these respondents constituted almost 20% of the total sample. This indicates clearly that informal contacts are important sources of knowledge and that a significant proportion of engineers greatly benefited from those contacts in relation to their own work. This confirms hypothesis 1b. Similarly, 61% of Schrader's (1991) sample considered colleagues in other firms to be an important, or very important, information source and only colleagues in one's own firm were considered to be more important.

4.2 Genesis of informal contacts – Testing propositions group 2

Table 2 shows with whom the engineers were in contact. More than half of the engineers in the sample had informal contact with former colleagues in the cluster. This indicates that mobility is important for the extension of informal contact networks. The relationships created by engineers working together seem to last longer than the actual time they work together. The second largest category is former classmates. The results confirm hypothesis 2a, since the relationships created over time are persistent.

Table 2 Who are engineers in contact with?

Category	Proportion of all engineers with at least one informal contact (N=259)
Former colleagues	66%
Classmates	50%
Private friends	47%
Others	8%

Note: The engineers were asked the following question: "Who are you in informal contact with?" They could pick more than one answer to this question.

To investigate further the role of mobility in the creation of informal contacts, we examined whether higher mobility results in there being a higher probability of having at least one informal contact. However, there was no difference in the frequency of informal contact between the engineers with higher or lower than average mobility between firms according to Table 3. The results are insignificant. Although the engineers stay in contact with former colleagues, it is clear that above-average mobility does not increase the probability that they will have at least one informal contact. Changing jobs does contribute in the form of informal contacts to 66% of the engineers, but it does not increase the number of people with contacts. This indicates that a certain proportion of the respondents are not interested in, or for other reasons are reluctant to have, informal relationships with people outside their own firm, even though they worked with them in the past. Note, however, that 16% of our sample had only recently entered the labour market (within the last two years) and were still working in their first job. They may be less likely to have developed informal contacts with employees in other firms, because the probability of having at least one contact may well increase with experience. This is investigated in Table 4.

Table 3 Mobility and informal contact

N=327	At least one informal contact	No informal contact	Total
Above average number of total job changes in career (high mobility)	78%	21%	100%
Below average number of total job changes in career (low mobility)	75%	25%	100%
Total	76%	24%	100%

Note: Chi-square test reveals that the result is not significant, i.e. there is no significant difference between high and low mobility.

The results for industry and cluster experience are very similar. Engineers with longer working experience are more likely to have at least one informal contact. This is not surprising, since the longer they have worked in the cluster or in the industry, the more conferences they will have attended and the more firms they will have worked in, each of

which factors increases their probability of having at least one contact. By contrast, the engineers with little experience have worked in fewer firms and met fewer people, so there is a smaller probability that they will have an informal contact. The proportion of more experienced engineers who place a high or average value on the knowledge is also larger than for the less experienced. While it cannot be confirmed that the engineers with more experience are more likely to acquire knowledge than those who are less experienced, the knowledge they acquire certainly has a higher average value to them. This indicates that the greater experience the engineers have, the better they are at acquiring useful knowledge from their contacts. They know whom they have to contact in order to acquire the knowledge or to help to solve their particular problem. This enables us to confirm hypothesis 2b only partly.

Table 4 Experiences and acquisition of knowledge

	At least one informal contact	No informal contact	Acquire knowledge	Does not acquire any knowledge	High or average value	Low Value
Cluster experience[1]						
2 years or less	68%	32%	37%	63%	50%	50%
3 years or more	82%	18%	43%	57%	71%	29%
Industry experience[2]						
3 years or less	69%	31%	38%	62%	52%	48%
4 years or more	82%	18%	43%	57%	72%	28%

1. Chi-square test reveals that the result is significant at a 1%-level (informal vs. no informal, N=342), is not significant (acquire vs. not acquire, N=258) and significant at a 5%-level (high vs. low, N=104).
2. Chi-square test reveals that the result is significant at a 1%-level (informal vs. no informal, N=342), is not significant (acquire vs. not acquire, N=258) and significant at a 5%-level (high vs. low, N=104).
Note: Generally, these chi-square test shows that there are significant differences between low and high experience for informal vs. no informal contacts and for high vs. low value, but the differences are insignificant for acquire vs. not acquire.

Having at least one informal contact could also depend on the function for which the engineers are primarily responsible in the firms. Table 5 shows the job functions of the sample. Engineers who work primarily with management issues are most likely to have at least one informal contact, although the proportion for the respondents working on R&D is not much lower. For those involved in production, the figure is much lower. More interestingly, the table also shows that management and production engineers tend to have higher levels of knowledge acquisition than R&D engineers.

Table 5 Function in firm and informal contacts?

	At least one informal contact	No informal contact	Acquire knowledge	Do not acquire knowledge
Research and Development	76%	24%	36%	64%
Production	53%	47%	56%	44%
Management	81%	19%	55%	45%
Total	76%	24%	40%	60%

Note: Marketing engineers have been removed from this table due to too few observations. Chi-square tests reveal that the result is significant at a 6%-level for both informal vs. no informal (N=329) and acquire vs. not acquire (N=248). This shows that there are significant differences across job functions.

Not only do more managers have at least one informal contact, but more of them also acquire knowledge from their contact(s) compared with R&D personnel. Managers are likely to have worked their way up the career ladder and perhaps started working as R&D engineers themselves at the beginning of their careers. Consequently, they have more experience than the rest of the sample; they have met more people from other firms and know where to obtain the knowledge they need. Furthermore, as managers, they might also attend more conferences and other events, where they may meet employees from other firms. All this will increase their chances of having at least one contact and of sharing knowledge. Schrader (1991) found percentages similar to these in his study, which included only technical managers.

Besides contacts arising from the above factors, the initial contact between engineers from two firms may be created by a formal joint project. If they work together on a specific joint project, there is a possibility that their relationship will last longer than the project itself. Engineers previously involved in formalised projects with employees from other firms in the cluster are also more likely to have informal contacts than engineers not previously involved, as shown in Table 6. It is plausible that some of the informal contacts arise directly from prior formalised projects. Working in a firm that has previously been engaged in a formalised project with another local firm increases the probability that the employees will have at least one informal contact outside his/her firm.

Table 6 Formal projects[1] in the past and informal contact

N=342	At least one informal contact	No informal contact	Total
Formal projects	87%	13%	100%
No formal projects	73%	27%	100%
Total	76%	24%	100%

1. We define a formal project as a cooperative agreement between two or more firms.
Note: Chi-square test reveals that the result is significant at a 2% level, which shows that those who have engaged in formal projects are significantly different from those with no experience of formal projects.

According to Von Hippel (1987) and Schrader (1991), firms might discourage their employees or even actively try to prevent their knowledge from being shared with an outside party. The management culture in firms might thus have an influence on how, and to what extent, the employees share their knowledge with others. Firms in this cluster became increasingly interesting objects of acquisition for multinational corporations (MNCs) throughout the 1990s. An interview-based study by Lorenzen and Mahnke (2002) indicate that the management culture of the MNCs has influenced the social networks of the acquired firms. Following the acquisition of a firm by an MNC, local networking is often discouraged while networking within the MNC is encouraged. Clearly, managerial regimes and culture can have an effect on the extent of informal relationships across the boundaries of firms and corporations.

It is known publicly that some of the engineers have competition clauses of various forms included in their employment contracts. These clauses can, for instance, limit the employee's possibility of taking a job in a competing firm or working with the same products immediately after ending the contract. In our sample, 16.2% of the engineers have such a competition clause in their contract. These clauses are used as a proxy for a firm's actions towards limiting the disclosure of knowledge to other firms through informal channels. Firms that include these clauses in the contracts of their employees are also more likely to have policies that prevent or discourage their employees from sharing the firm's knowledge with an informal contact. Table 7 shows the relation between competition clauses and the probability of having at least one informal contact.

Table 7 Competition clauses and informal contacts

N=338	At least one informal contact	No informal contacts
Competition clause	63%	37%
No competition clause	79%	21%

Note: Chi-square test reveals that the result is significant at a 2% level. Thus, there are significant differences between employees with a competition clause and those with no competition clause.

The engineers that have competition clauses in their contracts are less likely to have at least one informal contact outside the firm. Only 63% of the respondents with a clause like this have one or more informal contacts. This shows that firms with restrictive managerial regimes, i.e. with competition clauses in the contracts, are successful at limiting informal networking between their employees and those in other cluster firms. This supports hypothesis 2c, since some firms are trying to limit the contact between their employees and other firms.

Previously in this chapter, we presented evidence that general knowledge is the type of knowledge that is shared the most through the networks in this cluster. Notifications about new job openings are frequently mentioned in the literature as an example of a more general

type of knowledge. Below, we examine how the engineers primarily received information about their current job in relation to their participation in informal contacts with engineers from other firms. The primary channels for information about current jobs were divided into network-related factors, and non-network-related factors, as shown in Table 8.

Table 8 Network and non-network primary channels for information about current job

N=277	Informal contacts	No informal contacts	Total
Non-network-related factors[1]	69%	31%	100%
	43%	61%	47%
Network-related factors[2]	82%	18%	100%
	57%	39%	53%
Total	76%	24%	-
	100%	100%	100%

1. Non-network-related factors: Internet job databases, job ads, the press, etc.
2. Network-related factors: Former colleagues, classmates, employees in the new firm, etc.
Note: Chi-square test reveals that both results are significant at a 1% level. Both informal and non-informal contacts, as well as non-network and network-related factors, are significantly different.

Engineers with at least one informal contact made more use of network-related factors as their primary channel for information when changing to their current job. This shows that respondents with informal contact(s) use other channels to access knowledge about more general issues, such as new job openings, to a greater extent than those without such contacts. This is an example of the general knowledge or information that flows through the informal networks of contacts between employees and between firms in the cluster.

5 Conclusion

This chapter describes how previous claims that knowledge is diffused through informal social networks have been criticised recently. Critics of these claims state that agents will not generally disclose firm-specific knowledge to external agents because of their loyalty to the firm. They argue that employees will only tend to exchange more general information of low value, which will not be so disadvantageous to their firms.

The present chapter shows that knowledge flows through informal contacts do take place, using as a basis a survey of individual engineers in the NorCOM cluster. A large proportion of the responding engineers acquire knowledge from their social contacts, which they rate as being of high or medium importance for their own work. This tells us that informal contacts are potentially an important source of knowledge for the engineers in their daily working lives. Even specific knowledge about new products, which is likely to be very firm-specific

and which the firms are likely to want to protect from competitors, is shared among these engineers.

Besides exchanging more specific knowledge about their products and technologies, the engineers also share more locality-specific information. It might be difficult to place a value on such information, but it could have an important function in updating and strengthening the network of informal contacts. This is potentially important for the dynamics of a local community, since a larger proportion of the engineers who reported that they have social contacts acquired their current job through a social network than those without such contacts.

Certain limitations of this study should be considered in future research. These are important relative to the broader questions raised in the literature and in this chapter. This study shows that social networks and informal communication are diffusing knowledge between firms in a coherent group of firms located within in a rather small geographical area. Future research also needs to ask the individual in question to compare the value of knowledge thus acquired with other sources of information (e.g. colleagues in their workgroup, other colleagues in their firm, the internet, university-based research contacts, technical journals or similar sources). This would add to our knowledge of how more specific information and knowledge is actually exchanged, within and across organisational boundaries. The micro-level study of engineers should still be the unit of analysis, since the results may become more biased if the interviews and surveys are conducted at the level of the firm. It is impossible for managers to know the full extent, value and usefulness of each of their employee's informal social contacts.

This chapter provides insights as to the existence and value of informal relationships to the individual employee. However, little is known about the value to the firm and the effects of these relationships on firm performance. Future surveys linking the inter-firm informal contacts with firm performance investigations may provide interesting evidence of how firms are influenced, both positively and negatively, by the relations of their employees. The knowledge flowing through informal contacts is often considered in a positive light in the literature. The downside of information trading, for example the loss of information to competitors, which could potentially weaken a firm's performance, has to date, not received sufficient attention.

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Chapter 7

Social Networks in the R&D Process: The Case of the Wireless Communication Industry around Aalborg, Denmark

Social Networks in the R&D Process: The Case of the Wireless Communication Industry Around Aalborg, Denmark[1]

1 Introduction

How are social networks among R&D engineers carriers of knowledge between firms? Is knowledge actually shared communication between engineers in separate organisations through their social contact? Why do some engineers have social contacts, while others do not? What is the relationship between the probability of acquiring knowledge and the various characteristics of the engineers? These are the central questions addressed in the present chapter. They have been part of the research agenda for several years in various fields of sociology, economics, business, as well as economic geography. They continue to be objects in the debate and are central reference points for many theories including knowledge diffusion.

To address these questions social networks of informal contacts between employees in the wireless communication industry around Aalborg in North Denmark are examined. The genesis of informal contacts and knowledge diffusion are analysed by studying relationships, experience and other characteristics of the engineers. The analysis is carried out at the micro level, in this case taking the engineer as the unit of analysis. This provides a better picture of the social network of informal contacts than many of the previous studies that have e.g. been based on interviews with the managers of the firms. Such studies cannot completely reveal the extent and importance of networks. The manager then becomes the only representative for the matters inside the firm and in relation to the employees. The results are likely to be biased towards official firm policy and the manager's personal opinion.

The purpose of this chapter is to study the factors, which influence the likelihood that the individual engineer will be an active part of the social networks between the local firms. Furthermore, we investigate the likelihood that this engineer receives knowledge, and knowledge of high value more specifically. These models are estimated using data from a questionnaire survey of the wireless communications industry around Aalborg (labelled as

[1] This chapter is based on Dahl and Pedersen (2005) "Social Networks in the R&D Process: The Case of the Wireless Communication Industry Around Aalborg, Denmark" forthcoming in Journal of Engineering and Technology Management. This chapter somehow overlaps with Chapter 6.

NorCOM). The survey covers more than 300 engineers employed in 19 different firms. The main factors behind the informal social contact between the engineers are investigated in this chapter.

The remainder of the chapter is structured as follows. The next section presents theories of the importance of social networks and knowledge diffusion through informal contacts and builds models from the theoretical framework. Section 3 describes the NorCOM questionnaire survey on which the analysis is based and presents descriptive data. The results are presented in Section 4 and are discussed in Section 5. Finally, the conclusions are presented in the last section.

2 Social networks and knowledge diffusion

Knowledge flows have long been considered a part of social networks across firm boundaries. Allen and Cohen (1969) argue:

"*No research and development laboratory can be completely self-sustaining. To keep abreast of scientific and technological developments, every laboratory must necessarily import information from outside*".

They analysed two different ways of obtaining this information: literature and knowledgeable people outside the laboratory. They found that the so-called *sociometric stars* in the technical communication network in an organisation, which served as a source of information for their colleagues, used outside sources more than others. These stars also had a rather extensive social network of informal contacts outside the organisation compared to the majority of other employees. The diffusion of knowledge between firms can take place through formalised collaboration or through informal social networks. The latter type of knowledge spillover has received a lot of attention in the literature of various fields.

For describing the dynamics of such diffusion networks in local industrial communities, the idea of collective invention is useful (Allen, 1983). Collective invention is characterised by positive feedback, high invention rates, and fast knowledge accretion, though the mutual disclosure of information among competing agents. It is driven by the exchange and circulation of knowledge and information within networks of socially connected individuals. Allen's idea of collective invention arose from a case study of the blast furnace industry in Cleveland (UK) in the middle of the 19th century. Producers there shared knowledge about their furnaces, allowing them to discover, as a group, the positive relationship between productivity and the furnace height (Allen, 1983). Subsequent case studies – such as McGaw's (1987) history of the mechanisation of paper manufacture in the Berkshire area (New England) from the beginning of the 19th century, and Lamoreaux and Sokoloff's (2000) study of the American glass industry from 1870 to 1925 – have corroborated Allen's characterisation.

Although the idea of collective invention is appealing, it nevertheless seems most relevant to industries where firms do not spend substantial amounts on the development of new knowledge, or where it is expensive or nearly impossible to exclude others from these developments (Allen, 1983). Furthermore, Cowan and Jonard (2000) highlight two qualifiers of collective invention that are noteworthy in the context of knowledge diffusion. First, participation in such communities requires a high level of technical knowledge and skill to contribute to, and take advantage of, developments within these communities. Second, reputation effects are very important, because the provision of information in these communities is motivated primarily by an expectation of reciprocity.

In general, it also seems apparent that information does not flow freely among all agents in a given industry located in a given region. There are several limits to the size and extent of social networks and communities. Physical proximity does not imply the existence of social proximity, since such epistemic communities (see Cowan *et al.* (2000) and Steinmueller (2000)) never include all members of the local community. Knowledge may be far from accessible to most of those located nearby (Breschi and Lissoni, 2001). Knowledge circulates in small epistemic communities, which are centered around single firms, rather than flowing freely within local communities (Lissoni, 2001).

The sociology literature provides additional insight on identifying the social structures and interactions that contribute to the diffusion of knowledge in these communities. According to Ingram and Roberts (2000), social networks of informal interpersonal relationships are embedded in a social structure. In communities in a geographic region, divisions in a company, groups within a profession, or people in a team, agents specialise within social networks and integrate via bridges across social networks. Opinion, behavior and information are more similar within than between these groups and information flows appear more routinely inside the groups.

Another structural aspect of social networks from the sociology literature is the presence of gaps, or structural hole (Burt, 2004), between groups. Structural holes form gaps in the information flow. The effect of the structural hole depends on the similarity of and difference between agents. Burt (2004) argues that agents, which are connected across different social networks, have an advantage, since they are able to get information from different sources. They also have earlier access to a broader diversity of information and are more familiar with alternative ways of thinking and behaving. They are capable of bridging the different coding schemes in different organisations and become technological gatekeepers (Allen and Cohen, 1969). Burt (2004) analysed the structural holes in the social network of managers who ran the supply chain for a large US electronics company. He found that the managers who spanned structural holes (defined as a low network constraint) got better ideas, higher salaries and more promotions than managers confined in dense groups with a larger network constraint. The discussion of how different agents' positions in social structures

allow them to get access to information is highly influenced by Granovetter's (1973) argument of the strength of weak ties in the diffusion process. His argument is that agents with many weak ties are located better in the network in terms of diffusing and receiving non-redundant information. The weak ties maximize the amount of non-redundant information that the agent receives by allowing to connect to different social groups.

However, the uniqueness of the information must be contrasted with a range of other aspects, e.g. reliability and firm-specificity of the information (Ingram and Roberts, 2000). Since the transfer of information through informal contacts takes place without a formal agreement, the sender has few means of controlling what happens with the information later on. This creates uncertainty concerning the recipient's transfer of the information to others. Løvås and Sorenson (2004) argue that this uncertainty gets reduced through indirect ties. Mutual acquaintances between the agents reduce the uncertainty of reciprocity by reputation and improved means of monitoring and sanctioning. However, there is also a tradeoff between non-redundancy in the information and cohesion in the social network. Which ties that facilitate transfer of information the best depends on the situation, where an effective design for one type of network is not necessarily effective for another (Ingram and Roberts, 2000).

When these insights are applied to the question of inter-firm knowledge exchange, the existing literature (e.g. Rogers, 1982; von Hippel, 1987; Schrader, 1991), suggests that knowledge diffusion through informal channels occurs in the form of information trading. This type of informal exchange of knowledge between firms is a frequently observed phenomenon in product development, production and diffusion of technological innovations (see Martilla, 1971; Czepiel, 1974; Allen, 1984). Information trading refers to the informal exchange of information between employees working for different and sometimes competing firms (von Hippel, 1987). Colleagues in different firms provide each other with technical advice, expecting that their favours will be returned in the future. For instance, an employee in the production process might solve unforeseen technical problems by communicating with a colleague in a competing firm using the same production equipment. The colleague in the other firm has to decide whether to provide the information. If it creates disadvantages for his firm, he might want to keep it to himself. Otherwise, he would disclose it with a future favour in mind (Schrader, 1991).

These arguments are complementary to the terminology of social capital. In his discussion of social capital in the creation of human capital, Coleman (1988) argues that information channels are important forms of social capital, since they allow agents to access information. The social capital is important for the information trading. In the transfer situation, obligations, expectations and trustworthiness are key elements. The agent providing information must trust the other agent to reciprocate the favour (obligation) in the future. This form of social capital depends on two elements: Obligations and expectations

depending on trustworthiness, and information flow capabilities of the social structure, and norms and reputation accompanied by sanctions when defection occurs (Coleman, 1988).

Another facet to consider is the genesis and evolution of social networks. The creation of informal social networks goes through several phases, from relations between two individuals to entire networks (Maskell et al., 1998). The transformation begins with the transfer of knowledge between two individuals. Repeated interactions between agents reduce the costs of future interactions through the development of routines and conventions, thereby stabilising the relationship. Both vertically and horizontally related firms may benefit from a climate of trust and mutual understanding. This exchange will then facilitate more informal contacts and interaction both at the level of the firm and among individual employees (Maskell, 2001). Firms can then learn from the success and failure of others. In this way, they participate in a continuous learning process by comparing different solutions, selecting, imitating and adding their own ideas.

Employees must also play a role in the evolution of inter-firm networks. If strong ties are concentrated in small groups or communities divided by structural holes and the weak ties connecting the groups, then localised job mobility becomes important. Granovetter (1973) argues that job changes build social networks by bridging weak ties between the groups. The previous experience of working together might facilitate information flows more easily in the future, since trust and common coding schemes already exist.

The transfer of knowledge also represents a potential cost to the transferring firm. Whether or not it does represent a cost depends on the competitive context. Schrader (1991) points to three factors influencing these expectations. First, the rents that the firm can expect to gain from a given piece of information vary with the degree of competition. If the firm transfers information to a non-competing firm, the change in rent is likely to be zero, unless the other firm transfers this information to another competing firm. Also, if the two firms have different competitive goals, the receiving firm might still benefit without the transferring firm losing rent (see also Hamel et al., 1989). Second, the availability of alternative information sources has an effect on rent expectations. Similar knowledge and information can often, for example, be acquired from other sources, such as suppliers or competitors. Consequently, the competitive advantage accruing to a piece of information can erode even if the transferring firm refuses to release it. Third, the rents are affected by whether the information relates to a domain on which the two firms compete. Firms nonetheless compete along many dimensions, such as price, quality and consumer services.

On the other hand, firms might also benefit from transmitting information or knowledge. Studies by von Hippel (1987) and Rogers (1982) show that the transfer of knowledge is part of a relationship based on mutual exchange. Schrader (1991) points to two different approaches. The first assumes that the partners are interested in continuing the relationship. A firm would weaken the relationship if it did not return the favour, thereby excluding it

from rents associated with future knowledge exchange. The other approach builds on the possible social aspects of exchange relationships. Unwillingness to return a favour may induce feelings of guilt and lead to a poor reputation. It is therefore generally believed that receiving a benefit enhances the probability of the favour being returned. Moreover, the greater the benefit, the higher is the likelihood that the favour is repaid. Obviously, however, even if the receiver wishes to return the favour, the initial transmitting firm receives no gain from the relationship if the receiver cannot offer any beneficial knowledge. Therefore, Carter (1989) suggests that firms engaging in information trading tend to prefer partners that offer the most useful knowledge in return. Clearly, a firm is more interested in establishing relationships with firms near the forefront of technological development.

Breschi and Lissoni (2001) are critical of some of these ideas. Building on detailed studies, they make two main points (our emphasis). First, knowledge sharing through informal contacts is not likely to involve more than the sharing of relatively small ideas, which will not jeopardize the originators' rights to more strategic knowledge. Second, inter-personal communication is relatively more important for sharing knowledge with customers than with competitors (Lissoni, 2001). Moreover, Schrader (1991) finds that friendships have no significant impact on the probability that information is traded. However, he also claims that friendship might define the extent of the network. This is in contrast to Ingram and Roberts' (2000) analysis of the Sydney hotel industry. They find that friendship among managers has a positive and significant impact on a hotel's yield, and this improvement is larger for friendships with managers of competing hotels. The cohesive networks support social anticompetitive norms and provide verification of the information. The greater overlap of interests between competitors improve the depth and quality of information compared to non-competitors (Ingram and Roberts, 2000).

In analysing the Brescia mechanical industry, Lissoni (2001)finds that communities consist of individual engineers linked by personal ties of trust and reputation. Although they arise from successful commercial partnerships and deals, the communities are not based on inter-firm arrangements, but respect the appropriation strategies of each firm. Similarly, Breschi and Lissoni (2001) argue that there might be several competing networks of firms in a local community. The networks are built over time with the cooperation of partners, suppliers and customers. As a result of long lasting inter-firm cooperation, engineers have created their own 'codebook' and specific knowledge, which cannot easily be understood by competitors. Even in epistemic communities containing members from competing networks, the engineers retain their loyalty towards the firm or the network they belong to. They exchange general rather than more specific knowledge. Although local communities, like the present case, are seen as homogeneous knowledge communities, the firms still tend to be specialised in narrow market niches with customised products. As a result, only a fraction of firm-specific knowledge can possibly be diffused through the social networks (Lissoni, 2001).

In summary, earlier theoretical contributions argue that knowledge is diffused through informal contacts. Agents specialise within social networks and integrate via ties of different strength across social networks. The networks allow the agents to acquire non-redundant information from different groups. These agents are argued to be central in providing the organisation with new and unique information. There is, however, a tradeoff between cohesion in the social network and non-redundancy, usefulness, reliability and firm-specificity of the knowledge. Across firms, agents provide each other with advice and solutions to problems, but not all social contacts are used to diffuse knowledge. But some times they disclose even valuable firm-specific knowledge with future favours in mind despite the fact that it could be an initial disadvantage to the firm. However, this view has been criticised by other scholars (e.g. Breschi and Lissoni, 2001; Lissoni, 2001) arguing that agents will not disclose firm-specific knowledge to external agents because of loyalty to the firm. They will only exchange more general knowledge of low value. Based on these views propositions are developed below.

The propositions deal with the type, extent and causes of informal contacts. The extent of social networks between engineers in the wireless communication industry around Aalborg can be expected to be rather large in terms of direct and indirect ties. The engineers are working within the same specialty within a small geographical area, and many have graduated from the local university. This would increase the likelihood that the individual engineer's social network includes contacts working in other firms. The social network gets formed when people meet through work, studies or friends and build social capital. There are many different specialised sub fields within wireless communication technology, but there are also overlaps in the knowledge base. The probability of knowledge diffusion through informal contacts can be expected to be higher in a homogeneous knowledge community. However, a large share of these social contacts are likely not to be used for diffusion of knowledge usable in the engineers own job function, but merely for diffusing various information and gossip. The questionnaire applied in the data collection for this study deals with this distinction by asking the engineer whether he/she acquired knowledge through informal contacts that can be used in his/her own work. Afterwards the engineer is asked to value that knowledge (as high, medium or low).

The social contacts involve informal exchange relationships. They are stable over time, since the creation of informal contacts takes time and involves trust and frequent interaction. Working together or being former classmates helps building social capital and allows for future interactions. At first, only low-value knowledge is traded through a specific informal contact because of uncertainty about the relationship. But as the number of successful transactions and the level of trust increases, it is possible that more valuable knowledge will be traded. Engineers graduated from the local university might even be more likely to

diffuse knowledge through informal contacts, since the education is based on problem-based learning in groups.

As described by Granovetter (1973), a job change is a bridging of social networks. Over time employees tend to keep in contact with former colleagues and classmates as they change jobs within a local industry. If the engineers are used to working together, they are also more likely used to exchange knowledge. This social capital is likely to persist after the job change and is expected to increase the probability of future diffusion of knowledge, since the barriers are low. The mobility of the engineers might create more ties between different groups and, consequently, make it more likely that the mobile engineer acquires knowledge. Through a long working experience, an engineer develops contacts with more people and is employed in different project groups and firms. This builds up trust and a reputation and increases the number of contacts. But there are also forces working against the knowledge diffusion as discussed in the literature. The employer has an incentive to prohibit diffusion of certain types of knowledge through informal contacts. In order to minimize the loss of competitive advantage from valuable knowledge, the firm wants to limit the possibility of employees disclosing information about their businesses. This summary leads to the following questions to be investigated in the analysis of the chapter:

- *What are the factors explaining the engineers' likelihood of having social contacts?*
- *With whom are they most likely to be in contact?*
- *When are these contacts used to acquire knowledge?*
- *Who acquires useful knowledge through the informal social contacts, and what is the relationship between the probability of acquiring valuable knowledge and the various characteristics of engineers?*

3 Data and method

This chapter draws on data from the same questionnaire survey as in Chapter 6. A questionnaire was sent to engineers in the NorCOM firms. NorCOM is the name of a formal organisation formed by some of the firms in the wireless communications industry around Aalborg in North Denmark. When the survey was carried out, there were 25 members of NorCOM out of the 35 firms belonging to the local industry. The questionnaire was sent to the managers of the 25 NorCOM member firms. Nineteen of these managers agreed to recommend to their employees with engineering degrees (including computer scientists) to answer the questionnaire. The remaining six managers did not respond to our request. In order to increase the response rate and the managers' willingness to recommend the survey

to their employees, the respondents were given total anonymity. This means that it is not possible to identify which firm each respondent comes from.

The history of the wireless communication industry around Aalborg dates back to the mid-1960s, but the main entry of firms and growth in number of employees occurred during the past twenty years. NorCOM was founded in 1997 as a club of firms and the local university, Aalborg University. In 2000, NorCOM was formally founded as an association with a board of directors. The role of NorCOM is to represent the common interests of the group. The association interacts with the press by providing them with contact to specific firms or material on the local industry. It is also acts a forum for the managers and university faculty, where they meet and discuss general developments of the industry and how these affect the local group of firms. Through the association, the firms are trying to influence policy makers and university faculty to create better conditions for themselves.

The employees are not involved in the meetings, and the firm's membership of NorCOM does not seem to be likely to affect the extent of the ordinary employees' social network. The firms that were not members in late 2001, when the questionnaire survey was conducted, were generally smaller firms compared to the members. Five of these were rather young firms founded in 2000 or 2001. The rest of the non-members were local based companies, who for different reasons did not want to be members of the association. We have no reason to expect that the employees of these firms do not have social contact with employees from members of NorCOM and visa versa. Whether the managers' unwillingness to join the association is an indicator of a restrictive managerial regime is uncertain. Based on our knowledge of the firms, we do not suspect any significant difference in the extent of the social networks and willingness to diffuse knowledge.

Engineers are the single most important resource for research and development in NorCOM. In almost all of the firms, engineers account for a high proportion of total employment. After contacting the managers personally, we received information about the number of employees in this category. Of the 791 questionnaires sent to the 19 firms, 346 questionnaires were returned, a 44 percent response rate.

After asking for some basic information and educational background, we inquired about the following issues: (i) Work experience in communication technology and in different locations, (ii) characteristics of the present job as well as important parameters in the job selection process, (iii) reasons for job changes, (iv) contact with engineers from other firms, (v) contact with university staff, (vi) the need for, and use of, further educational opportunities, (vii) the importance of, and reason for, membership/non-membership of labour unions, and (viii) the entrepreneurial spirit and opportunities for establishing new firms in the future. When the engineers were questioned as to whether they received knowledge, we asked them only to consider knowledge that they could use directly in their current job function.

In the questionnaire, we define an informal contact as a person working in another firm (in the same local industry) with whom the engineer has a social relationship, which is not part of a formalised agreement between the two firms. We use 13 different variables in our studies of the likelihoods of having informal contacts, acquiring knowledge and acquiring high-value knowledge. Most of these variables are categorical and derived directly from the survey. The only exceptions are work experience and mobility rate. Experience is calculated as the number of years of work experience since graduation. Mobility rate is number of job moves divided by years of experience. The distributions of the categorical variables are shown in Table 1.

Table 1 Distribution of observations across the categorical variables

Variable	Number of observations	Percentage of observations	Cumulative No. of obs.	Cumulative Percentage
Informal contact				
No	87	25.14	87	25.14
Yes	259	74.86	346	100.00
Knowledge acquisition				
No	240	69.36	240	69.36
Yes	106	30.64	346	100.00
Value of knowledge acquired				
No knowledge	242	69.94	242	69.94
Low	38	10.98	280	80.92
Medium	57	16.47	337	97.4
High	9	2.6	346	100.00
Function-speciality in firm				
R&D	260	75.14	260	75.14
Other specialities	86	24.86	346	100.00
Contact with former colleagues				
No	175	50.58	175	50.58
Yes	171	49.42	346	100.00
Contact with former classmates				
No	216	62.43	216	62.43
Yes	130	37.57	346	100.00
Contact with private friends (within local industry)				
No	223	64.45	223	64.45
Yes	123	35.55	346	100.00
Previous formal projects				
No	277	80.06	277	80.06
Yes	69	19.94	346	100.00
Educational institution				
Local university	180	52.02	180	52.02
Other institutions	166	47.98	346	100.00
Competition clause				
No	290	83.82	290	83.82
Yes	56	16.18	346	100.00

Source: NorCOM Survey

The table shows that the 75% of the respondents are in informal contact with employees in other firms. 30% of the respondents acquire knowledge through their contacts. 2.6% of the sample acquires high-value knowledge. The majority of the respondents are working

primarily with R&D assignments in their firm. Almost 50% are in contact with former colleagues; almost 40% with former classmates and 35% are private friends with their contacts (i.e. they meet in a social context not related to work). 20% of the engineers have previously been part of formalised project with other firms in the local industry. 52% of the respondents are graduates from the local Aalborg University, and 16% of the respondents have non-compete covenants or competition clauses in their employment contract.

Table 2 Basic descriptive statistics and correlation matrix

Variables	Mean	Std. dev.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12
-. Age	33.21	6.62	23.00	59.00												
1. Informal contact	0.75	0.43	0.00	1.00												
2. Knowledge acquisition	0.31	0.46	0.00	1.00	**0.37**											
3. Value of knowledge	0.52	0.86	0.00	3.00	**0.35**	**0.90**										
4. Contact with former colleagues	0.49	0.50	0.00	1.00	**0.57**	**0.23**	**0.24**									
5. Contact with former classmates	0.37	0.49	0.00	1.00	**0.44**	**0.16**	**0.12**	0.03								
6. Contact with private friends	0.35	0.48	0.00	1.00	**0.41**	**0.20**	**0.16**	**0.22**	**0.21**							
7. Previous formal projects	0.19	0.40	0.00	1.00	**0.14**	**0.20**	**0.21**	**0.19**	0.03	0.07						
8. Experience	8.60	6.45	1.00	34.00	-0.04	**0.11**	**0.15**	**0.26**	**-0.36**	-0.05	**0.26**					
9. Educational institution	0.52	0.50	0.00	1.00	**0.20**	**0.12**	**0.16**	-0.02	**0.34**	0.04	0.09	**-0.13**				
10. Competition clause	0.16	0.37	0.00	1.00	-0.14	-0.04	-0.02	**-0.18**	0.05	-0.05	0.00	-0.02	0.06			
11. Mobility rate	0.35	0.29	0.05	2.33	**-0.04**	**-0.12**	**-0.13**	**-0.24**	**0.20**	0.05	**-0.16**	**-0.50**	0.00	0.06		
12. Function-speciality in firm	0.75	0.43	0.00	1.00	0.02	**-0.11**	**-0.14**	-0.07	0.14	-0.07	-0.08	**-0.28**	-0.04	0.09	0.08	

Source: NorCOM Survey

Note: Figures in bold have associated p-values lower than 0.05.

Table 2 shows the basic statistic for all variables including the correlation matrix. The table also shows that the average age of the respondents is relatively low (33.2 years). This is due to the rather rapid growth of the local industry in the mid- and end-1990s, where many firms also had recruitment problems due to lack of available and qualified labour. The correlation matrix shows a considerable number of significant correlation estimates indicating that many of the variables are correlated.

4 Results

We estimate three different types of models in our analysis. First, we estimate a logistic regression model (Model 1) on the probability that a respondent has one or more informal contacts with employees in other local industry firms. Second, we examine the probability that a respondent acquires knowledge through the contact that can be used in the respondent's own work. This is also done through logistic regression models (Models 2a-c). Finally, we investigate the probability that the respondent acquires knowledge, which can be characterised as high-value knowledge. This is done in three different value-ordered probit regression models (Models 3a-d). The results of first estimations are shown in Table 3.

Table 3 Results of the logistic regressions

	Model 1		Model 2a		Model 2b		Model 2c	
Variables	Parameter Estimate	Standard Deviation	Parameter Estimate	Standard Deviation	Parameter Estimate	Standard Deviation	Parameter Estimate	Standard Deviation
Dependent	Informal (Prob=Yes)		Knowledge (Prob=Yes)		Knowledge (Prob=Yes)		Knowledge (Prob=Yes)	
Formal projects in the past (vs. no)	0.44 **	0.203	0.38 **	0.155	0.37 **	0.157	0.37 **	0.1559
Experience	-0.02	0.025	0.04 *	0.233	0.03	0.024	0.03	0.0252
Educational institution (vs. other)	0.45 ***	0.140			0.18	0.138		
Function-speciality (R&D vs. other)	0.14	0.162			-0.22	0.153		
Competition clause (vs. no)	-0.48 ***	0.172					0.07	0.182
Mobility rate	-0.41	0.504					-0.66	0.560
Contact with former colleagues (vs. no)			0.36 ***	0.135	0.38 ***	0.136	0.35 **	0.138
Contact with former classmates (vs. no)			0.42 ***	0.144	0.38 **	0.151	0.43 ***	0.144
Contact with private friends (vs. no)			0.34 **	0.132	0.33 **	0.134	0.35 ***	0.132
Intercept	1.43 ***	0.447	-0.80 ***	0.265	-0.68 **	0.299	-0.43	0.400
Observations	330		330		330		330	
Concordant	65.9		71.9		73		71.8	
Likelihood ratio	24.859 ***		44.507 ***		48.745 ***		46.112 ***	

Source: NorCOM Survey

Note: *: P<0.1, **: P<0.05, ***: P<0.01.

Note: Models 1 and 2a-c are logistic regressions.

The first model investigates the factors that may have significant influence on the likelihood of having informal contact with employees in other local industry firms. The estimation shows that three of the chosen factors have highly significant effects on the likelihood. Most notably, the educational institution and whether there is a competition clause in the respondent's contract are significant. This shows that the likelihood of having informal contact increases, if the respondent is a graduate from the local university. On the other hand, the likelihood decreases in the cases, where the engineer has a competition clause. This shows that employees in the more closed firms, which strongly control its employees with competition clauses, also have fewer informal links to the outside. Additionally, the likelihood of having informal contacts increases, if the engineer has been part of a more formalised cooperation project in the past. Years of work experience, function in firm and the mobility rate does not have any significant effect on the likelihood of having contacts. The likelihood ratio for the model is highly significant, which indicates that the model has a good fit. The concordant is 65.9%, which shows that the model has better chance of predicting the outcome compared to a random 50/50 prediction.

The second issue to be investigated in this analysis is the likelihood that respondents will acquire knowledge from their informal contacts, which they can use in their own job. This is examined in Models 2a to 2c. Similar to the previous model, the likelihood of acquiring knowledge is also significantly affected if the engineers were previously part of a formal cooperation project with another firm. This variable is positive and significant in all three models. Furthermore, the estimations show that the engineers that form relationships with former colleagues, former classmates and are private friends with other engineers employed in the local industry have a relatively higher probability of acquiring knowledge from these contacts. The dummies for contact with these parties are also significant and positive in all three models. Work experience is only significant in the first model, giving only weak support for the idea that engineers will be more likely to acquire knowledge, if they have relatively more work experience. Competition clauses, educational institution, mobility rate and function in the firm have no influence on the likelihood of acquiring knowledge. The likelihood ratio is also highly significant and positive, and the predictive power of the models is also high (71.9%-73%).

Table 4 Results of the value-ordered probit regressions

	Model 3a		Model 3b		Model 3c		Model 3d	
Variables	Parameter Estimate	Standard Deviation	Parameter Estimate	Standard Deviation	Parameter Estimate	Standard Deviation	Parameter Estimate	Standard Deviation
Dependent	Value (Prob.=High)		Value (Prob.=High)		Value (Prob.=High)		Value (Prob.=High)	
Formal projects in the past (vs. no)	0.22 **	0.086	0.20 **	0.087	0.20 **	0.087	0.20 **	0.087
Experience	0.03 **	0.013	0.03 **	0.013	0.02 *	0.013	0.02	0.014
Educational institution (vs. other)			0.20 ***	0.077	0.19 **	0.078		
Function-speciality (R&D vs. other)					-0.13	0.084		
Competition clause (vs. no)							0.07	0.100
Mobility rate							-0.28	0.304
Contact with former colleagues (vs. no)	0.23 ***	0.076	0.23 ***	0.076	0.24 ***	0.076	0.23 ***	0.077
Contact with former classmates (vs. no)	0.23 ***	0.079	0.18 **	0.083	0.19 **	0.083	0.24 ***	0.080
Contact with private friends (vs. no)	0.13 *	0.074	0.15 *	0.075	0.14 *	0.076	0.13 *	0.074
Intercept 3	-2.17 ***	0.206	-2.28 ***	0.213	-2.18 ***	0.222	-2.00 ***	0.260
Intercept 2	-0.95 ***	0.152	-1.02 ***	0.157	-0.92 ***	0.171	-0.78 ***	0.222
Intercept 1	-0.55 ***	0.147	-0.61 ***	0.152	-0.50 ***	0.168	-0.37 *	0.220
Observations	330		330		330		330	
Concordant	68.1		69.6		69.1		68.1	
Likelihood ratio	43.751 ***		50.788 ***		53.059 ***		44.964 ***	

Source: NorCOM Survey

Note: *: P<0.1, **: P<0.05, ***: P<0.01.

Note: Models 3a-d are value-ordered probit regressions.

The likelihood of acquiring highly valuable knowledge is investigated in the four variations of Model 3 shown in Table 4. The results again show that the likelihood of acquiring valuable knowledge will increase, if the engineer has previously been part of a formalised cooperation project. The variable is positive and significant in all four estimated models. The contact variables have similar effects, although the dummy for contact with private friends is less significant compared with the two other contact dummies. This shows that relationships with former colleagues and classmates have strong effects on the likelihood that an engineer will acquire more valuable knowledge. In contrast to the previous models, experience is more significant (except for Model 3c) and positive. This gives some indication that experience will be more of an advantage, when looking at the likelihood of acquiring valuable knowledge. The educational institution dummy is also positive and significant when included in Model 3. This shows that the engineers with a degree from the local university might have a more central location in the network, which will increase the likelihood that they acquire valuable knowledge. On the other hand, the variables on function in firm, mobility rate and competition clause have no effect on the probability in this model. The concordants indicate a predictive power just below 70%, while the highly significant likelihood ratios indicate that the models have good fits.

5 Discussion

The analysis shows that the work experience of engineers does not have an impact on whether the engineers have informal contacts. Neither does there seem to be a relationship between work experience and the likelihood of acquiring knowledge. Experience does not seem to increase the likelihood of having contact or acquiring knowledge. However, when looking at the likelihood of acquiring valuable knowledge, the experience of the engineers has a more significant impact (except for Model 3d). Experience increases the likelihood of acquiring valuable knowledge. This indicates that the engineers are better at using their contacts to acquire valuable knowledge the more experience they have. They know whom they have to contact in order to acquire the most valuable knowledge or to get help to solve their particular problem. What is seen here could be that experience builds up reputation, as argued by Maskell et al. (1998). This could make some of the weaker ties stronger and more able to disclose valuable knowledge. This also relates to the debate of cohesion in the social network versus uniqueness of the knowledge that we see in Granovetter (1973) and Ingram and Roberts (2000). It is however not possible to investigate the relationship between uniqueness of the information and value from the data. But the overall picture is that the relatively more experienced engineers are not more likely to have contacts or acquire knowledge than other engineers, but in general the knowledge that they do acquire is of higher value to them.

The initial contact between engineers from two firms may be created by a formal joint project. If they work together on a specific joint project, there is a possibility that their relationship will last longer than the project itself. Working together across firm boundaries increases the probability that engineers connect across structural holes, as described by Burt (2004), or that they are able to bridge different coding schemes of organisations, related to the notion of Allen and Cohen (1969). Engineers previously involved in formalised projects with employees from other firms are more likely to have informal contacts than engineers not previously involved in such projects. It is plausible that some of the informal contacts arise directly from prior formalised projects. They are also more likely to acquire knowledge and do also have a higher probability of acquiring more valuable knowledge. Working in a firm that previously has been in a formalised project with another local firm increases the probability that the employees will have an informal contact, acquire knowledge, and acquire higher valued knowledge. This clearly shows that the relationships, which are created through the formal project, are persistent even after the project itself. Project participants remain in social contact, which increases the probability that knowledge will be shared.

Who the engineers are in contact with is also important. The estimations show that the engineers that have social relations with former colleagues, former classmates and are private friends with other engineers (from other firms in the local industry) have a relatively higher probability of acquiring knowledge from these contacts. This is what we expected based on the literature (e.g. Allen and Cohen, 1969; Granovetter, 1973; Ingram and Roberts, 2000). The relationships with former colleagues and classmates also have strong effects on the likelihood that an engineer will acquire more valuable knowledge. This shows that previously working or studying together with other engineers increases the strength and trust of the connection, which will increase the likelihood that valuable knowledge will be shared later in the working life.

Education is the centre of the concept of human capital as used by Burt (2004). The engineers form social networks during their education and keep in contact with their classmates.[1] However, the dummy for educational institution (Aalborg University vs. other institutions) is not significant for the probability of having informal contacts or acquiring knowledge in our estimations. But engineers educated at this university have a significantly higher probability of receiving more valuable knowledge. This might be because the engineers have a more central position in the social network or have larger networks. The data, however, cannot map individual engineers' social networks to explore this further.

As proposed by Granovetter (1973), mobility might be important for the extension of informal contact networks. To investigate this, it is examined whether a higher relative

[1] 52% of the engineers in the sample are graduates from the local university.

mobility rate will increase the probability of having at least one informal contact. However, the results show that there is no impact on the likelihood of informal contact between the engineers, when considering the mobility rate. The impact was also insignificant when looking at the likelihood of acquiring knowledge or the likelihood of acquiring higher valued knowledge. So although the engineers have important contacts with former colleagues and project partners, this shows that a higher rate of mobility does not increase the probability of having contacts or getting knowledge. All in all the results show that engineers have the strongest and most important connections (in terms of acquiring higher valued knowledge) with their previous colleagues and project partners, and they are more likely to get valuable knowledge, if they maintain these relationships. But this likelihood is not influenced by the rate of mobility.

Firms might discourage their employees or even actively try to prevent their knowledge from being shared with an outside party (von Hippel, 1987; Schrader, 1991). Managerial regimes and culture can have an effect on the extent of informal relationships across the boundaries of firms. Competition clauses can, for instance, limit the employee's possibility of taking a job in a competing firm or working with the same products immediately after ending the contract. Here the clauses is used as a proxy for a firm's actions towards limiting the disclosure of knowledge to other firms through informal channels. Firms that include these clauses in the contracts of their employees are also more likely to have policies and norms preventing or discouraging their employees from sharing the firm's knowledge through informal contacts.

The engineers that have competition clauses in their contracts are less likely to have at least one informal contact outside the firm. This shows that firms with restrictive managerial regimes - i.e. with competition clauses in the contracts - are successfully limiting informal networking between their employees and those in other cluster firms. However, the presence of a competition clause does not have an impact on the likelihood of receiving useful knowledge or on the value of knowledge received. So once the contact and network connection is established, competition clauses do not hinder knowledge diffusion, but they can prevent people from establishing networks.

6 Conclusion

This chapter describes how previous claims that knowledge is diffused through informal social networks have been criticised recently by scholars stating that agents will not generally disclose firm-specific knowledge to external agents, because of loyalty to the firm. They argue that employees will only tend to exchange more general information of low value, which will not be so disadvantageous to their firms. The analysis shows that some engineers actually do acquire, also valuable, knowledge from the informal social networks. The

engineers, which have previously been part of formalised projects with other firms and which are in contact with their former colleagues and classmates, are much more likely to receive knowledge of higher value.

The overall conclusion of this chapter is that the long-term relationships, which are more likely to be based on trust and reputation, are also more likely to be a channel of diffusion of valuable knowledge. This is based on the results that experience, contact with former colleagues and formal projects from the past are the most important factors explaining the likelihood that engineers will acquire valuable knowledge. These relationships are potentially very strong and likely to involve a considerable degree of trust.

This study shows that social networks and informal communication are diffusing knowledge between firms in a coherent group of firms located within in a rather small geographical area. Future research also needs to ask the individual in question to compare the value of knowledge thus acquired with other sources of knowledge (e.g. colleagues in their workgroup, other colleagues in their firm, the internet, university-based research contacts, technical journals or similar sources). This would add to our knowledge on how more specific information and knowledge is actually exchanged within and across organisational boundaries. The knowledge flowing through informal contacts is often considered in a positive light in the literature. The down-side of knowledge trading, for example the loss of knowledge to competitors, which could potentially weaken a firm's performance, has not been treated to a sufficient extent in the literature so far.

Furthermore, it would be constructive to know more about how individuals are linked in networks of informal relationships across firms. Identifying how networks and epistemic communities operate in different sectors and on regional levels could shed some light on how widely knowledge is exchanged through a network. A limitation in the questionnaire used in this chapter is the anonymity of the engineers. By asking engineers to name, say, their three most important informal social contacts in the local industry, it may be possible to map a web of informal contacts and to gain a more accurate picture of the extent of the social networks. This important issue is still to be addressed in the debate on the importance, characteristics and borders of these networks.

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Chapter 8

Technological Life Cycles: A Regional Cluster Facing Disruption – What can be learned?

Technological Life Cycles: A Regional Cluster Facing Disruption – What can be learned?[1]

1 Introduction

This chapter is focused on how regional clusters may react on the emergence of new disruptive technologies. The case to be studied in detail is a small cluster of high technology based wireless communications firms in the region of North Jutland, Denmark. A special emphasis is given to the study of whether and how a 'collective spirit' may be formed and turned into collective action in periods of major threats and challenges. This again leads to a discussion of the interaction between privately and publicly initiated efforts and policy initiatives.

The term cluster is applied as "*geographic concentrations of interconnected companies…. linked by commonalities and complementarities*" (Porter, 1998, p.199). It is important how precisely these commonalities and complementarities are conceived and defined. Martin and Sunley (2003) has surveyed the wide array of cluster definitions applied in the literature more recently. The cluster concept appears to be very elastic and imprecise in academic as well as is policy circles. The present chapter faces this problem by using a concise and operational definition.

The object of the analysis is a rather precisely specified regional cluster, NorCOM, consisting of approximately 50 firms, a science park, NOVI, and Aalborg University, AAU. The small size has facilitated more easy information access and made it possible to survey an entire cluster. The delimitation of the cluster has deliberately been narrow, i.e. a common knowledge base focused on radio waves as an information carrier. The small size has made it possible to base the chapter on extensive interviews and interaction with a significant share of the major players in the cluster as well as to be rather specific in the discussions of policy issues.

The growth of the wireless communications industry (manufacturing and services) has been among the fastest of all industries in the 1980s and 1990s. Technological innovation has been radical and very fast, not least in the dominant segment of the mobile telephony. The industry also contains such areas as maritime communications and navigation, whether radio or satellite based. But the entire telecommunications sector experienced a deep crisis

[1] This chapter is based on Dalum, Pedersen and Villumsen (2005) "Technological Life Cycles: A Regional Cluster Facing Disruption - What can be learned" forthcoming in European Urban and Regional Studies. This chapter overlaps somehow with Chapter 2, 4 and 5.

from 2001. This has, however, not caused a slow down in technological change, but major restructuring processes have been envisaged (Fransman, 2002; Edquist, 2003). During the 1980s and 1990s new mobile communications technologies have emerged as a series of distinct 'generations'. The introduction and diffusion of each of these have caused major disruptions in the industry, but also opened opportunities for new entrants. The shifts from one generation to the next have also involved some major policy issues, such as choice of regulation and standardisation set-up and the need for large investments in university R&D.

Ideally, the chapter aims at pointing at some features and mechanism of more general relevance for evolution of regional clusters based on fast developing technologies and the opportunities and potential necessities for developing policy measures in periods of major disruptions.

The following Section 2 highlights the general theoretical background of the chapter, which is the re-born interaction between geography and economics since the early 1990s. Section 3 focuses on the concepts of technological life cycles and the role of disruption. The cluster in its regional context is introduced in Section 4 and 5, while Section 6 contains the analysis of the interaction of various generations of mobile communications technologies, other wireless technologies and the dynamics of the cluster. Section 7 focuses on the future challenges for the cluster and the role of policy and privately initiated collective efforts.

2 The interaction between geography and economics

Since the early 1990s, the literature on the importance of geography for economic development has been revitalised. Inside the economics profession Krugman (1991; 1995) has engaged in a 'crusade' aiming at integrating the spatial dimension into mainstream economic theory. This has borne fruit in such theoretical work as Fujita et al. (1999) as well as influenced e.g. the discussion on income convergence versus divergence among European regions. Krugman's writings also caused a comprehensive but rather hostile reaction from the community of economic geographers during the 1990s, surveyed by Martin and Sunley (1996) and Martin (1999).

In 1990 another stream of literature dealing with the geographical dimension of economics emerged from research rooted in a strategic management perspective, in terms of Porter's (1990) highly influential reinterpretation of Dahmén's (1970; 1988) development blocks as regionally based *industrial clusters*. Also emerging in the early 1990s was the literature in *innovations systems*, whether national (Lundvall, 1992; Nelson, 1993), regional (Cooke, 1992) or based on specific technologies (Carlsson and Stankiewicz, 1991) or broader sectors (Breschi and Malerba, 1997). Technical change and its diffusion has been a core driver of the innovation systems literature as well as in Porter's work. They share the view that the traditional linear model, where scientific discovery and invention move on to industrial

innovation in a fairly simple manner, cannot explain the dynamics of industrial development, neither at present nor historically. On the contrary, they share an emphasis on the systemic character of technical innovation - the institutional set-up matters as do interaction among a great deal of actors, such as firms, universities, industry associations, standardisation bodies, government regulators (at the national as well regional level), science parks etc. While the innovation system literature has emphasised the role of inter-firm cooperative networks, Porter on the other hand emphasised local competition as a main dynamic force in the development of clusters.

Recently, major attempts to synthesise and integrate these various lines of work have been presented. *The Oxford Handbook of Economic Geography* (Clark et al., 2000) represents a great effort to bring together the various contributions, although without necessarily solving the differences between the various approaches; there is still a rather large gap between mainstream economics and the other approaches. Edquist's (1997) presents the various contributions to the innovations system literature, which to a large extent appear to have been integrated through that effort.[2] Porter (1998; 2000) contains an effort of further integration of the strategic management perspective with the emerging research tradition in economic geography and innovation systems.

The various lines of research on the interaction between territory and industrial development have, thus, somehow tended to converge. Major efforts to do empirical comparisons of regional innovation systems have been performed in several European projects during in the second half of the 1990s with an early proponent of the concept of regional innovation systems as a central node, see e.g. Braczyk et al. (1997), Cooke et al. (2000) and Cooke (2001). These studies have focused on the most important innovation networks as the supposed core drivers of regional economic development.

The present chapter is focused on a particular line of research in this context, that of high technology based regional clusters. Many of the available cluster studies have been focused on more static descriptions of their characteristics at a given point in time, although flavoured with evidence of some of the main features of their history. A more systematic focus on the development of specific clusters over longer time spans has somehow been given less priority. This may be due to the great variety of regional clusters. Generalisations across this variety may seem difficult, especially concerning different patterns of evolution over time. This chapter intends to further develop the analysis of sequential disruptions by using the concept of technological life cycles and apply this on a single case over an extended period of time, including several cycles.

[2] See also Freeman (2002), Lundvall et al. (2002), Malerba (2002) and Carlsson et al. (2002) for more recent state of the art surveys.

In the theory of the patterns of technical innovation the concepts of product, industry and technological life cycles seem fit to a more dynamic analysis of the development of regional clusters. Klepper's (2002) analysis of the early concentration of the automobile industry in Detroit is an example of the merit of the industry life cycle approach. For detailed analysis of clusters in electronics, the theories of technological life cycles seems fit because a given cluster often experiences the passing of several life cycles. It is the capability of a cluster to adapt to these continuous 'bombardments' of new technologies, which is the core field of the study. Saxenian's (1994) account of the history of Silicon Valley is closely related to the emergence of radical new technologies, as is her analysis of how the Route 128 region got stuck in one, at the time highly successful, technology – i.e. minicomputers. Two new technological life cycles (Unix based 'workstation' computers and the PC) were at the heart of the Silicon Valley resurgence in the 1980s, when the Boston area, according to Saxenian, was left behind in the computer industry.

The role of radical technological change may cause disruptions for existing clusters as well as form the foundation for the emergence of new ones.

3 Theory of technological life cycles and disruptive technologies

The transformation and change of sectors, industries or products is in the literature on industry life cycles (Vernon, 1966; Klepper, 1996) and product life cycles (Abernathy and Utterback, 1975) shown to follow a life cycle from birth to maturity. Also Storper and Walker (1989) and Thompson (1975) have studied the industrial transformation process with special emphasis on regional instability and dynamism in these different phases. Abernathy and Utterback (1975) focused on technological innovation, where product and process innovations were integrated into a single model explaining the evolution of a product life cycle.

In the beginning (the fluid phase), there is a lot of experimentation with different designs etc., resulting in a high number of product innovations. The early stage then turns into a phase dominated by incremental innovations, when a dominant design emerges. As the rate of product innovations drops and technological uncertainty is lowered, the rate of process innovations increases. Consequently productivity increases and the scale of production grows (Utterback, 1994). The focus shifts from product performance maximisation to cost minimisation (the transitional phase). In the following mature phase, the overall rate of innovation fades, the products become standardised and the production processes become more efficient and closely integrated with the products.

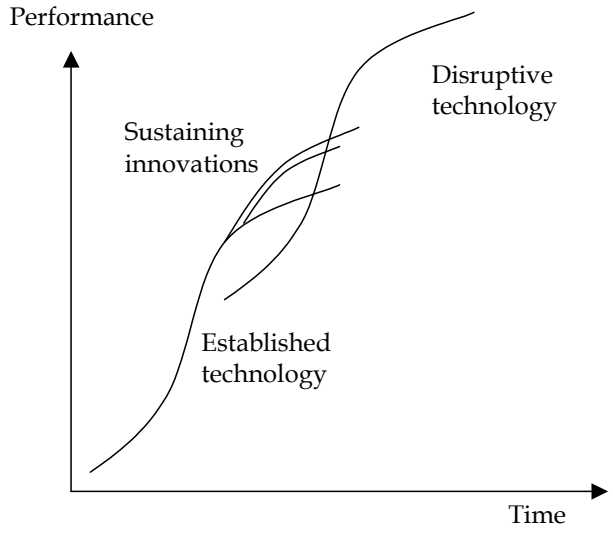
The industry life cycle and the product life cycle are closely linked. Entry, exit and growth are added to the product life cycle to form the industry life cycle model. In addition, the fluid phase of an industry is characterised by a high number of entrants. But as the industry enters

the transitional phase and the number of firms peak, a shakeout occurs resulting in concentration. The prices also decline during the cycle and while the market size initially is small, it grows rapidly in the transitional phase.

The organisation of the firm and the character of its innovative activity also change during the cycle (Utterback, 1994). In the early phase there is high innovative activity among smaller firms and new entrants, while in the mature stage, with less product innovation, there tends to be an advantage in the innovative activity of large and established firms (Audretsch and Feldman, 1996; Klepper, 1996). In Cainarca et al. (1992) the industry life cycle is split into (different) life cycles of sub-industries, defined by their technology - the result is a 'technological life cycle'. This is more than a product but less than an industry life cycle. It is also important to note that each technological life cycle has different features i.e. competition, user needs, applications etc. can be different.

Utterback uses a S-curve model where the evolution of technology, industry or product follows an S–curve over time. The performance is usually either measured by technological performance or market penetration. Utterback uses the American ice industry as an example, but finds a similar pattern in others, such as the computer industry. The S-curve model is also used in Freeman et al. (1982), who shows how the miniaturisation of electronics from 1940 to 1975 follows an S-curve model with parts per cubic inch as the performance indicator.

Figure 1 S-curves for the established and disruptive technology



However, the coexistence and shifts from one technological life cycle to the next is not straightforward. The life cycle of an established technology may be prolonged by 'sustaining innovations' or may be disrupted by the emergence of a new technology. Sustaining innovations are not necessarily incremental, but may be quite radical.

The term disruptive refers to such significant changes in the basic technologies that may change the industrial landscape. Tushman and Anderson (1986) describes the disruption as a technological discontinuity that is so significant that no increase in scale, efficiency or design can make the older technologies competitive with the new one. Initially the disrupter under-performs the established technology, but it enables new applications for new customers, presents new benefits and the performance improves rapidly. The disruptive technology may first have a lower performance than the established and may also serve different customers and applications. For a long period the established technology may continue to perform better and the disrupter may not be seen as a threat. Because the disrupter has a different improvement trajectory, it can eventually outperform the old technology, although the latter may fight back for a prolonged period.

The evolution paths of the cycles are, obviously, not as deterministic and predictable as indicated in Figure 1. Many potential disruptive technologies will not win or outperform the old technology due to technological lock in, de facto standards, sustaining innovations, timing etc. A possible cause can be different types of disruption. Tushman and Anderson (1986) categorises these as product (new product class, substitution, or fundamental improvement) or process disruption (substitution or radical improvement), which are either competence destroying or enhancing. Bower and Christensen (1995) and Lewis et al. (2001) have emphasised that the causes of disruption usually are a new business models, applications or customers, but not necessarily the technology itself.

The disruptive technology often comes from outsiders and not the industry leaders (see Utterback (1994) and Bower and Christensen (1995)) and is therefore very hard to predict. Even disrupters may be disrupted. Brower and Christensen studied the disk-drive industry and predicted, in line with the previous evolution of the disk-drive industry, that the next disrupter would be the 1.8-inch drives. Reality showed, however, that this technology never took off. But when a new technological life cycle successfully takes off, the outcome is often a shift of market leaders and location. Likewise, a new technological life cycle may offer new opportunities for existing or emerging regional clusters. Audretsch and Feldman (1996) shows that there is a tendency in the early stages of an industry life cycle for innovative activity to cluster, whereas it is more dispersed in the mature stages.

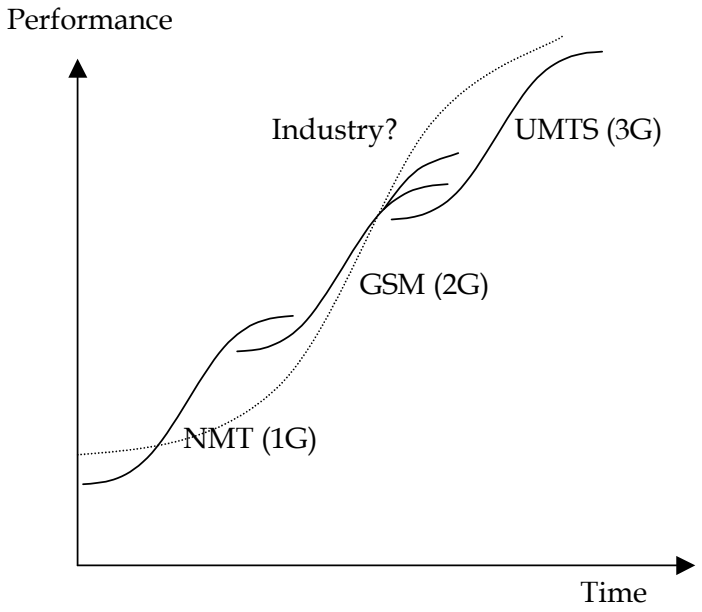
4 Technological life cycles in the mobile communications industry

The concept of technological life cycles fits neatly the evolution of mobile communications technologies. The significant changes in the basic technology from the first generation (1G) Nordic Mobile Telephony (NMT) technology to the second generation (2G) GSM constitutes a shift of technological life cycles. Likewise the emerging third generation system (3G) UMTS represents a new potential cycle. The pattern for the European mobile communications

industry is shown in Figure 2, which also contains an 'envelope curve' in order to illustrate that there may be a life cycle pattern of the entire industry moving towards the mature stage already at present, due to (temporary?) market saturation of mobile phones in the most dominant markets.

The 1G cycle consisted of analogue mobile systems, of which the Nordic NMT - the first international system operating from 1981 - became very successful. The disrupter and subsequent new technological life cycle was the pan-European GSM, which was a shift to digital technology and required a new infrastructure. The disruption caused by GSM did not only lead to replacement of NMT; GSM even became the de facto dominant world standard. GSM also became a disrupter to the fixed telephones and satellite cell phones networks as well as in the telecom service provision industry. (Mannings and Cosier, 2001; Dalum, 2003).

Figure 2 The technological life cycles of the European mobile communications industry



Within each of the generations different systems have been competing worldwide. The Nordic NMT system became adopted in several, mostly European, countries as well. But technically inferior and internationally incompatible systems were implemented in the dominant European markets of Germany and France, while the UK adopted an adjusted version of the US (1G) AMPS system, TACS. During the 1G cycle the US and Latin American markets were dominated by the AMPS system. Although the highly successful GSM have emerged as the dominant world standard within the 2G technologies, the US D-AMPS and CDMA-One have caused fierce competition between these rivalling systems, especially in the US as well as e.g. Korea. Also within the 3G technologies, no universal standard could be established. The European-Japanese UMTS system competes with the US CDMA2000 and a

potential Chinese rival standard, TD-SCDMA, has not been decided on yet. For detailed historical accounts on the various generations of mobile communications systems, see Funk (2002), King and West (2002), Hommen (2003) and Dalum et al. (2002).

At present – i.e. 2004 - the industry is in the transition phase between 2G and 3G. However, the 2G technologies are 'fighting back' with the sustaining innovation EDGE (or 2.5G) that offers the data transmission speed of the same magnitude as the first 3G networks. The latter are just in the process of being rolled-out and have been hit by various delays, such as lack of sufficiently attractive terminals. A situation quite similar to what happened a decade ago during the early implementation of the first GSM networks. But the open question is will the smooth pattern indicated in Figure 2 be realised? Or said differently will history to a certain extent repeat itself? The outcome is not easy to predict. The recent history of the industry indicates that an exaggerated optimism concerning the transition from 2G to 3G has led to a technology push dominated approach where customer needs have played a too minor role.

The UMTS variant of 3G requires a completely new infrastructure. The order of magnitude of the estimated costs are reported to be around $150bn, while the costs for the major European operators to acquire 3G licenses during the spectrum auction processes during 2000-1 were around $120bn. The operators have vested interests in the rollout of 3G in Europe, but it is nonetheless not straight forward to which extent 3G will cause radical disruption, partly because of the sustaining innovations, such as EDGE, and other potentially disruptive technologies. Especially Wireless Local Area Networks (WLAN), which are providing low cost, high-speed short distance wireless Internet access, may be considered a potential disrupter to the emerging 3G networks.

5 North Jutland – the emergence of ICT

How has this series of technological life cycles influenced the electronics industry in the small region of the North Jutland County at the northern tip of the peninsula of Jutland at the top the Central European continent? The population is around half a million people, slightly less than one tenth of the Danish total. Total employment was 245,800 persons in 2001, of which the private sector share was 161,700. The largest municipality is Aalborg, the fourth largest city in Denmark, with 163,000 inhabitants (see the map in Figure 3). The region has traditionally been characterised as peripheral with an unemployment rate among the highest in Denmark. The industry structure has previously been dominated by more traditional industries, such as agriculture and food processing, fishery, tourism, shipyards, textiles, tobacco and cement.

However, during the late 1980s and the 1990s the region has experienced a process of structural change. North Jutland is 'specialised' (i.e. has an above national average

employment share) in the primary sector and in metal products, but also in mechanical engineering and electronics. The latter is among the features to indicate that the industrial structure is not peripheral any more. The industrial structure is at present in line with the average Danish 'non-metropolitan' counties. The two 'metropolitan' regions are Copenhagen (including its suburbs) and Aarhus.

Table 1 The structure of the ICT sector in North Jutland – private sector employment

	North Jutland						Denmark		
	Specialisation		Employment (persons)	Share of ICT (percent)	Development 1992-01 (1992=100)	Change (persons)	Share of ICT (percent)	Development 1992-01 (1992=100)	Export specialisation (1998)
	1992	2001							
Manufacturing	**1.05**	**1.10**	2,512	29.7	**101.2**	29	22.4	98.2	0.52
Office machinery	**4.33**	0.25	2	0.0	0.8	-246	0.0	14.0	0.15
Computers	0.70	0.46	60	0.7	55.6	-48	1.3	84.8	0.41
Electronic components and wire	**1.55**	**1.44**	468	5.5	74.4	-161	3.2	80.9	0.21
Telecommunications equipment	**3.13**	**4.81**	1,211	14.3	**129.7**	277	2.5	85.3	**1.14**
Consumer electronics	0.27	0.63	322	3.8	**270.6**	203	5.0	**117.8**	0.78
Electro medical	0.48	0.41	189	2.2	82.5	-40	4.5	96.5	**1.70**
Instruments etc.	0.41	0.43	260	3.1	**120.4**	44	5.9	**117.5**	0.94
Services	0.53	0.74	5,935	70.3	**228.7**	3,340	77.6	**163.4**	-
Wholesale trade	0.33	0.44	937	11.1	**152.4**	322	20.9	**116.0**	-
Telecommunications	0.62	0.92	1,747	20.7	**197.4**	862	18.6	**134.5**	-
IT services and software	0.67	0.83	3,251	38.5	**296.9**	2,156	38.2	**242.8**	-
Total ICT sector	0.70	0.82	8,447	100	**166.3**	3,369	100	**142.3**	-

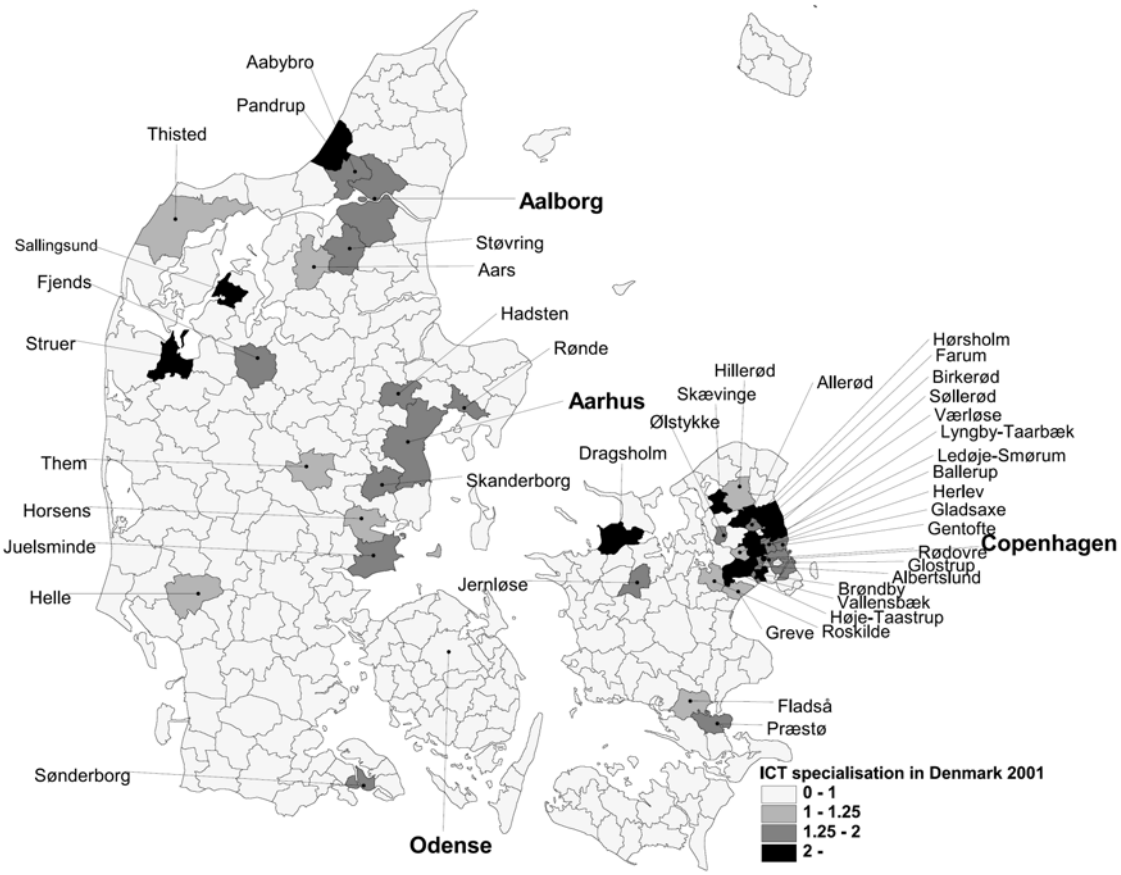
Note: A positive change in employment or specialisation above 1 is marked in bold. Instruments etc. are instruments and equipment for detecting, measuring, checking and controlling physical phenomena or processes. The export specialisation is based on trade by commodities statistics for OECD (23).
Source: Statistics Denmark and OECD (2000) *International Trade by Commodities Statistics*, No. 1.

The presence of a fairly visible segment of the ICT sector is a rather recent feature. Table 1 shows the structure of ICT employment compared to the national average in the 1990s. Total ICT employment was almost 8,450 in 2001 of which 30% was in manufacturing compared to 22% for Denmark. Specialisation in ICT manufacturing increased to 1.1 (i.e. a 10% larger ICT employment share than the national average) during the 1990s concentrated on two segments, telecommunications and components. Especially telecom hardware has been outstanding with an increase from a three to nearly five times larger employment share compared to the national average.

The region has not been specialised in ICT services in general although the specialisation indicator increased from 0.5 to 0.7 during 1992-01. However, in telecom services the region is close to the national average, which represents a skewed distribution with concentrated on the two 'metropolitan' regions of Copenhagen and Aarhus. Telecom services in North Jutland consist of a non-R&D oriented section of the previous incumbent monopoly operator, TDC, and the main part of the first Danish private GSM operator, Sonofon. The specialisation pattern at the municipality level is shown in Figure 3, which confirms the relative concentration of ICT around the university cities of Copenhagen, Aarhus and Aalborg,

although Odense, the third largest city in Denmark and an university city, was not specialised in ICT in 2001.

Figure 3 Geographic specialisation of the Danish ICT sector 2001 – private sector employment



Note: The four largest cities are marked in bold types.

6 The NorCOM history – the interaction of technological life cycles with disruption

These statistical patterns cover a wireless communications cluster, NorCOM, in North Jutland consisting of two related fields, mobile telephony (development and production of hardware and telecom services) and equipment for maritime communications and navigation. The cluster, called NorCOM from 1996, originates back to the mid 1960s when the 'mother' company SP Radio switched from being a consumer electronics producer for the domestic market to radio telephones for small ships. This firm quickly became one of the world leaders in its field.[3] An important trigger for further industrial development was the

[3] For details of the firms and the history of the cluster including a 'family tree', see www.norcom.dk.

start of Aalborg University (AAU) in 1974, which integrated two previous undergraduate level engineering schools both with departments in electronic engineering.

During the 1970s a few maritime communications firms emerged as spinoffs from SP Radio. At the beginning of the 1980s North Jutland had become visible in an industrial context as a maritime communications and printed circuit board concentration. At the university the first M.Sc.'s in electronic engineering graduated in 1979 and research activities were growing rapidly.

6.1 The NMT (1G) life cycle – an embryo of a cluster formed

From 1981 the Nordic mobile telephony operators (incumbent government owned monopolies) launched the first cross national public mobile telephony system ever seen, the NMT.[4] The system became an enormous – and unexpected - commercial success in term of user penetration, which called for significant attention internationally. The main producers of the equipment was Swedish Ericsson, which was the unchallenged leader in infrastructure equipment, and Danish Storno, located in Copenhagen, being strong in terminals (taken over by US General Electric in 1976).

A new technological life cycle had emerged and barriers to entry were smaller at the early stage, at least within the terminals market. Among the new entrants was Finish Nokia, a 100-year-old company in the paper and rubber industry, who acquired the Mobira start up, and the North Jutland firm, Dancall, which started as a maritime communications spinoff from SP Radio. The 1980s became the decade of the 1G life cycle. Growth was very rapid for Ericsson, Nokia, Dancall and Storno. The business opportunities appeared very promising, but competition increased. Prices and size of the terminals decreased, while technological performance increased rapidly. While the next generation of systems could be seen in the horizon, Storno was sold to the dominant US terminal producer Motorola in 1986. In North Jutland another maritime communications start up from the 1970s Shipmate also entered the NMT field in 1985 as Cetelco.

At the end of the 1980s North Jutland had become internationally visible as an NMT region. Several of the large telecommunications multinationals had entered the NMT terminals market, such as Siemens and Alcatel. The first Alcatel terminals were thus developed in North Jutland by T-Com in 1986 - a spinoff from Dancall to become acquired by Korean Maxon in 1991. The coincidence of the take off of NMT from 1981, the first vintage

[4] AT&T in the US developed the first cellular wireless system. The basic idea was demonstrated at Bell Labs already in 1947. A prototype of the AT&T's 1G AMPS system was tested in 1978 in Chicago, but due to a series of complications, mainly rooted in the ongoing antitrust case against AT&T, a 1G analog system was first launched commercially in the US in 1983. See West (2000) and King and West (2002) for detailed analyses of the causes of the late start of wireless services in the US.

of M.Sc.'s finishing their degree in electrical engineering at AAU in 1979 and the close industry-university interaction in the emerging mobile telephony industry paved the way for this early development. It was not an outcome of a deliberate industrial policy effort, although it could not have happened without the result of a deliberate outcome of a public policy effort, the start of Aalborg University in 1974.

6.2 The GSM (2G) life cycle – the regional cluster consolidated

During the last half of the 1980s a new life cycle was emerging. The tremendous success of NMT inspired the European telecommunications operators to create a Pan-European system, entirely based on digital technology. This process was given strong political backing by becoming a Europe 1992 'flagship project'. The standardisation process of the GSM system was taken over by a new EU organisation, the European Telecommunications Standards Institute (ETSI). The GSM system was planned to become operational in 1992 and a large amount of prestige and political momentum was embedded in the entire process.

GSM – and its competing 2G technologies in the US and Korea - represented an entire new technological life cycle. The infrastructure had to be rebuilt in terms of antennas and base stations in the landscape. The technological challenges for developing this new infrastructure as well as the GSM terminals were huge. A veritable race began because many of the incumbent telecommunications hardware producers saw the commercial opportunities already harvested by Ericsson, Storno/Motorola and, not least, Nokia in the second half of the 1980s.

The challenges were of such a magnitude, that some of the major multinationals formed pre-competitive alliances for developing parts of the equipment. Nokia, until the 2G cycle not active in infrastructure equipment, formed with Alcatel and AEG the ECR900 consortium to develop GSM infrastructure technology (Dalum, 1993). Ericsson cooperated with Siemens at some stage during the 1988-92 period as part of the contract of building the Deutsche Telekom 2G infrastructure.

In the North Jutland context the advent of GSM was a major challenge and also seen by many as a major threat, given the character of the small and medium sized firms. GSM was no doubt seen as a major disruptive phenomenon in the horizon. However, local university research had flourished during the NMT boom and the interaction with the local industry thrived. The knowledge infrastructure of the region began to become internationally visible. The two local producers and competitors, Dancall and Cetelco, announced in 1988 a pre-competitive joint venture, DC Development, to develop the basic technology for GSM terminals - located on neutral ground at the newly founded Aalborg University science park, NOVI. The two firms explicitly planned to close the joint venture when the mission was accomplished and compete based on different features of the terminals, such as design. Close

interaction with AAU and the National Telecom Agency in testing of the new terminal equipment were among the 'outside' factors of importance for the project.

The DC Development team peaked at approximately 30 persons in 1992 and managed to develop a GSM terminal presented at the CEBIT fair in Hanover, Germany in 1992. At the time terminals were presented by only a handful of companies, including Ericsson, Motorola, Nokia and Dancall-Cetelco (in various disguises such as Philips, Hagenuk and Dancall). Although a new technological life cycle could be envisaged, the NMT market was still growing and it coexisted with the emergence of the 2G cycle. The competition in the NMT market had changed during the 1G life cycle, the many entrants and the success in terms of a rapid diffusion of the mobile phone and (at the time) high user penetration had led to decreasing prices and fast technological change. The innovative effort in GSM by the small North Jutland firms basically drained them financially, because the competition was fierce in NMT market. Both were taken over by foreign companies. Dancall was acquired by UK Amstrad, then by Bosch and later again by Flextronics and Siemens. Cetelco was taken over by German Hagenuk, to be sold later on to Italian Telital (closed down in 2003).

At this stage, the first private GSM operator Sonofon[5] decided to build its main operations in Aalborg and the AAU research profile was consolidated by a new research Centre for Personal Communication (CPK), which 1993-2002 became an important international actor at the research scene in wireless technologies. But there was a widespread fear at the time, that the (planned) closing down of DC Development would be the end for the region in mobile telecom hardware development and production. However, instead of dying this group of industrial development engineers managed to start a cloning process – through existing firms or via spinoffs - which resulted in the region becoming a development hub for GSM terminals with six-seven firms developing GSM equipment, basically for foreign companies.

The shift from the 1G cycle to 2G had caused a significant amount of disruption. The advent of a new cycle had created uncertainty and a major technological challenge for the firms in the NorCOM cluster. The 'solution' was thought to be the joint venture model for developing the basics of a GSM phone between the two largest firms. The strategies of other firms in the cluster were less coordinated and more diverse. The local affiliate of Maxon continued to develop NMT phones since this market still was growing and Maxon had a deliberate strategy of postponing its entrance into GSM technology for some years. The

[5] The European telecom regulation set-up required from the beginning of the GSM phase at least two operators with nationwide coverage in each country. The result was heavy competition not least in the 'lead user' Nordic countries. Their previous monopolies, the government controlled incumbents, were broken leading to fierce competition, even in the early stage with only two operators. Sweden became the first country in the world with four nationwide GSM operators. Competition in the service industry appeared to be strongest in the Nordic countries, although the character of regulation was very different from the US system. The key feature was the requirement of nationwide coverage, which led to very fast diffusion of 2G technology in these countries. They maintained their lead from the 1G cycle in terms of the highest per capita penetration ratios.

emerging cluster thus consisted of firms with radically different strategies, from early movers to late entrants who followed a more opportunistic wait-and-see strategy. In the first half of the 1990s the cluster consisted of somehow fragmented small and medium sized players with rather different strategies.

The latter half of the 1990s became a period of very rapid growth. To some extent the events of the late 1980s were replicated but on a larger scale. And what became more and more evident already from the early 1990s were the contours of a wireless communications cluster, to a certain extent based on close personal interaction between engineers with a high degree of inter-firm mobility (Dahl, 2002; Dahl and Pedersen, 2003).

During the 1990s this cluster was widened horizontally[6]. Several firms entered the cluster as spinoffs or as inexperienced entrants. Many of these started working in other wireless communication technologies than the dominant mobile or maritime communications technologies e.g. a group of engineers left Dancall and were joined by a group from Maxon to found RTX, which during the decade became a world leader in developing cordless phones for big companies on OEM terms. In the second half of the decade RTX entered Bluetooth technology and mobile communications as well. A new collaborative activity was initiated between some of the firms in the cluster and some 'outside' firms in the field of cordless phones. A standardisation project involving a group of Danish firms (North Jutland firms, Bang & Olufsen and Ericsson founded Dansk DECT Udvikling focusing on further specification of the European standard for cordless phones, DECT. The main idea was that the European standard was too loosely defined and would not necessarily allow for seamless compatibility of equipment or parts from different producers. By making a more detailed specification of the DECT standard and getting it approved at the European level they went for creating a Danish advantage within the cordless segment of the industry. The cordless phone technology was, however, disrupted by the rapid diffusion of mobile phones, but survived more as an add-on to the fixed line telephony system. In 1995 the consortium was taken over by Ericsson that continued working on cordless technology, but soon diversified into other technologies (Bluetooth and later on UMTS) but the competencies stayed in the cluster.

Parallel to the horizontal proliferation, a vertical deepening was also seen. The first significant event was the decision to locate the major activities of the first private mobile phone operator Sonofon in Aalborg from 1991, which resulted in nearly 1000 jobs at the end of the decade. This deepening was matched later on by upstream entrance of specialised component developers, especially marked when one of the US leaders in chip sets for mobile phones Analog Devices opened an affiliate in Aalborg in 1997. Analog delivered chipsets for two of the local terminal developers and wanted to be present at the now thriving GSM

[6] For a discussion of cluster dimensions, see Enright (2001).

development hub. This deepening was brought further by the Texas Instruments acquisition of a GSM developer ATL in 1999. Texas Instruments, the world leader in Digital Signalling Processors (DSP), also wanted a presence in this environment and did so by being engaged directly in developing terminal equipment. A parallel strategy was followed by Infineon, one of the largest semiconductor companies in Europe (and owned by Siemens), which founded DWD a small GSM developer in 1999. Two Cambridge, UK firms both specialised in delivery of specialised software for GSM terminals entered the cluster in 2001. Also in 2001 the DECT firm Cortech was taken over by the German Rohde & Schwarz and transformed to a local affiliate of this world leader in test equipment for mobile telecommunications. In parallel to these upstream entrants, a downstream newcomer was founded in 2000 as End2end focusing on delivery of content packages to the mobile phone operators. The financial foundation was delivered by corporate venture capital from HP, Cisco and Deutsche Bank.

University R&D and education thrived further in the late 1990s, when CPK at AAU was prolonged with a second major research council grant 1998-2002. All over Europe there was a general lack of electronic engineers in the late 1990s. Any region that could offer qualified engineers and an innovative research environment in the wireless field could attract multinational companies – and North Jutland indeed did.

At the end of the decade the GSM developers moved into 'sustaining' solutions, such as GPRS and EDGE, who are able to speed up the data communication performance of GSM solutions. This indicated the early beginning of the next major technological life cycle 3G. In general major players in the industry were attracted by the viability of NorCOM and saw opportunities as using the region as also a development hub for 3G technology. This was the explicit aim by Nokia and Ericsson when they founded 3G development units in North Jutland in 1999.

In 1999 and the first half of 2000 the NorCOM cluster, thus, became clearly visible on the international scene, but dark clouds appeared in the horizon.

6.3 Is UMTS (3G) a major threat?

The emergence of 3G as a new technological life cycle is also expected to create disruption, but the telecommunications turmoil began long before the roll out of 3G networks. The turmoil was caused by the global crisis in the ICT sector that started in 2000, as well as the characteristics of the spectrum auctions in Europe and the emergence of other potentially disruptive wireless technologies. Complexity and convergence are two central issues. The increased complexity of the technology creates disruption because development of UMTS technology requires huge resources; and the convergence between wireless technologies and the fixed net has potentially created even more disrupters.

The complexity and costs of making a mobile phone have increased 20-30 fold in each cycle. The increased complexity from the 1G to 2G required a large R&D effort, which mainly could be managed by the large firms. Multinational companies entered the promising market and other firms formed alliances and cooperated in the early stages of the technology. Development of 3G handsets – let alone the equipment for 3G infrastructure - requires huge R&D resources, which has led the big players to form joint development consortia as well as joint production activities have emerged. Sony and Ericsson founded a joint venture developing 3G handsets; Toshiba and Mitsubishi formed an alliance, as also has been the case for NEC and Matsushita (Panasonic).

In North Jutland the density of firms in the cluster increased during 1999-2000 and at the end of 2000 there was 35-40 firms employing 4,200 persons, which was about half of the total ICT employment in the region. Several firms were doing GSM development and the cluster became significantly denser compared to the peak of the 1G cycle. But compared to the most outstanding regional concentrations or clusters in the ICT sector, such as Silicon Valley, Southern Sweden, Southern Finland, Munich and Cambridge, it was still sparse. The following firms performed R&D in UMTS in 2000: L.M. Ericsson (125 employees), Siemens (350), Maxon (105), Shima (60) and Condat (20). In 2004 the pattern has changed; Maxon is focused on sustaining innovations, while Shima has been closed down. Ericsson has closed its 3G development in North Jutland and Siemens has downsized its R&D staff from 350 to 200 during 2001-2003, but has increased employment again in 2004 to 270. Development of the basic 3G technologies does not appear to take place in the cluster to the same extent (in relative terms), as was the case in the initial GSM phase a decade earlier. The crisis in the telecommunication industry and the increased complexity has enforced many of the players to focus their R&D in larger units and form alliances. However, the high complexity and the demand for an increased number of functionalities of the 3G handsets open new opportunities for specialisation.

The evolution of the mobile communications technology has lead to convergence between different ICT technologies. The mobile devices and the wireless networks are converging with the fixed net. The transmission of speech, text, pictures, video etc. will be in focus. There is an increasing demand for Internet access and data availability everywhere and at all times. Although there is convergence, there are still differences between the mobile Internet and wireless access to the fixed Internet.

One of the major driving forces behind 3G is the 'killer' demand for data access on the move. There seems to be a huge demand for the combination of mobility and communication, which provides access to data and other corporate, commercial and communications services. However, other technologies capable of creating wireless access to the Internet are also available, and they may cause serious disruption to 3G.

The character of the firms in the NorCOM cluster had changed during the latter part of the 2G cycle, basically caused by the (grossly exaggerated) commercial potential seen at the time in the emerging 3G cycle. While the cluster in the transition phase between 1G and 2G still mainly consisted of small and medium sized Danish owned firms, the ownership structure was changed significantly during the second half of the 1990s. Then very fast growth of the GSM market and the perspectives for the coming 3G led to a massive expansion process among all the major large multinationals in the industry. The lack of qualified engineers was so outspoken that the big players virtually 'hovered' every region of Europe, and increasingly so elsewhere, for getting access to and plug into local pools of labour. Ericsson, Nokia, and Siemens set up UMTS development units in the region and Motorola acquired a local Bluetooth development firm. And the big players in the chip set technologies for 2G and 3G also established or acquired development units in the region, such as Texas Instruments, Analog Devices and Siemens' semiconductor 'arm', Infineon.

The outcome for the cluster was that these large players did not go for local collaborative strategies, such as especially the joint GSM effort, DC Development, which became crucial for the vitality of the cluster during the 2G cycle. An initiative was, however, taken among the small players in the region - such as Maxon, Telital, Shima and RTX - to discuss the establishment of precompetitive collaborative ventures in 3G technologies. The lesson from the initial stage of the 2G cycle concerning the potential benefits of collaboration was clearly understood within the cluster, but the companies could not agree on common goals and joint strategies. At a lower level of ambitions NorCOM was formed as a club in 1997 with aim of encouraging knowledge exchange between the firms and the university research community at AAU. From early 2000 – i.e. before the burst of the ICT bubble – NorCOM was strengthened further and transformed to a business association with an elected board and chairman. The common interest in promoting the region as an attractive working environment for engineers was – at that stage -the main motive behind the creation of this more formalised cluster governance structure.

6.4 Is 'beyond 3G' or '4G' a major opportunity?

The massive investments required to build the coming 3G infrastructure paired with deep financial problems of the telecommunications sector in general in the early 2000s has increased the focus on what is coming next in the horizon. 4G have loosely been defined as the complete integration between the wired and the wireless spheres of telecommunications with speeds of data communications of 100-150 Mb/s and in operation in, say, 2010. But there is a certain amount of ambivalence prevalent in the terminology at present. 'Premature' versions of 4G are much closer – in fact already available - consisting of a combination of 2.5G and WLAN technologies.

This potential disrupter to 3G is wireless local area networks, WLAN, a technology that makes short distance high-speed wireless Internet access possible. The access device is mainly a laptop or PDA, but the speed is much higher than 3G and WLAN based solutions seems very attractive even in the short run. The users will have to move to 'hotspots' in the terrain, such as hotels, airports, railway stations, cafés, petrol stations, to be able to reach the Internet. Instead of waiting until the 3G networks have been rolled out (which still may take several years), users may demand a kind of 'surrogate 4G' solution where they will have to move around in the terrain with their laptop PCs or PDAs *and* mobile phones. This kind of solution requires an infrastructure of hotspots in the terrain.

Given that the US is lagging seriously behind the European mobile telecom infrastructure – with severe implications for the US mobile hardware industry - there are very strong incentives in the US market to promote a decentralised WLAN based wireless Internet access approach. The latter should be conceived as a supplement to the ordinary wired telecom infrastructure.[7] On this background there is a rapid process of technological change in this segment of telecommunications going on at present.

WLAN is, opposite to UMTS, using unlicensed spectrum and is highly deregulated. One of the attractions is the possibility to build up small range high-speed wireless networks for low cost and avoiding some of the problems of carriers controlling the 'last mile'. But there are advantages and disadvantages with 3G as well as WLAN solutions. To summon a few, WLAN has higher speed, but is limited to hotspots, while the mobile networks are significantly slower but have much better coverage.

The potential disruptive effects of the WLAN technology vis-à-vis 3G may turn out to be a potential opportunity for the NorCOM cluster and the North Jutland region. Given that development of 3G handsets has been organised by the large telecom multinational companies in pair wise alliances, this is a field very difficult to enter for small firms – at least in the initial phase of the 3G technology life cycle. However, the risk of 3G becoming a major failure cannot be neglected in light of the heavy financial burden the 3G infrastructure is causing for the mobile operators. This is the basic background for the present true uncertainty about the future infrastructure: will 3G or WLAN solutions win? Or will they co-exist as true complements?

[7] A WiFi network starts with a DSL or other high-speed connection to the wired infrastructure. The connection is then linked with an access point allowing wireless access to the Internet by a WLAN card in the computer.

7 What are the opportunities for public policy and collective efforts?

The uncertainties analysed above are of a global character. Although the institutional set-ups differ between the main group of players in Europe, the US and Japan, the present situation can be characterised as very open ended, where quite different outcomes all may have some degree of probability.

The relevance of policy measures and/or coordination between groups of actors at the *national level* may be of most relevance in exactly the very uncertain transition phase between two technological life cycles. The emergence and very fast growth the 1G and 2G mobile telephone industry in initially the Nordic countries followed by several continental European countries may to a considerable extent be attributed to the standardisation initiatives performed by first the Nordic PTTs followed by the EU created ETSI standardisation body.[8] Both efforts were due to visionary telecom regulators and (initially) incumbent monopoly wireless operators.

This path to standardisation is often nicknamed the Nordic or continental European way, as opposed to the US approach, often characterised by a decentralised, if not anarchistic, bottom-up dominated procedure. The latter has been very successfully applied in the case of the Internet, where the process has been dominated by US actors, which has led to a US lead in the equipment industry as well as the emerging e-business industry, as analysed Mowery and Simcoe (2001) and Kenney (2002).[9] The Nordic and European experience, so far at least, have fostered a common understanding of the significance of international coordination efforts ex ante. But the general crisis in the telecom service industry as well as among the equipment vendors from 2001 coupled with the huge rents that some of the major European governments have extracted from the coming 3G service providers in the auctions for 3G licences has caused a significantly higher degree of uncertainty in the transfer from the 2G life cycle to 3G. The outcomes are very difficult to predict, but they are on the other hand deeply dependent on actions taken by the major actors.

The outer poles of the future scenarios may be represented by:

1. 3G systems may dominate the mobile communications networks with WLAN solutions as a complementary service basically controlled by the incumbent mobile carriers.
2. 3G may prove to be a new 'Titanic' in Europe, if not Japan, because the US telecom industry may strike back by not adopting a 3G system at any large scale, but

[8] Surveyed in detail by Gessler (2002).
[9] The lack of US dominance in the wireless industry is analysed by West (2000) and King and West (2002).

exploit the sustaining innovations in 2.5G and combine them with the evolving opportunities offered by more decentralised WLAN experiments.

At the *regional level* there is also room for policy and collective efforts. Given such fundamental uncertainties it may prove relevant for a region involved in these technologies to put forward field experiments with the patterns of telecommunications services seen from a user perspective, including firms, government agencies at all levels as well as private consumers. The aim can be to be prepared for different future trajectories, if not to influence these outright. Even small regions may eventually influence the future development abroad if they may use their potential institutional advantages in terms of organising field experiments that may be visible internationally.

In the case of North Jutland such options may be argued to be present, if the necessary consensus could be established. This region was in 1999 appointed as one of two Danish 'IT Lighthouses', or as the so-called Digital North Denmark (DDN). The national government did allocate approximately €25m and another €50m has been added by local government organisations (municipalities and the North Jutland County) as well as private firms, not restricted to be local.

The IT Lighthouse has been divided into four fields, of which the local IT infrastructure is one. A series of nearly 90 IT projects have been started during 2000-2003. Under the label of North Jutland Netforum, an Aalborg University group is collaborating with the largest IT service firm in the region, KMD, and a small group of municipalities in order to design local optical fibre based network solutions, which will bring 'true broadband' to local government organisations as well as to private firms and consumers – i.e. a Fibre-To-Home vision. Given that how to organise this infrastructure – and not least the 'last mile' problem - still is one of the fundamental barriers for diffusion of IT in general, such experiments are of considerable importance in their own right.

The infrastructure projects of the IT Lighthouse open unique opportunities of creating field experiments with an optical fibre based local infrastructure that *also* contains extensive possibilities for WLAN access – i.e. field experiments which have been labelled 'premature 4G' above. The opportunity for the entire region is that the present growing pessimism, caused by troubles of the GSM developers to get a foothold in the 3G world, could be changed with a vision focusing of combining some of the existing knowledge assets of the region and the country at large.[10]

Taking into account that a considerable competence has been developed in the NorCOM cluster in developing 2G, sustaining innovations and – at least among some of the firms – competence in various parts of 3G technology as well as a significant competence has been

[10] For details of this vision see the Vision North Star report produced by a group of university researchers and managers from the local ICT industry, published in Danish as "Vision Nordstjernen" (NOVI, 2002) .

developed in the other fields e.g. in data transmission over very short distances, there are several important points of departure, which may form an ideal background for coming at the forefront in wireless-to-wired data communications field – i.e. to become involved as a visible player in the early stages of a new technological life cycle.[11] Not necessarily because of major technological breakthroughs, but *through the capability as a region* to combine unique field experiments in the area of wired and wireless telecom convergence with competence among several NorCOM firms to find various footholds in the field in the early stage, and especially to be placed as a 'core player' in the international standardisation efforts through documented user experiments. If the some of the field experiments may prove successful the rumours could spread internationally, create visibility and attract some of the big global players. Echoes of the implementation of this vision may be heard internationally – as happened successfully concerning the capacity of the region to become an international hub (although at a fairly small scale) during the GSM cycle.

The policy challenge is to perform the act of (i) combining efforts at experimenting with the consumption structure - i.e. the telecom infrastructure, (ii) supporting the basic university research in the field of convergence between wireless and wired telecom and (iii) interacting with the local industry as well as the global.

At the cluster level the NorCOM firms realised that again there was a need for collective efforts, given the fundamental uncertainties and the more peripheral role that these companies were approaching in the field of 3G technologies. NorCOM has been quite active in promoting the 'North Star' vision. Aalborg University and the cluster organisation have jointly invested considerable efforts in gaining new ground in the basic R&D background needed to become visible players in the market for solutions for the future ICT infrastructure as well as in the international academic community in this field. A significant outcome has been the establishment of Centre for Teleinfrastructure, CTIF, at AAU in 2004 consisting of more than 100 researchers. Among the foreign contributors to CTIF is the large EU 6th Framework Programme project MAGNET, where AAU is the coordinator, as well as grants from Samsung, Siemens, and Nokia. The establishment of CTIF has been an outcome of a prolonged battle to get support at the national level. The Danish government has been fairly hesitant, but finally gave support through a specific innovation consortium scheme. What probably has been a decisive catalyst for the final establishment of the centre is support and commitment from national and not least local industry and three local foundations, which have allocated money for free basic research. The support and commitment from the local

[11] At the national level that there is a parallel cluster of optical communications equipment firms in the Copenhagen region as well as a strong research competence at the Technical University of Denmark, DTU, in Copenhagen. These two clusters and their knowledge background at the respective two large technical universities are basically complementary, which is an ideal background for national co-operative R&D programmes in this field.

players - firms as well as foundations – has been an outcome of a 'collective spirit' accumulated among the network of regional players over nearly two decades. In this specific case the public policy authorities at the national as well as regional level has been somehow reluctant. The final outcome has more been a result of efforts from local firms, foundations and university paired with significant contributions from large multinational telecom companies.

Policies at the regional level, and in the Danish case at the national level neither, cannot by their very nature *create* competitiveness among local high tech firms, such as those in the NorCOM cluster, which has not been the outcome of any 'grand plan' designed ex ante. However, some of the components behind the emergence of this cluster were definitely the outcome of deliberate policy efforts and long-term struggles, such as the establishment and further consolidation of Aalborg University in 1974 and the science park NOVI in 1989. A 'grand design' of the future cannot be planned for the same reasons. But the probability to find luck may be increased for the prepared mind. Social experimentation with different solutions may be key activities, if indeed the general public is prepared to take risks and accept that taxpayer's money may be lost, but not necessarily wasted, through such a process. These are the 'rules of the game' for policy experiments in an evolutionary setting.

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9 Appendix

Table 2 Companies in the North Jutland wireless communications cluster 2003

Firm	Activity	Employees	Established	Owner
Analog Devices	Wireless systems applications (chipsets for mobile communications)	35	1997	Analog Devices (Boston, US)
BD-Consult	Production & development of specialised mobile comm. equip.	16	1988	Founder (DK)
Bluetags	Bluetooth applications	8	2000	Founder (DK)
CPK	Research center	60	1993	Sponsored by Aalborg University, research councils, EU and industry
CSR - Cambridge Silicon Radio	Design of single-chip radio devices. Applications for Bluetooth.	9	2001	CSR, (Cambridge, UK)
Danphone Communications Systems	Development of land mobile (closed) radio communication systems	21	1990	Eltomatic (DK)
Digianswer	Development of Bluetooth technology	83	1986	Motorola (US) majority. Founder (DK) 1/6
Danish Wireless Design (DWD) A/S	Development of GSM/GPRS equipment	48	1999	Infineon (Munich, GER)
Eurocom Industries (SP Radio)	Production & development of maritime comm. & navigation equipment (GMDSS/VHF) & satcom. Equipment	250	1992 (1948)	SAIT-Radio Holland (BEL-NLD) & STN Atlas (GER)
End2End	Wirefree Application Infrastructure Provider (WAIP).	42	2000	Pre-tel Wireless (London, UK)
ETI	Telecommunication analysis equipment	86	1985	Private owned
Flextronics	Production of mobile terminals and DVD equipment	1700	2000	Flextronics (US)
Force Electronics	Development, marketing and distribution of satellite TV receiver equipment	40	1989	Satellit Kompaniet (Oslo, NO)
Futarque	Development of satellite TV receivers	25	2001	NOVI A/S, Erhvervsinvest Nord (DK)
GateHouse	System software and data protocols for satellite and radio communications	35	1992	Founders and employees
GlobeSat	Production & development of satellite disks	3	1993	Founder (DK)
LH Technologies Denmark ApS (LH Agro)	Development, manufacturing and marketing of electronics for agriculture	80	1992 (1976)	Spraying Systems Co. (Illinois, US)
LH COMLOG A/S	Systems for communication and logistics in the transport business	32	1998	Founder (DK)
Maxon (T-Com)	Development of GSM/GPRS equipment	130	1991 (1987)	Maxon Telecom Co. (KOR)
M-tec	Equipment for GPS based road pricing	20	1998	Founder (DK)
Niros Telecommunications	Development of professional land mobile radio equipment (LMR)	8	1985	Private owned
Nokia	Software for WAP and UMTS	20	1999	Nokia (FIN)
NOVI	Science Park at Aalborg University	43 firms (8 from this table)	1989	Major Danish institutional investors and as minor shareholders regional authorities
On-Air	Software for real-time end-to-end video streaming solutions to cellular and wireless products	11	2000	A/S Dansk Erhvervsinvestering,IPM Management A/S,Erhvervs Invest Nord, HC Projects, Vaekstfonden

Note: Updated 08-04 2003. The firm names in brackets are the former name of the firm.
Source: The homepage of the NorCOM cluster (www.norcom.dk)

Table 2 Companies in the North Jutland communications cluster 2003 (continued.)

Firm	Activity	Employees	Established	Owner
Penell	Bluetooth. GSM-modems.	20	1991	RTX Telecom A/S
RF Micro Devices, Design Centre Denmark	Design of radio frequency chips	7	2000	RF Micro Devices, North Carolina (US)
Rohde & Schwarz Technology Centre A/S	Development of test equipment for UMTS and Bluetooth	40	1993	Rohde & Schwarz GmbH & Co. KG (Munich, GER)
RTX Telecom A/S	Development of DECT, Bluetooth, CDMA and UMTS equipment	210	1993	Founders (DK) 46%, National Semiconductors (US)
S-Card	Production of chip cards for telecom (e.g. SIM cards)	20	1991	Founder (DK)
Siemens Mobile Phones A/S	Development of GSM/GPRS and UMTS equipment	225	2000	Siemens (GER)
Simrad (Shipmate)	Production & development of maritime navigation and communication equip. (GPS/VHF)	120	1994 (1977)	Simrad (NOR)
Sonofon	Mobile communications. Service provider	1000	1991	Bell South (USA) 47,5% and Telenor (NOR) 52,5%
SpaceCom	Production & development of satellite communications equipment	16	1989	Founder (DK)
STMicroelectronics	Development of protocol software for GSM/GPRS and UMTS chips	10	2001	STMicroelectronics (FRA, ITA)
TDC	Service provider. Mobile and fixed net	45 (Total TDC employment 17,000)	1990	Ameritech (US)
Texas Instruments	Development of GSM and UMTS equipment	105	1996	Texas Instruments (US)
TTPCom	Software for GSM/GPRS and UMTS	18	2001	TTPCom (Cambridge, UK)
WirTek	Wireless software technologies	15	2001	Founders
Aalborg University (AAU)	Technical, social science & humanities faculties	13,000 students and 1,700 staff	1974	Government

Note: Updated 08-04 2003. The firm names in brackets are the former name of the firm.
Source: The homepage of the NorCOM cluster (www.norcom.dk)

Part Three

The Digital North Denmark

Chapter 9

Incremental Versus Radical Change – the Case of the Digital North Denmark Programme

Incremental Versus Radical Change – The case of the Digital North Denmark Programme[1]

1 Introduction

The Digital North Denmark (DDN) was an IT programme running from 2000 to 2003 in the North Jutland County in Denmark with national government support of € 23 million. The Danish government initiated the programme with the aim of further strengthening regions with an already proven ICT capability (Dybkjær and Lindegaard, 1999, p.96-100). The declared approach was to build on the existing competencies in industry as well as at universities. The national government chose two regions – Ørestaden, a new concentration of knowledge-based institutions near Copenhagen Airport, and North Jutland. The Copenhagen programme was basically concentrated on, literally, construction of a new IT University, a new neighbouring science park and a new media centre for the public broadcaster, Danmarks Radio. The North Denmark programme was, on the other hand, organised as a large-scale experiment based on project-offers within four themes. The participants - meant to be project consortia of ideally private firms, public or private organisations as well as regional and municipal government bodies - could get a maximum national government support of one third of the total project sum.

The point of departure of the chapter is the theories of regional innovation policy based on localised change. Innovation policy is public action aimed to influence technical change and other kinds of innovation (Edquist, 2001). A policy programme is 'localised' if it is targeted to create incremental change in a region. It aims to reproduce and strengthen existing structures, but does not necessarily imply following deterministic trajectories, since unpredictable changes may occur and new variety is mainly directed and channelled by the existing environment (Dosi et al., 1988; Boschma, 2004). The challenge is to support the (positive) development path of the regional production system, while avoiding technological and institutional lock-in. It is not sufficient only to learn, but also important to unlearn at the firm as well as at the policymaker level (Lorenzen, 2001).

The North Jutland region was chosen as 'IT-lighthouse' due to several reasons. It was considered to have a great ICT potential; it was well known for network cooperation between firms, university, science park and public organisations; it had experienced a

[1] Based on Pedersen and Dalum (2004). See also Pedersen and Dalum (2004) and Dalum and Pedersen(2004). This chapter somehow overlaps with Chapter 2 and 4.

process of structural change from being a crisis area in the 1980s to an ICT growth area in the 1990s, and it was home of a successful international visible wireless communication cluster, NorCOM. The local university was considered to have been an important actor in the transformation process of the region and was intended to become a key player in building the 'IT lighthouse'. The region had since the 1980s been supported by several EU programmes and the county administration had proved to be quite experienced in organising support programmes based on project offers. The proven capability of cooperation between private and public organisations, the wireless cluster firms, and the university were considered as key features. The policy programme, however, faced some tension in the formulation of a goal: Could the successful cluster be used to develop other parts of the ICT sector, or should the programme be used to promote development broadly in the region?

During the implementation of the programme this profile was significantly changed. The wireless cluster firms and the university were largely missing as participants and some of the large projects revealed a lack of cooperation between firms and public organisations. Dramatic external events also influenced the results. DDN was presented in 1999, when the ICT sector was booming, but implemented from late 2000, when the ICT crisis had begun.

The purpose of this chapter is to analyse how the shift from incremental to radical change has affected the programme and whether and how the programme may have long-term consequences for the development perspectives for the regional ICT sector.

This chapter investigates how the profile of the programme changed from focusing on localised change targeting the producers of ICT in the region, to be initiated as a radical change project focusing on the users. In addition to the more historical accounts for DDN the actual implementation will also be analysed. The analyses of development perspectives for the regional ICT sector will focus on the participation of the university and the cluster, and three cases of large projects.

The chapter contains in Section 2, a discussion of our theoretical approach. Section 3 presents an analysis of the structural change in the 1990s with an emphasis on the ICT sector. Section 4 analyses the history of DDN and the shaping of its final profile, while Section 5 deals with the actual implementation. DDN's impact on the development perspectives of the ICT sector are presented in Section 6 with a study of the large projects on Digital TV, e-business and IT infrastructure. Finally, the conclusions are presented in the last section.

2 Incremental versus radical change in regional innovation policy

A variety of regional polices have in recent years been used as tools for development of peripheral regions in Europe. The role of regional policy and its effectiveness has been debated in the literature (see e.g. Cooke, 2001; Lorenzen, 2001). One of the main issues is

whether it is at all possible to create more fundamental change in the development trajectory of a region through public policy or whether the only realistic aim for policies is to improve existing structures and avoid lock-in, as stated by Edquist (1999):

> *"..'lock-in' failures imply a role for policy in adapting to shifts in new technologies and demand. This means that a key issue is the choice between supporting existing systems (with their historically accumulated learning and knowledge bases) and supporting the development of radically new technologies and supporting systems" (Edquist, 1999, p.17)*

Innovation is a complex phenomenon, embracing products, processes and services. It includes technological as well as organisational innovations (Edquist, 1999). It is also a pervasive phenomenon, which penetrates all aspects of economic life, and is a result of on-going processes of learning, searching and exploring (Lundvall, 1992). Thus innovation is a powerful explanatory factor behind differences in performance among regions. Regions with a successful innovative activity prosper while less innovative regions are lagging behind. Therefore, regions that want to catch-up must increase their innovative activity (Fagerberg, 2005).

Freeman and Soete (1997) classifies innovations according to how radical they are compared to the existing technology by the terms incremental and radical. This approach can also be applied to the change in industry structure. These are then classified according to how radical they are compared to the current structure.

Radical innovation is major change that represents a new technological paradigm. Radical change implies that the codes developed to communicate a cumulatively changing technology will become inadequate (Rogers, 1995). The producers that follow a given trajectory will have problems understanding and evaluating the potentials of the new paradigm (Lundvall, 1992, p. 58). *Radical* change creates a high degree of uncertainty in organisations and industry. It also sweeps away significant parts of previous investments in technical skills and knowledge, designs, production techniques, plants and equipment (Utterback, 1994, p. 200). The change is not necessarily delimited to the supply side. It may come from a change at the demand side and in the organisational or institutional structure. Incremental innovation, on the other hand, is gradual and cumulative. Incremental innovations are only small changes in technology, organisations, processes, products or services. Subsequently *incremental* change refers to continuous improvements and changes in the current industry structure.

Boschma (2004) distinguishes between two ideal types of aims for regional policy: 'localised' versus 'structural' change. *Localised* change is following the development trajectory based on the existing structure in the region. The change is location-specific and determined by the past, which define the limits. It is incremental and cumulative and

reproduces and strengthens existing structures. The (positive) cumulative change and path dependence may, however, result in a lock-in, which at a later stage may produce negative effects. When a region is facing technological and institutional lock-in, it becomes vulnerable to external changes in the economy.

Each region has according to Maskell et al. (1998) a set of capabilities that consist of the institutional background, the structure of industry, natural resources, knowledge and skills. These have been developed through a historical interactive process. Further evolution relies on the creation, utilisation and reproduction of knowledge. Public and private organisations in the region are interconnected and interact. The organisations affect the regions through localisation and through creation and demand of skills and knowledge. But the organisations are also outcomes of the existing structure and institutions in the region (Storper, 1997). New variety is thus mainly directed and channelled by the existing environment. Localised change is cumulative and path dependent, but not deterministic and predictable, and bound to end in a lock-in situation (Boschma, 2004).

Structural change is more dramatic. It is based on technological, organisational and institutional transformation and relies on creative destruction (Boschma, 2004). It implies a shift of the regional development trajectory. A lot of uncertainty is related to the structural change. The outcome is less predictable. The element of chance is high, since small historical events may be reinforced by agglomeration economics and spinoffs. Such processes are well known from the studies of regional industrial clusters (Krugman, 1991; Porter, 1998; Klepper, 2001). But the speed of change is not necessarily high (Boschma, 2004). Structural change is not immediate, but new trajectories emerge and develop gradually. Structural change points at transformation of the industrial structure of a region. But new trajectories develop gradually or incrementally in most cases. It could be expected that many incremental changes may accumulate a structural change over time. However, the more radical the change is, the greater the possibility that it may also require improvements of infrastructure, and organisational and social changes to succeed.

The goal of policy programmes can target 'long-run' structural change or focus on localised change. This distinction is, however, often blurred in reality – i.e. hidden in the rhetoric of the programme declarations. The notions of incremental versus radical innovation are easier to distinguish and to make operational. A policy programme based on experiments can exemplify this. When initiating a programme, it is possible for the policy makers to outline a goal and set a frame for the experiments. If it is based on project offers the outcome is partly defined by the applicants. The policy makers can set some requirements in the tender material and carry out selection among the applications. This makes the potential outcome of the programme uncertain. The individual projects also have a higher degree of uncertainty, and some are likely to fail. Variety is created in the regional system since the organisations are involved in different search strategies. A localised policy

programme based on firm-level experimenting would contain some projects focused on incremental and others on radical change. The latter are novel and could introduce new technologies or consumption patterns etc. Some of these could change the development trajectory for parts of the region and, over time, lead to a structural change. The radical and structural change are sometimes argued to be the most important for changes in the industry structure, while others argue that the cumulative impact of incremental changes are just as great and therefore the continuous incremental changes leads to structural change over time.

If we look at policies for structural change there is a difference between national and regional policies. At the national level polices are associated with creating new industries (becoming first mover) or catching up, and usually not directed towards specific regions. Public procurement appears to have been the most successful in this respect (Lundvall, 1992; Edquist, 1997; Edquist, 2001). This instrument can also be effective at regional level, where a boost from public demand or a clear expression of will/support can reduce uncertainty related to innovation. The effect is of course not known ex ante, since the evolution is still uncertain. But as argued by e.g. Mowery and Nelson (1999), there have been successes as well as failures in public policies targeting radical changes in industry structure. Lundvall and Borrás (2005) points at some limits for the public sector competence in technology policy. They argue that technology policy might be pursued where the public sector operates as a major or lead user, while it should be more cautious when it comes to developing specific new technologies for the market.

The role public demand plays an important part in the evolution of industries. It can lead the producers on a development trajectory that could prove to be beneficial and create growth and innovation, but also lure the producers into unfavourable position. One of the prerequisites is close interaction between users and producers. A lack of interaction or less competent users can lead to unsatisfactory innovations, while advanced and competent users can lead to innovations and a competitive advantage. Advanced users tend to demand higher quality goods and thereby forcing the producers to innovate and upgrade (Lundvall, 1985; Mowery and Nelson, 1999).

There is some tension between policy support of diversity and scale in an innovation system. The more open an innovation system is for impulses from outside, the less chance to miss promising new development paths that emerge outside. Thus it is important for policy makers to keep the innovation system open and to avoid lock-in in the innovation activities due to path-dependency (Fagerberg, 2005). In addition Lundvall and Borrás (2005) argues that diversity and competition are two key elements for successful innovation systems. A general definition of the innovation system includes all important economic, social, political, organisational, institutional, and other factors that influence the development, diffusion, and development of innovations (Edquist, 2005). This definition applies on national as well as

regional level. A more specific set of dimensions the regional innovation system is given by Howells (1999, p. 72), who argues that three dimensions reinforce its importance:

- The regional governance structure, both in relation to its administrative set-up and in terms of institutional arrangements
- The long-term evolution and development of regional industry specialisation
- Additional core/periphery differences in industrial structure and innovative performance

However, the regional innovation system is not independent, but a part of the national innovation system. The regional innovation systems in a country differs, but are still affected by changes at national level. Likewise, the various industries are also a part of sectoral innovation systems that cut across the regional and national borders (Howells, 1999). The regional innovation system is thus a part of a interplaying multi layer system, but as the geographical scale becomes less, the institutional and organisational context becomes more specific. Howells (1999, p. 82) identifies five core elements in the micro-foundations of the regional innovation system: Localised communication patterns relating to the innovation process both at an individual, firm, and group level; localised search and scanning procedures; localised invention and learning patterns; localised knowledge sharing; localised knowledge performance.

Innovation policy must take point of departure in the existing innovation system. The linkages and quality of interaction between the actors in the innovation system are important. Lundvall (1999) claims that learning is a cumulative process and in order to improve the innovative activity it is necessary to take point of departure in the existing knowledgebase and given institutional context. Likewise Lundvall and Borrás (2005) argues that there is no way to define an effective innovation policy without analysing the innovation system compared to other. This analysis should include how it produces and reproduces knowledge and competences. The policies depend on size and stage of development[2]. Thus the analytical basis of the innovation policy is a combination of what is good practice and what are the characteristics of the innovation system (Lundvall and Borrás, 2005). Therefore the innovation policy is often incremental since policy makers are more likely to take point of departure in existing development trajectories. Regional innovation policies are sensitive to the regional endowment, trajectories and context. Localised polices should take regional variety as a point of departure, and be based on a bottom-up strategy attuned to the regions needs and resources (Maskell et al., 1998; Cooke, 2001; Boschma, 2004).

[2] Therefore they argue that in small countries the structures and institutions that affect absorption and efficient use of technology are more important than promoting development of new technologies at the front (Lundvall and Borrás, 2005, p. 626) Lundvall (1999) argues that investments in technology that neglects user competences, social needs, and the need for organisational renewal can do more harm than good in a learning economy. He states that technology is an instrument and not a goal in itself (Lundvall, 1999, p. 20).

The analysis of the innovation system constitutes the basis for the innovation policy, but it is also necessary to mobilise the actors in the system to participate:

> *"Developing an interaction and dialogue on policy design between government authorities on the one hand and the business community, trade unions and knowledge institutions on the other is a necessary condition for develop socially relevant and clear policy programs that can be implemented successfully" (Lundvall and Borrás, 2005, p. 614)*

In summary, the theories state that there is a difference between regional policies targeting incremental change, and radical change. The incremental change policy aims at strengthening the existing structure, while the radical change policy aims at changing this structure. However, from a regional policy perspective it is necessary to take point of departure in the regions needs and competences, and to mobilise users and producers. The mobilisation is important to create user-producer interaction. There is no simple policy solution or recommendation, but initiating incremental change requires mobilisation of the targeted actors, while radical change involves more risk taking and requires willingness to change, but still implies mobilisation of regional actors.

3 The North Jutland region – from lagging behind to catching up

The North Jutland County is located at the northern tip of the peninsula of Jutland, the part of Denmark connected to the European continent. The population is around half a million people, slightly less than one tenth of the Danish total. Total employment was 246,500 persons in 1999, of which the private sector share was 163,500. The largest city is Aalborg, the fourth largest in Denmark, with 163,000 inhabitants. The region has traditionally been characterised as peripheral and lagging behind with an unemployment rate among the highest in Denmark. The industry structure has been dominated by more traditional industries, such as agriculture and food processing, fishery, tourism, shipyards, textiles, tobacco and cement. However, during the late 1980s and the 1990s the region has experienced a process of structural change with jobs moving from the traditional sectors to the service and the high-tech sectors. Although the firms in North Jutland are still specialised in the primary sector (i.e. an above national average employment share) and the metal product industry, they are also specialised in especially mechanical engineering as well as in electronics. The latter has been among the features, which indicates that the region has caught up. The industry structure is at present in line with the average Danish 'non-metropolitan' counties. The two 'metropolitan' regions are the greater Copenhagen area and Aarhus. The region has undergone a structural change, but still has structural problems, and has an above average unemployment rate and a below average income compared to the Danish average (Dalum et al., 2002, p.9-10).

Aalborg University (AAU) plays an important role in North Jutland. It was established in 1974 and has today 13,000 students and 1,700 employees in Humanities, Engineering, Natural Sciences and Social Sciences. AAU was until 2000 the one of only two universities in Denmark that offered the MSc in engineering and in the 1990s approximately fifty percent of the Danish MSc's in engineering graduated from AAU. From its establishment AAU has been very active in cooperation with private firms and it participates in many networks and joint research projects (Dahl, 2003). Almost 40% of the total number of graduates from the university got their first job in the region. (Nielsen et al., 2002, p. 81).

From 1986 the region has been supported with several EU Programmes due to the crisis in North Jutland especially in fishing, shipbuilding from the last half of the 1980s and the structural problems with a high unemployment rate[3]. Especially the Objective 2 funds for Industrial Reconversion have been used to promote the structural change in the region[4]. In the period from 1986 to 1999 the region was supported with € 210 million from the EU, which generated additionally € 247 million in support from Danish public organisations and € 302 million from private firms. In comparison the DDN programme was financed by € 23 million in public support and the current Objective 2 EU programme running from 2000 to 2006 has received € 246 million in public support. The evaluation reports of the EU programmes indicate that the overall effect has been positive for the region, but due to their fragmented nature, the direct effect in terms of employment and indirect effects e.g. creation of networks is difficult to measure[5]. The direct effect of DDN is expected to be smaller than Objective 2 due to the difference in size. The North Jutland County administration has been the administrator for the EU programmes, i.e. organising the project offers, putting together the financing, attracting external partners, and other related tasks. Through this work the County Administration created competencies and established a wide network to the different participating actors, which were useful in the DDN programme.

3.1 The ICT sector in North Jutland before the DDN programme

The ICT sector in North Jutland had experienced high growth during the 1990s. Employment grew with 63.5% from 1992 to 1999 compared with a growth of 33.7% at the national level. Total ICT employment[6] was 8,300 in 1999, but the region has not been

[3] From 1980 to 1992 the average unemployment rate in North Jutland was 2.5-3 percentage points higher than the national average (Ministry of Industry, 1994).

[4] The programmes have been quite broad in their objects, e.g. the Objective 2 programme for Industrial Reconversion has supported projects with physical investments in private companies, knowledge building projects in private companies, knowledge building projects with soft framework conditions, infrastructure, education in firms and education with soft framework conditions.

[5] Http://www.nja.dk/serviceomraader/erhvervogarbejdsmarked/euprogrammer/resultaterafnordjyskeeuprogrammer.htm

[6] The ICT sector is defined as the following industrial classification codes NACE/DB(93): 3001, 3002, 3130, 3210, 3220, 3230, 331020, 331030, 331090, 3320, 3300, 514320, 516410, 516520, 6420, 713310, 72

specialised in ICT employment. The specialisation indicator increased from 0.7 to 0.8 during the period. The region has been catching up from a rather low level.

The structure of the ICT sector in North Jutland is different from the overall Danish structure, since 45% of the employment was in manufacturing compared to 25% for Denmark. Specialisation in ICT manufacturing increased during the 1990s from 1.05 to 1.5 concentrated on two segments, telecommunications equipment and electronic components. Table 1 reveals that especially employment growth in telecom hardware has been outstanding with an increase from a three to nearly six times larger employment share compared to the national average. Denmark was internationally specialised in exports in manufacturing of telecommunication equipment in 1998.

Table 1 The structure of the ICT sector in North Jutland

	North Jutland						Denmark		
	Specialisation		Employ- ment	Share of ICT	Development 1992-99	Change	Share of ICT	Development 1992-99	Export specialisation
	1992	1999	(persons)	(%)	(1992=100)	(persons)	(%)	(1992=100)	(1998)
Manufacturing	**1.05**	**1.51**	3,731	44.9	**150.3**	1,248	25.3	**104.3**	0.52
Office machinery	**4.33**	**6.81**	288	3.5	**116.1**	40	0.4	73.7	0.15
Computers	0.70	0.36	52	0.6	48.1	-56	1.5	94.4	0.41
Electronic components and wire	**1.55**	**1.14**	511	6.2	81.2	-118	4.6	**110.2**	0.21
Telecommunications equipment	**3.13**	**5.92**	1,936	23.3	**207.3**	1,002	3.4	**109.5**	**1.14**
Consumer electronics	0.27	0.89	467	5.6	**392.4**	348	5.4	**120.1**	0.78
Electro medical	0.48	0.42	193	2.3	84.3	-36	4.7	95.5	**1.70**
Instruments etc.	0.41	0.55	284	3.4	**131.5**	68	5.3	98.1	0.94
Services	0.53	0.63	4,573	55.1	**176.2**	1,978	74.7	**147.7**	-
Wholesale trade	0.33	0.35	846	10.2	**137.6**	231	24.5	**127.9**	-
Telecommunications	0.62	0.99	1,777	21.4	**200.8**	892	18.4	**125.2**	-
IT services & software	0.67	0.63	1,950	23.5	**178.1**	855	31.9	**190.1**	-
Total ICT sector	0.70	0.85	8,304	100	**163.5**	3,226	100	**133.7**	-

Note: A positive change in employment or specialisation above 1 is marked in bold. Instruments etc. are instruments and equipment for detecting, measuring, checking and controlling physical phenomena or processes. The export specialisation is based on trade by commodities statistics for OECD (23).
Source: Based on data from Statistics Denmark and OECD (2000) *International Trade by Commodities Statistics*, No. 1.

The region has not been specialised in ICT services where specialisation only increased from approximately 0.5 to 0.6 in the period from 1992 to 1999. The employment in ICT services grew 76% in the period compared with 48% at national level, but this segment is still rather weak in North Jutland. The ICT service consists of three parts: Wholesale, Telecommunication service, and IT service & software. The latter is the largest segment in Denmark and North Jutland. It contains most of the new IT firms of the 1990s, but despite of a high employment growth the specialisation in North Jutland declined from 0.67 to 0.63. However, in telecom services the region was at the national average, which otherwise was concentrated in the regions of Aarhus and the Copenhagen area (Dalum et al., 2002).

A special feature of the ICT sector in North Jutland is the presence of a wireless communication cluster mainly consisting of firms working with mobile communication equipment and equipment for maritime communication and navigation. In 1999 the cluster consisted of 30 firms, which employed more than 40% of the total number of employees in the ICT sector and a large share of these were related to R&D activities (for a detailed analyses of the development of the cluster see Dalum et al., 2002; Dahl et al., 2003). The cluster had grown out of a few maritime communication firms from the late 1970s and had experienced high growth in the 1990s. It attracted many subsidiaries of large multinational companies. The cluster was thus an important part of the entire ICT sector and it also attracted a lot of attention at national level due to its success and international profile during the last half of 1990s.

3.2 DDN, innovation system, innovation policy, and the ICT sector

The basis for innovation policy is analysis of the innovation system with point of departure in the existing knowledgebase, institutional context, regional industry specialisation, and how the system produces and reproduces knowledge and competences. Thus deliberate innovation policy is often focused on incremental change by following the existing trajectories.

The terms radical and incremental change are classified according to how radical they are compared to the current structure. Therefore a programme targeted at the ICT sector in North Jutland would be incremental if it focused on cumulative improvement of the existing structure including the cluster. Radical change implies a shift of the regional development trajectory. To promote this the focus could be on the more dispersed, but promising activities in the ICT sector The radical and incremental change could both be supported by the university since it provides a supply of qualified labour and have top-level research groups in knowledge bases that are not or only a little present in the existing industrial structure. The radical change could then stem from the university through spinoffs or joint projects.

The DDN programme was to be an experiment, based on project-offers, and not necessarily include local ICT firms (due to competition rules). These three features are important, since the first implies a higher degree of failure, the second increases the uncertainty profile and outcome, and the third lessens the effect on the regional ICT sector, unless the non-local firm are attracted and opens an affiliate.

4 The history of DDN and the shaping of the profile

The early formation of DDN programme prior to the first project offer in June 2000 can be divided into the invitation from the government and the response from the region. The concept behind DDN was changed considerably within a period of six months.

4.1 Why North Denmark? The minister's invitation and The Digital Denmark report

At the 25 year anniversary of Aalborg University in September 1999 the Minister of Research and Information Technology invited the region of North Jutland to build an 'IT Lighthouse'. The programme was a part of the government's ICT strategy on 'The Digital Denmark'.

The strategy was further described in a report in November 1999 from the ministry "*The Digital Denmark – conversion to the network society*" on how Denmark should evolve from an information society into a network society (Dybkjær and Lindegaard, 1999). One of the policy measures to achieve the goal was the creation of two IT lighthouses: one in Copenhagen and one in North Jutland. While the programme in Copenhagen was focusing on creating infrastructure the DDN programme was to be an experiment (Dybkjær and Lindegaard, 1999, p. 90-93). The rhetoric was very ambitious about creating international visible IT lighthouses that should be a 'cornerstone' of the network society, and 'light up and show the way' for the rest of Denmark. They were inspired by international ICT growth areas, and believed that focused public policy had played an important role in the development of these. The purpose of DDN was to strengthen and develop the strong growth in the ICT sector from the 1990s further.

> *"An IT lighthouse should be established in Northern Jutland on the basis of the very positive co-operation which has already been established between enterprises, Aalborg University, Northern Jutland's Science Park (Nordjyllands Videnpark – NOVI) and central political decision makers in the area." (Dybkjær and Lindegaard, 1999, p.90)*

The government wanted to build an IT lighthouse, but did not define directly what it was. A clear description of an IT lighthouse cannot be found in the background report for the policy programme. Although the rhetoric in the report makes parallels to Silicon Valley, Kista and Oulu it would be wrong to conclude that the intention was to create radical change by building a new Danish Silicon Valley. But it seems clear that the purpose was to support incremental change of the existing strengths in the ICT sector, i.e. the wireless communications cluster. The goal of incremental change is also supported by the argument of building on the existing network cooperation between public and private organisations.

> *"The purpose of a large-scale experiment in Northern Jutland, an IT lighthouse, is to promote development in an area which has already shown that it contains great IT potential, with private enterprises, Aalborg University and NOVI as driving forces. The large-scale experiment should promote IT development and IT use and, via concrete projects, kick-start life into the network society. The concrete projects should reinforce the electronics infrastructure, competence development, e-commerce, efficiency and service in the public sector, the democratic dialogue and opportunities for the individual citizen to exploit the potential of the network society." (Dybkjær and Lindegaard, 1999, p.91)*

When giving the invitation in September 1999 the Minister stressed that it was required that the public organisations, the university and private firms cooperated on designing a programme and building the IT Lighthouse.

> *"In a large-scale experiment, Northern Jutland could be Denmark's first IT lighthouse via the activities which have already been commenced and via a number of prioritised initiatives which should be formulated in partnership between the Government, decision-makers in Northern Jutland and the private enterprises in the area" (Dybkjær and Lindegaard, 1999, p.91)*

Given that the proposal was presented at the university anniversary it was a common belief at least among the university employees that the programme would get a strong research profile based on joint research projects with private firms. The fear was that the DDN programme would be used to support many fragmented small projects like a traditional development programme for less favoured regions.

4.2 The response from the region

In September 1999 it was believed that a quick response was needed to show that North Jutland was able to fulfil the task. The county administration established a regional interim board consisting of the county mayor, the mayor of the municipality of Aalborg, the mayor of the municipality of Hjørring, the rector of Aalborg University and representatives from the Danish Trade Union Congress, the Confederation of Danish Industries and the Danish Employers' Confederation.

After six weeks the result was a report on why North Jutland should be an ICT lighthouse, a vision of how it should be build and a roadmap for the further work. The vision for North Jutland consisted of ten points (The North Jutland County, 1999, p.36-38, www.detdigitalenordjylland.dk):

- *North Jutland should become a learning region*

- *North Jutland should have a strong and coherent educational system that is in the front in Denmark*
- *North Jutland should have high level research within IT*
- *North Jutland should have education and continuing education for the future worker*
- *North Jutland should have a strong service industry*
- *North Jutland should have leading development and sales firms within IT*
- *In North Jutland all citizens should have direct or indirect access to a computer and the Internet*
- *In North Jutland use of e-business and e-services should be widespread among the citizens*
- *North Jutland should provide good framework conditions for private firms.*
- *North Jutland should have a public sector that is the most open in Denmark with good service accessible 24 hours a day*

Almost every 'political correct' goal was included. The bullet points did not express any clear selection or choice. The list included both objects of radical and incremental change, and even some points that already were fulfilled (e.g. leading development and sales firms within IT). However, a new focus on improving the efficiency and quality of the public sector had been included. The effectiveness in the private sector was also stressed.

By fulfilling the 10 points it was believed that the productivity in the private and public sector would increase. The rationale was that the technological development would not result in rationalisation and increase in productivity in itself, without a joint effort with education and organisational development. IT was not considered a goal, but as a mean to build the lighthouse. To create positive synergies it was stated that the forthcoming experiments should be large and comprehensive in order to 'make a difference'. The selected experiments should be able to reach and be important for a large proportion of the citizens of North Jutland (The North Jutland County, 1999, p.42).

It was specified that an important part of the vision was North Jutland as a learning region. There was, however, no clear definition of this concept, although the keywords were ability and will among citizens, firms and other organisations to change, renew, innovate, learn, cooperate and to build new capabilities, networks and supporting institutions (The North Jutland County, 1999)[7]. These are the principles underlying structural change, but the means were of an incremental nature. The profile of DDN had thus begun to change from having a focus on research, industrial development of the ICT sector and networks between

[7] Dybkjær and Lindegaard (1999, 2000) do not use the term learning region.

university and firms, to become broadly user-orientated with a wider purpose of IT education, application and diffusion.

The DDN organisation was to consist of a board of directors with the responsibility to select the themes of the programme in cooperation with the ministry. It was also to appoint[8]:

- Project groups connected to each theme
- A board of executives with the responsibility of the practical implementation
- Project groups with the responsibility to select the winning projects
- A secretariat with responsibility of all the practical work.

The interim board of directors was almost identical in the new DDN organisation. The editors of the report[9] were to be a part of the board of executives (The North Jutland County, 1999, p.48). The board of directors included a wide selection of interest groups to secure a broad acceptance in the region, especially among the municipalities. The selection of specific actors in the two boards strongly influenced the DDN profile.

The wireless communications cluster and the university had almost not been included in the plans for DDN[10], but the building of the lighthouse could still offer opportunities for these actors.

5 Building the lighthouse

The discussions of the DDN programme became intensified after the region's response in November 1999. In the report it was stated that the final profile still could be changed. As a result various ideas of the implementation of the programme flourished. The report on DDN had described a roadmap for the building of the lighthouse. The board of directors was to decide upon four themes and the profile and then appoint four project groups to select the projects. DDN was to be organised as project offers within the four themes.

Three different profiles were competing for dominance in the large-scale experiment (see also Bruun, 2001):

1. The industry innovation orientated profile that stressed the importance of industrial development through innovation and cooperation with the university.
2. The research-orientated profile that had a point of departure in the university research projects with industry

[8] In addition they wanted to nominate an independent participatory research group consisting of university researchers to carry out research in relation to the DDN. The present authors are members of this group.
[9] The editors were the clerk to the county council and the university director.
[10] The phrases of 'development of the ICT sector' and networks with the university' had been toned down in the report.

3. The user-orientated that focused on extensive use of IT.

5.1 The planning phase and the final programme

The board of directors was officially appointed in February 2000. Their first task was to specify the four themes further and appoint the four projects groups. But this work had already begun in advance. During December and January the themes were specified and enrolment of actors to the project groups and mobilisation of actors to create ideas and projects had begun.

The director of the Lighthouse Secretariat joined the board after her appointment in the spring 2000. The board thus included a wide selection of groups to secure a broad acceptance of the programme and to mobilise as many actors as possible. The selection was, however, dominated by political and organisational interests, and the interest of the ICT sector was given low priority.

The profile was, however, not definitely decided upon in mid-January. The heads of the county and the university administrations, both members of the board of executives expressed opposing views publicly. They admitted that the 'fight' could be whether the money should be used broadly for IT experiments for the population of North Jutland or more narrowly in targeted research. The head of the university administration argued that the funds should be used to increase the present high level of the ICT sector while the head of the county administration argued that the funds should only be invested in projects with a (short-run) return[11].

In January 2000 the four themes were selected[12]:

- IT infrastructure
- IT industrial development
- Qualification and Education
- Digital Administration

A project group was attached to each theme, which was to participate in the selection of winning projects from the forthcoming project offers. Their first task was to create a project strategy and frame. Based on these each group should select the best projects, and the board of directors would afterwards appoint the winners. A professor from the university was selected as chairman for the first theme. A managing director from a private firm was selected for group two, a chief executive from a municipality for theme three and a director

[11] Thorhauge, Claus "Nordjysk IT fyrtårn leder efter ideer" Computerworld 14 January 2000

[12] The names of the themes are a bit different in January, but they are covering the same areas: Infrastructure, E-business and technological framework conditions, IT in the public sector, and Qualification and Education.

from the county administration became chairman for theme four. The four groups consisted of up to nine members and had a strong influence of public organisations. The groups worked from April to June on the description of the four themes in the project offers.

In February 2000 the Ministry of Research and Information Technology approved the DDN programme. Although no project offers had been held, the work continued on the sidelines. In mid-February several forthcoming DDN projects appeared in the media[13]. The head of the county administration argued e.g. for a project that included a PC for all the public sector employees in North Jutland. This idea was, however, never turned into a specified proposal.

The DDN secretariat was also established in spring 2000 and a head of the secretariat was hired, with a background in Humanistic Informatics from the Aalborg municipality administration[14]. She represented the broad user-orientated profile of DDN that became dominant. The appointment also clearly indicated the direction of DDN. The profile had been changed from the original idea described in the Dybkjær and Lindegaard (1999) report and in the minister's speech in September 1999. The profile was not specified to build on the existing industrial and research strength in region, but to broaden the use of IT to lift the entire region and create a learning region. The project was not to focus on a single sector but all sectors and not concentrate on a single problem or area, but 'cover it all' (The Lighthouse Secretariat, 2000, p. 5).

The allocation of funds to the four themes in the first round of project offers assist the user-orientated profile[15]:

- IT infrastructure received € 2 million
- IT industrial development € 2 million
- Qualification and Education € 4 million
- Digital Administration € 2.7 million.

5.2 How the university was put on the sideline and the missing participation of the wireless cluster firms

In spring 2000 the Ministry of Finance decided that the national government must not pay more than a third of the total project sum. This meant special rules for public financed

[13] Special supplement to Computerworld 28 February 2000

[14] The core themes in the human informatics education are that of building competencies among the users and the construction of user-friendly systems (Bruun, 2001).

[15] Of the total project sum on € 23 million were € 21 million allocated to projects, whereas the rest were to cover administration costs, participatory research and evaluation. Approximately 50% of the funds were allocated to the first project offer.

organisations and organisations that wanted to use EU Objective 2 funds for the DDN projects. As a result the university could not use regular funds or let the employees participate as a part of the two-thirds of the funding that had to be self provided. To participate the university had to use external funding for the projects or let the potential project partners pay the total funding. It was believed by many university people that this put an end to university participation in DDN projects and clearly influenced its profile.

The funding rules did stop many project ideas, but the university still managed to become partner in some projects through special arrangements. But DDN did not become as research-orientated as the university believed it should have been. Analysis of the timing of events and processes, however, indicate that the user-orientated profile of DDN already was determined, and that the university was put on the sideline before the ministry decided on the rules for funding. Researchers from AAU participated in 15 % of the DDN projects (The Lighthouse Secretariat, 2003). In terms of university research groups the participation had moved away from the technical disciplines to the more 'soft' research fields.

The missing participation of the wireless communications cluster firms became evident during the project offers. They only participated in 6 of the total 90 DDN projects. The main participants were the service provider Sonofon and L.M. Ericsson, while other cluster firms only participated in two small projects. There were no representatives from the cluster or the ICT sector in the regional interim board of directors who wrote the initial DDN report. Later on a member from the cluster was included in the board of directors, but as a representative for the local Confederation of Danish Industries.

The DDN profile did clearly not encourage the cluster firms to participate. The IT infrastructure theme was focused on the fixed network and the IT industrial theme was mainly directed at e-business. Why the cluster only was sparsely involved in shaping the DDN profile is still unclear. But it could be related to the boom in the industry in 1999-2000. The main problems within the cluster were the increasing wages and the lack of qualified labour. The cluster firms had plenty of projects with a higher priority than DDN. However, before the first round of project offers the cluster association arranged meetings to mobilise members to participate in the DDN programme. The cluster association wanted to secure that the DDN policy programme did not become a failure that could have negative reputation effects for the region.

Although only six DDN projects had participation by cluster firms there was a group of projects that included mobile e-business and diffusion of the mobile phone platform to various industries. These areas were in the periphery of the focus of the wireless communications firms.

5.3 What determined the broad user–oriented DDN profile

Bruun (2001) analysed the initiation and the first steps of implementation of DDN as a process. He described five determinants in shaping of the broad user-orientated profile:

- Strong commitment from the leadership of influential public organisations
- The composition of the DDN organisation
- Formal mode of operation
- Ministry rules for funding
- Appointment of the director of the lighthouse secretariat

These five factors seem, however, not to be mutually independent. It seems that the strong commitment from the leadership of influential public organisations lead to the broad user-orientated profile. The ministry rules for funding have weakened the 'university preferred' research-orientated interpretation, but it seems as if the user-orientated profile already dominated when the ministry issued the rules. The appointment of the director of the lighthouse secretariat with a profile that supported the user-driven DDN interpretation is more a consequence and underlining of the already selected DDN profile[16].

A possible determinant is somehow missing in the list. The ICT sector was booming and there was a widespread fear that the public sector was lagging behind. The solution to this problem could be to diffuse ICT broadly in society and to upgrade the use of ICT in the local public administration and other public organisations. This fear combined with the strong commitment from the public sector and the exclusion of representatives from the ICT sector seems to have outlined the final DDN profile.

5.4 The winning DDN projects and the shift from radical to incremental change

Many of the first round projects in Autumn 2000 were 'high profiled', i.e. large projects with many participants and high ambitions. They were mainly focusing on radical change. The enrolment of many public organisations had clearly created a bulk of applications, but also other organisations felt that they had to participate due to the commercial value and to avoid that DDN became a failure. The prestige attached to DDN also attracted participants.

[16] The director had been involved in the writing of the initial report, but it is unclear to what extent, see Bruun (2001).

The DDN secretariat received 118 project-applications and 44 projects were selected as winners in the first round (The Lighthouse Secretariat, 2001). The € 11 million in support generated a total project sum of € 50 million[17]. The distribution was:

- The IT infrastructure theme received 10 applications and 4 winners were selected.
- IT industrial development received 33 applications and 12 winners were selected.
- Digital Administration received 24 applications and 7 winners were selected.
- Qualification and Education received 51 projects applications and 21 winners were selected.

The aims of the projects were very diverse and could be characterised as let a thousand flowers bloom. Among the high profile and ambitious projects were:

- The Digital County Administration and The Open Municipality on digitalising the county administration and the administrative procedures in the municipalities.
- North Jutland Netforum planning an optical fiber based infrastructure.
- TV2 Nord Digital broadcasting digital TV with interactive services among the first in Europe.
- Personal Mobilised Broadband Services using front line technology and creating and testing the future home mobile broadband services.
- The Digital Mall was to be the electronic shopping site on the Internet preferred by citizens of North Jutland.
- E-business between private companies and the North Jutland county administration, a full-scale e-business solution.
- Digital Villages in North Denmark, an effort to maintain and develop the rural districts as vital enterprising and viable local communities and to attract new inhabitants to the villages.

Many of the 'high profile' projects later on had to adjust their goals and change methods to complete the projects. Some of the projects shifted from radical to incremental change. The international crisis in the ICT sector also had a major influence because it fundamentally changed the beliefs on what was possible and what not.

In the later rounds of project offers the winning projects were more focused and specific than the first projects, i.e. more focused on incremental than radical change. The themes were also more specific in the later projects offers (The Lighthouse Secretariat, 2002):

[17] The funding given to each theme varied slightly from the expected amount, the expected amounts are noted in this chapter.

- Qualification and Education with a focus on democracy, children and young persons, and adults with weak IT competencies in the spring 2001 (€ 3.6 million).
- Digital Administration with a focus on the healthcare system in the summer 2001 (€ 3.4 million).
- IT industrial development with a focus on competitiveness in small and medium sized firms in the summer 2001 (€ 2.4 million).
- Qualification and Education with a focus on art, culture and IT in the network society in early 2002 (€ 0.9 million).

But although the themes in the later projects offers became more coherent and the type of projects changed it does not change the overall picture of DDN as a very wide range of projects.

Due to the large variety in the projects it is hard to compare the success rate of the first round projects with the other rounds to see if the incremental projects were more or less successful than the radical projects. The projects on digitalising the county administration or the hospitals sector could potentially have a huge effect on the public sector and could, when completed, be a success factor for DDN. Also projects on creating the Digital Mall, broadcasting interactive Digital TV and planning (and building) a fiber based infrastructure for the entire region could be important parts in making DDN a success. Especially the latter project could - if implemented - make the IT infrastructure in North Jutland the most advanced in Denmark and in most of Europe. This would create a visible and lasting effect of DDN.

6 The development perspectives for the ICT sector and DDN

The analysis in this section will focus on the interaction between the ICT sector and the large DDN project on IT infrastructure, Digital TV and The Digital Mall. DDN generated 90 winner projects with a total sum of € 90 million, which was considerable higher than the expected sum of minimum € 64 million, i.e. the government funding of the projects was on average less than one fourth (The Lighthouse Secretariat, 2003). The projects were initiated during 2000 to 2002 and have been finishing continuously.

On the positive side the DDN programme created lots of ideas, initiated many projects and constituted a large commercial value for the region for a rather modest government support compared to the objective 2 funds. Interviews with participants conducted during 2002 and 2003 reveals that the programme has formed networks between firms and public organisation that may contribute positively to the development perspectives for the ICT sector in North Jutland. There were some success stories of small local IT service firms who

benefited from the programme, and many projects where participation has been considered positive, but with an uncertain overall effect.

ICT firms participated in many of the 90 projects as project partners or suppliers of software services and hardware. The impact of DDN on the development perspectives of the ICT sector in North Jutland is blurred, since the ICT firms participated in different ways and not all of the participants were located in North Jutland. Participation was not restricted to the North Jutland region. It is also important to distinguish between ICT firms that participated as suppliers of standard software and hardware and firms that developed software and services that were more specific towards the project. The latter group could experience a competence enhancement and create externalities that would affect the development perspectives more positively than the pecuniary effect on sales. The description of projects reveals that ICT firms participated in more than 40 projects, but the scope of the projects are varying and the internal competence building is not possible to assess without more thorough analysis that is beyond the scope of this chapter.

6.1 The cases of Digital TV, the Digital Mall and IT infrastructure

The projects on Digital TV the Digital Mall and IT infrastructure were radical change projects from the first round. The Digital TV project intended to transmit digital TV with interactive services among the first in Europe. The Digital Mall wanted to be the electronic shopping site on the Internet preferred by citizens of North Jutland. The IT infrastructure project wanted to design local optical fiber based network solutions, which would bring broadband to local government organisations as well as to private firms and consumers. These large projects could have had a larger and more visible impact on the region than the many diverse smaller DDN projects. They clearly contained elements of radical change from the outset.

6.1.1 Digital TV[18]

In 2001 the local affiliate in Northern Denmark of a national public service TV broadcaster, TV2 Nord, founded a new company with the purpose to begin broadcasting terrestrial digital TV. The project was supported with € 0.8 million, which was less than one sixth of the total amount. It also received support from the European Objective 2 funds. There were several partners, such as a TV station, which should supply the employees, a large bank interested in the possibilities for e-commerce via digital TV, a science park that wanted to support the local activities in the digital TV industry, the local municipality and several content providers. Terrestrial digital TV was known from other parts of Europe, but

[18] See also Chapter 10

not with transmission of enhanced content and other interactive services based on the open Multimedia Home Platform (MHP) standard.

In the early phase the development of applications for games, betting, e-business and home-banking etc. was given a lower priority. Instead the focus was on creating enhanced content. They found that the promised technical possibilities in digital TV were many and widespread, but there were also many limitations in the MHP standard and the existing equipment. Although the project progressed fairly slowly, it attracted a lot of attention from other TV stations, whereas interest from the large equipment manufactures was sparse.

A panel group tested digital TV with enhanced content for six months and a different group received digital TV with interactivity (backward link through a modem) and a small hard disk. The results show that the users have been more positive than expected, in spite of some technical errors and omissions. TV2 Nord Digital has been running many tests on their systems and has subsequently gained a lot of experience in building and running a digitalised TV station. Many foreign TV stations have visited TV 2 Nord Digital to gain inspiration and advise. The broadcasting equipment was not supplied by the large equipment manufactures, but compiled from many smaller suppliers combined with own solutions, since the price was too high. The test of new equipment has attracted some manufactures and some degree of cooperation has taken place.

The project has been a success and got the test period extended. It has also been rather active in cooperation with Danish hardware manufactures regarding the set-top box and trying to get the local university involved in research related to digital TV, which seems to have happened on the content side.

The experiment in North Denmark cannot create competitiveness for the local industry in itself, but could provide some guidelines for the companies. This would especially have been important if the Danish government had decided on a full-scale implementation of digital TV. An ambitious plan for a fast transition from analog to digital TV could have created some interesting perspectives on the role of advanced demand and social experimentation since the two major TV stations in Denmark are public service channels financed at least partly by license fees. However, the Danish government decided in late 2003 upon a less ambitious plan, which may undermine the entire experiment in North Denmark. Although the project has turned out to be a success in terms of technology and users, the future of the project is still highly uncertain due to the missing boost in demand caused by the slow transition from analog to digital TV in Denmark.

6.1.2 The Digital Mall[19]

The Digital Mall was a DDN project of a mobile communications service provider, a regional bank, a logistics company, a supermarket chain, and a software company. The mall was intended to attract 'Business-to-Consumer' (B2C), 'Business-to-Business' (B2B) in the industrial sector and to be the site where the national government organisations, county and municipalities would undertake their purchases.

The Digital Mall was developed with a focus on North Denmark but the concept could later be extended to the remaining country. The philosophy was: Think big and keep expanding your market continuously. The main idea was to create a common Internet portal where different shops were collected. To overcome some of the problems with e-commerce, such as trust, payment, return policy etc., they wanted a single standard payment system and common return system. The idea was to signal that e-commerce is simple, the partners and the payment system could be trusted upon and if anything went wrong the return policy was shared and easy. They wanted well-known brands and high security.

The project, however, ended shortly after the start, basically because a 'focus group' approach based series of interviews with potential customers clearly indicated that consumers were not willing to pay the extra costs for the new services. One of the problems is that the revenue on groceries is quite low since the market is very competitive and although the potential customers would like to use the Digital Mall and also pay extra for the service, the expected revenue was not sufficient to make the project profitable. Other problems were related to creating a high volume to cover the marketing costs, which did not seem possible in the short run without a combined effort in the region from both public and private organisations.

The volume of the project was too small to be commercially viable, and it seems that a boost from a large supermarket chain or the public sector is necessary to carry out a complete e-business solution like the Digital Mall, since a chicken-and-egg situation emerges with the costumers waiting for many shops and goods on the site before buying, and the shops are waiting for the demand before joining the e-business site. The county administration was considering joining the project or using the e-business solution, but decided to build a separate e-business solution as a part of the Digital County Administration. A group of municipalities including the large municipality of Aalborg also decided to create separate e-business solutions as a part of DDN. If these projects had merged it could maybe have been possible to create a commercial sustainable digital mall, since the joined effort could have created a large volume and a lot of publicity, but cooperation, a common will and vision were not established to the necessary extent.

[19] See also Chapter 10

6.1.3 IT infrastructure[20]

The IT infrastructure project consisted of the North Jutland Netforum and KMD Netbroker with the purpose to plan the long term IT infrastructure in North Jutland and initiate the building of an IT infrastructure based on optical fibers[21].

The rapid technological development in the optical fiber industry combined with declining prices has made fibers direct to the home a real alternative as an Internet connection. Optical communication (transmission via light signals) has usually only been used in the Internet and telecommunications backbone, but the increasing demand for data capacity and speed in the network for all users, have made it clear that the best development path in Internet connections is to pull an optical fiber cable directly to each home and firm. The broadband connections could also be used to transmit digital TV signals. The idea is to design an optimal network according to the existing infrastructure, households, firms and public organisations and coordinate the digging to an overall plan, when firms are laying down cables, sewers etc. Sweden has been among the lead countries in the use of fibers direct to the home. In Denmark the construction of an optical fiber network has been delayed because of the lack of political support and commitment.

The information infrastructure should be regarded to be as important as the more traditional physical infrastructure, such as roads and power. This standpoint has, however, not been shared by the public authorities. As a result has the planning of the information infrastructure been uncoordinated and uncontrolled. This lack of coordination is creating a significant waste of resources since nobody knows who are laying down fibers, when and where. The price of laying down the cables is mainly determined by digging costs. Especially in the cities, the digging is very expensive. By planning an optimal infrastructure and coordinate the digging activities it is possible to build a complete fiber network at an affordable reasonable price.[22] By planning the IT infrastructure with the goal of connecting every household[23] in Denmark with optical fibers, the combined demand will drive down prices on each connection and also allow for households and firms in the rural districts to get a true broadband connections.

To fulfil this plan it is necessary to get public and private organisations to cooperate and coordinate. The public sector is especially important to boost the project, to coordinate and also decide that this is the vision for the future IT infrastructure and join the plan. The project started the planning process with three small rural municipalities and has subsequently tried

[20] See also Chapter 10

[21] North Jutland Netforum was an independent organisation established in cooperation between Aalborg University, a bank, the County of North Jutland, the municipality of Aalborg and an IT firm. The KMD Netbroker was a commercial organisation established as part of KMD A/S in collaboration with the municipalities of Brønderslev, Hals, Frederikshavn and Sæby.

[22] See also http://www.nordjysknetforum.dk/

[23] Using other technologies like Fixed Wireless Access (FWA) could connect the most isolated household.

to expand the planning, but it has suffered from a lack of cooperation between firms and public organisations. Several municipalities in North Jutland County are trying to create an initiative to expand the planning and initiate the building of IT infrastructure, but need a more committed the backing from the county authorities.

In the three-year period the project has been running many actors have been interested in entering the market for broadband Internet connections. Especially the power suppliers have been interested in entering and in North Western Zealand in Denmark the power supplier has begun offering optical fibers direct to the home to its customers[24]. At present they only offer fibers to customers in the cities and only in neighbourhoods with a sufficient number of interested customers. The former monopoly service provider TDC is planning optical fiber Internet connections to the most of the Funen County or at least the easiest accessible areas including the third largest city in Denmark, Odense. The price for each connection is, however, several times higher than the calculated price in the DDN project.

While the North Jutland County has been very slow to react, Danish counties especially Viborg and South Jutland County have been faster. In cooperation with North Denmark Netforum, they have created similar organisation, Western Denmark Netforum, with a wider geographical scope. The counties have already begun making the initial preparations to begin planning of the future IT infrastructure, such as collecting information on the existing IT infrastructure and putting down empty tubes for future infrastructure, whenever digging[25].

The DDN infrastructure project opened unique opportunities of creating field experiments with an optical fiber based local infrastructure that also contains extensive possibilities for a combination with other technologies[26]. The DDN project also opened opportunities for planning and building the best IT infrastructure in Denmark, but other regions are catching up and even forging ahead. The County of North Jutland seems at present to have missed the opportunity of becoming a 'lead user' in this field.

6.2 The future of DDN

DDN ran from 2000 to 2003 and the last projects have been finalised in the spring of 2004. There are at present no announced plans to continue the large-scale experiment after the end of financial support from the government. The original DDN report stressed the necessity that the experiment not just faded away after the end of financial support. To avoid this it

[24] http://www.nve.dk

[25] With an empty plastic tube it is possible to lay down extra fibers when the capacity is needed, without digging, since the cable can be 'blown' through the empty tube.

[26] One of the derived effects of the project is the foundation of a Centre for Tele Infrastructure (CTIF) at Aalborg University joining the research competencies within the wireless technologies with research in the wired infrastructure (Dalum et al., 2002).

appeared necessary to collect the experiences by a continuous documentation of the results (The North Jutland County, 1999, p.48).

However, from the beginning of the DDN project period in late 2000 the expectations have apparently been that the programme would end with an evaluation. This lack of a future vision could be the result of many years' of structural problems as a peripheral region and reliance on outside financial support. This could be due to a kind of 'clientism-mood' in the region, where one financial support programme currently has been substituted by the next. DDN could then have been conceived to be yet another programme that was going to bring money and activity to the region. A possible rationale for a region that previously suffered from this kind of 'clientism' could have been to use the money to create some activity, hope that the positive experiences would remain in the region, evaluate the programme and sit back and wait for next support programme. Such an interpretation appears exaggerated in the DDN case. The 'clientism-mood' of the region is on its way out, but has apparently not disappeared sufficiently yet. A group of public organisations formed in early 2003 a think-tank named North Jutland Innovation Forum to evaluate and create initiatives related to the future development of the region. It is, however, not evident that this forum in reality has the political momentum to carry on the positive initiatives created by DDN.

Radical and incremental change is an ongoing process, but DDN seems to fade away leaving the initiative of continuation of the process of change to the individual actors. However, there are some in-built problems in DDN like many other programmes in relation to sustain the processes started by the programmes, after the end of financial support. This creates some tension between to end the support or continue with a new program until the processes are self-sustaining. Likewise Lundvall and Borrás note:

> "*Many evaluations end up addressing users of the programs with questions about the efficacy of the program. Not surprisingly, such studies often end up reporting that the program was very good and that more of the same would be welcome." (Lundvall and Borrás, 2005, p. 611)*

Although 'more of the same' seems to be a frequent conclusion in evaluations it could be a fair conclusion if the goal is long-term 'radical' change. In January 2002 a group of managers from the ICT sector, science park, local bank, and university researchers described a vision on a continuation of the DDN programme after 2003 by making North Jutland a large-scale field experiment where researchers and firms could test new ICT solutions (NOVI, 2002). The continuation of DDN was to be more closely related to the existing strong competencies within software development and IT service. A key component was a combination of the IT infrastructure project and wireless technologies. The vision also included proposed joint effort from industry and university in the basic R&D needed to become visible players in the market for solutions based on the future ICT infrastructure as well as in the international

academic community. The vision has not really been adopted in the region since the local policy makers did not support it. However, a significant outcome of the vision, and somehow derived effect of DDN, have been the establishment of Centre for Teleinfrastructure and Centre for Network planning at AAU in 2004. These are combining the existing research competencies within wireless communication at AAU with research in wired communication technologies.

7 Conclusion

From the outset, the original government vision of DDN appeared to have been a radical change of North Jutland towards a 'network society'. But the means proposed – although they were never clearly formulated - appear to have been rather incremental in terms of building on what was already achieved in the region, which undoubtedly referred the progress of the wireless communications cluster during the 1990s. The means were conceived as a 'localised' policy programme focusing on incremental change. Apart from all the rhetoric and 'hot air' on the transformation to a network society and a learning region, the main purpose was to build on the existing strong capabilities of the ICT sector.

In North Jutland the wireless communication cluster was an important part of the ICT sector, but these firms were not successfully mobilised in DDN. The university was only partially integrated in the programme. It played an active role in DDN, but the technical research groups that probably are the most important for a major part of the ICT sector have not been active in to any significant extent in DDN.

The profile became broadly user-orientated as a result of a deliberate strategy among the dominant actors at the very early stage of the programme. The strong commitment from the leadership of influential public organisations and the missing representatives from private ICT firms lead to the final profile. On the other hand the industry side could, perhaps, be blamed for not being sufficiently active in this process. The strong growth in mobile communications industry – up until 2001 - was likely to make them less interested in participation. The business opportunities were plenty at the time.

The goals of DDN were multiple and somehow lost focus. It could be characterised as let a thousand flowers bloom, which proved to be problematic since 'people who do not know where they are going usually end up somewhere else'[27]. The initial idea of localised change following the development trajectory of the ICT sector was replaced with a more chaotic framework. The goals of DDN contained a lot of radical-change-like rhetoric. The winner projects within the IT industry theme included a mix of radical as well as incremental change

[27] A quote related to the lack of a clear specified goal in DDN is: Alice came to a fork in the road. "Which road do I take?" she asked. "Where do you want to go?" responded the Cheshire cat. "I don't know," Alice answered. "Then," said the cat, "it doesn't matter." (Lewis Carroll, Alice in Wonderland).

oriented projects in many different sectors, and at different levels. But the large and 'high profiled' radical-change-like projects have not been realised at a sufficient scale. From an ICT industry perspective DDN appears to have been too broadly formulated – the effects to have been too scattered.

The role of DDN and its impact on the development perspectives of the ICT sector could also be more broadly sketched in a user-producer interaction in a system of innovation approach. The demand side of the NorCOM cluster is global. Likewise the users of IT services are a part of a global system. The local market for wireless communication equipment is very small[28], while the some of the IT service solutions still have a Danish specificity. The global market for these parts of the ICT sector puts additional requirements on the advanced users and user-producer interaction, since the pecuniary effect of the local market is small. The IT infrastructure, however, is also a part of a global market, but it also has a clear regional effect. This project represents advanced demand that could be used to connect the demand and supply in the region and potentially create user-producer interaction for the cluster firms and the fragmented IT service segment.

DDN was supposed to make the ICT environment in North Jutland stronger and better equipped to be an IT lighthouse of an international standard. The profile of DDN programme when it was initiated was, however, much softer and broader than proposed by the Minister, mainly targeting the public sector and many widespread smaller projects. The profile became broadly user-orientated, instead of oriented towards industrial R&D and innovation and public research, which at no surprise affected the programme significantly.

It appears on the other hand fair to state, that there has been a series of positive results from DDN in a business development context. There are several success stories of small and medium sized local IT service firms who have benefited from the programme, and many projects where the participation has been positive for the participants, but with no significant impact on the development of the ICT sector in North Jutland *per se*, at least so far. DDN has created a focus on the ICT sector in the region and has represented a certain commercial value. The programme seems to have created some contacts among firms and public organisation[29] that may contribute to the future development perspectives for the ICT sector in North Jutland. Whether the effect will be higher than a more narrow Keynesian multiplier effect is hard to tell yet and the overall and lasting effects on the region remain still to be seen.

[28] Measured in sale of terminals. Some of the cluster companies have customers within the cluster.
[29] Often catalysed by the IT Lighthouse Secretariat

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Chapter 10

The Digital North Denmark:
Digital TV, M-commerce, and IT infrastructure

The Digital North Denmark: Digital TV, M-commerce, and IT infrastructure

1 Introduction

This chapter is based on case studies from the Digital North Denmark programme. The focus is on projects with participation of firms from the ICT sector in North Jutland. These can be grouped in three broader industrial activities: Digital TV, m-commerce, and IT infrastructure. The purpose of this chapter is to analyse these fields using the DDN projects. The analyses will focus on the emergence, structure, technologies, hurdles, successes, and the development perspectives of the areas. This chapter is also background material for the analyses in the previous chapter and is used in the discussion of the overall DDN programme and the development perspectives for the ICT sector in North Jutland in the conclusion of this thesis.

The remaining part of this chapter consists of three independent sections. Section 2 investigates the move towards digital TV in North Jutland from the traditional TV industry and the computer industry. Section 3 analyses the development of m-commerce focused on the interaction between various involved actors. Section 4 analyses the future IT infrastructure - if more liberalisation or more planning are needed

2 DDN and digital TV in North Jutland

The basic principles behind a television set have not changed much since the 1960s, but the present transition from analog to digital TV is disruptive to the industry, and can be compared with the shift from analog to digital network technologies in the mobile communications industry (for an analysis of technological life cycles in the mobile phone industry see West, 2000; Dalum et al., 2005). The term disruptive refers to such significant changes in the basic technologies and business models that may change the industrial landscape. In the period of uncertainty between two technological life cycles the barriers to enter an industry seem to be lower (Klepper and Simons, 2000). Under the uncertainty of disruption it may prove next to impossible, not least for small countries, to navigate and react upon future threats. However, for some technologies, where dependence of regulation and standardisation is outspoken, smallness may also contain a source for exploiting the threats and turn them to opportunities. When the future consumption structure, in this case digital TV, is unsettled, experiments with consumption patterns may prove to be an

adequate way to reduce uncertainty and promote technological development. But such social experimentation requires unique capabilities to combine public or private regulation, public R&D initiatives as well as industrial efforts at a broader level. Several sub-standards for broadcasting and services have emerged, but these are mainly proprietary. In Europe, however, the interest of governments has moved towards digital TV based on open standards[1]. This interest might have an impact on the industry, since the power of governments is considerable because the industry is highly regulated through licenses, public service requirements and limited access to the transmission network.

The digital TV industry may also be disrupted by Internet technologies, since the features of interactivity and transmission of data/pictures are somehow overlapping. The entrants in the digital TV industry are both traditional TV/consumer electronics manufactures, but also firms from the computer industry. The latter are developing set-top boxes, software, and services.

In a series case studies[2] different approaches are found in the move towards Digital TV from the traditional TV side as well as from the computer/Internet side. The traditional TV industry is heavily regulated while the computer industry and especially the Internet has been widely unregulated. The first case is a field experiment in North Denmark with terrestrial transmitted digital TV with interactive services and enhanced content. The success of the field experiment is highly dependent on the policy decisions concerning the implementation of full scale terrestrial based digital TV in Denmark, since that decision would open the market for digital TV equipment and services. But we also find that the existing equipment on the market still lacks many technological features before interactivity can be fully explored. The second case is a manufacturer of consumer electronics that is producing a DVD player with Internet access, TV-tuner and hard disk. The case represents the computer alternative to digital TV, since the computer or DVD player becomes a TV, when the screen is added. The third case is about optical fiber to the home, i.e. a 'true broadband' Internet connection that gives access to digital TV and video-on-demand services[3].

[1] In particular the DVB (digital video broadcasting) standard with the MHP (multimedia home platform) substandard for interactive services.

[2] The case studies are made from desk research and interviews with Peter Hinrup and Jesper Rom Knudsen, Flextronics, Bent Bjørn, TV2 Nord Digital, and Kjeld Jensen from the Digital North Denmark (DDN) secretariat. Information is also used from informal talks with participants and formal presentations in the DDN policy program during the DDN project partner seminars held in the period 2001 to 2003.

[3] Broadband is usually defined as a 2Mbit/s or faster network connection.

2.1 Introducing digital TV

Digital TV is a different way of broadcasting with better quality pictures and sound, and it also offers the possibility for interactive services. Instead of broadcasting analog signals, the digital signals are transmitted as compressed digital data, which requires less bandwidth. This allows for more channels within the same frequency band and makes it possible to add different services to the TV signal. The most interesting new features of digital TV are the possibilities for enhanced content and interactivity. Interactive digital TV, however, requires a backward channel to the service provider such as a telephone line modem or cable network. This link allows the viewer to be directly involved in the content and opens possibilities for many new services e.g. games, email and e-commerce etc. The television set itself is still analog and it requires a converter (set-top box) to access the digital signal and services, but digital TV sets are emerging[4].

Japan was the first country to launch digital TV (in 1989) and other countries have followed or have planned to do so. The transition to digital TV has proved to be less simple than planned and even though many governments have set a date for turning off the analog broadcasting signal (US and Germany in 2006, and Sweden in 2008) these countries still have a low penetration of digital TV. This is partly related to the differences in technical standards for broadcasting, receiver devices and software platforms. The broadcasting standard affects the possible transmission method and defines the requirement for the receiver device. The latter also depends on the software platform for enhanced content.

Digital TV services can be broadcasted by satellite, cable and terrestrial (the signal can be received by an ordinary antenna) or through optical fibers. The latter transmission method is new compared to traditional TV. The digital TV signal demands a high bandwidth, which has not been possible at reasonable costs until recent. The technological development within optical fibers and the ubiquitous demand for broadband Internet connections has made 'direct to home' optical fiber possible. The Internet combined with compression techniques for digital signals, have also created possibilities for video-on-demand, download of (pirate copied) movies and other services.

2.2 Digital TV standards

Several different standards for broadcasting digital TV exist in Japan, Europe and the US. Implementing a standard like digital TV that requires very large investments provide many challenges. Funk (2002) describes how the standard setting for digital TV in US involved several new parties. In addition to the traditional consumer electronics firms, manufacturing firms from the computer industry also entered. The computer firms saw opportunities in the

[4] Some TV manufactures (e.g. Sony) have developed a digital TV set supporting the MHP standard.

TV marked, where their computers could be used as television receivers. Also the cable operators, that are a major player in the US TV market, and Hollywood, that was worried about intellectual property protection, joined the committee. The manufactures were the main drivers behind the standard, but the involvement of many different and new parties lead to various problems: The broadcasting and cable companies were mainly interested in the technology to offer additional channels rather than higher quality programming and new services, Hollywood demanded copy protecting[5], and the computer industry wanted the standard to be compatible with their video graphics standard. The latter problem was solved by not specifying the display format, but the copy protection problem has delayed development of digital TVs. The US digital standard was finally introduced in 1996 after years of discussion, but it favoured a high definition digital scheme that is more costly and difficult to implement compared to the European and Japanese standards (Funk, 2002).

On the market side problems also emerged since the broadcasting industry operates in a highly regulated market where the government allocates frequency spectrum and licenses. In the case of digital TV there were no new entrants in broadcasting which hampered competition in introducing digital services since the incumbent service providers mainly wanted digital TV to broadcast additional channels and not introduce new services. New licences have successfully been used before to introduce variety and increase competition in regulated industries. As a result a chicken-and-egg-situation has emerged with the users waiting for services, before buying the digital receivers and the broadcasters waiting for customers before installing the expensive equipment for transmitting digital signals. These problems have lead to a very slow implementation of digital TV in US, whereas Europe and Japan appear to be more successful (Funk, 2002).

The work on a pan-European platform standard started in the early 1990s. The European Launching Group was founded in 1991; among the participants were a broader group of manufactures, broadcasters and regulatory bodies. In 1993 the group drafted and signed a memorandum of understanding setting the rules by which the standard was to be established and implemented. The group was renamed to the Digital Video Broadcasting (DVB) Project and continued in developing a complete digital television system based on a unified approach. The European Telecommunication Standardisation Institute (ETSI) later turned these specifications into a European standard. The European DVB organisation, however, quickly realised that the satellite and cable would be the first to deliver the broadcast of digital TV, since the technology was less difficult and the regulatory system less strict. Digital satellite and cable broadcasting systems were thus to be developed quickly and the terrestrial to follow[6]. Consequently three standards were agreed upon DVB-C (cable),

[5] Since it is possible to make perfect digital copies of a digital TV transmission without loss of quality.
[6] http://www.dvb.org

DVB-S (satellite) and DVB-T (terrestrial). These were, however, not compatible even though the content can be the same, since they apply different modulation methods[7].

2.3 Digital TV

Transmission of digital TV uses the same frequencies as analog transmission, but the transmission capacity depends on the distribution method. The capacity of satellite broadcasting is slightly higher than cable, but both are much higher than terrestrial broadcasting. Broadcasting digital TV requires less bandwidth than analog TV, since the digital signal can be compressed by different techniques. Without compression, the digital signal would demand too high capacity to be feasible. The compression[8] removes all the unnecessary information from the TV pictures before broadcasting and as a result only the changes in the picture are transmitted. The capacity used by transmission varies depending on the level of changes in the content, the compression technique and the quality. High quality pictures such as high-definition TV (HDTV) requires more capacity than standard digital TV, but even standard digital TV has a better quality picture compared to analog TV at the same resolution.

The signal can be seen on a digital TV, but since almost all existing TVs are analog, a set-top box is needed to convert the signals. In satellite transmission a digital receiver is used to convert the signals. Digital TV can also be viewed on a computer or any other consumer electronic device with a TV tuner card. The receiver/converter device varies with the transmission method and it has a conditional access function that can be used to allow certain users to receive specific content. The development of the DVB standard is moving towards IP (Internet protocol) by DVB, i.e. the set-top box gets an IP address. The receiver device also has another function since it can be equipped with a return channel that allows for interactivity and thus a possible wide range of services. The return channel gives the users the opportunity to participate actively in the transmission compared to analog TV where the extra services are transmitted continuously, e.g. text TV. This can be further developed when a hard disk is added and it is possible to store the information.

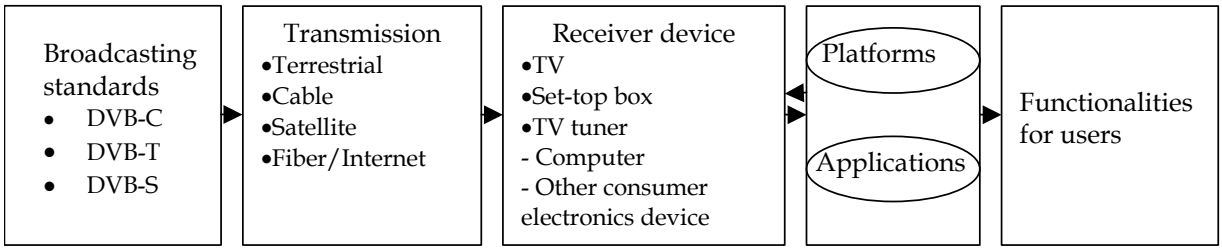
The software platforms on the receiver device have mainly been running on proprietary operating system software, since the set-top box or satellite receiver has been subsidised by the TV stations. A different approach has been used in the development of set-top boxes for terrestrial digital TV with enhanced content and interactivity. The focus has been on using the open DVB 'sub-standard' MHP (multimedia home platform). Governments and the manufacturing industry have backed this approach. It is possible to run a wide range of

[7] Modulation is a method to modulate or change a carry wave to contain the desired information.
[8] Digital TV uses the MPEG-2 compression technique.

applications on this platform. However, the governments seem to require an electronic programme guide (EPG) as a minimum.

Summarising digital TV consists of different broadcasting standards that apply to various transmission methods. A variety of receiver devices running on various platforms with several applications can receive the signal and create functionalities for the users, see Figure 1.

Figure 1 Digital TV

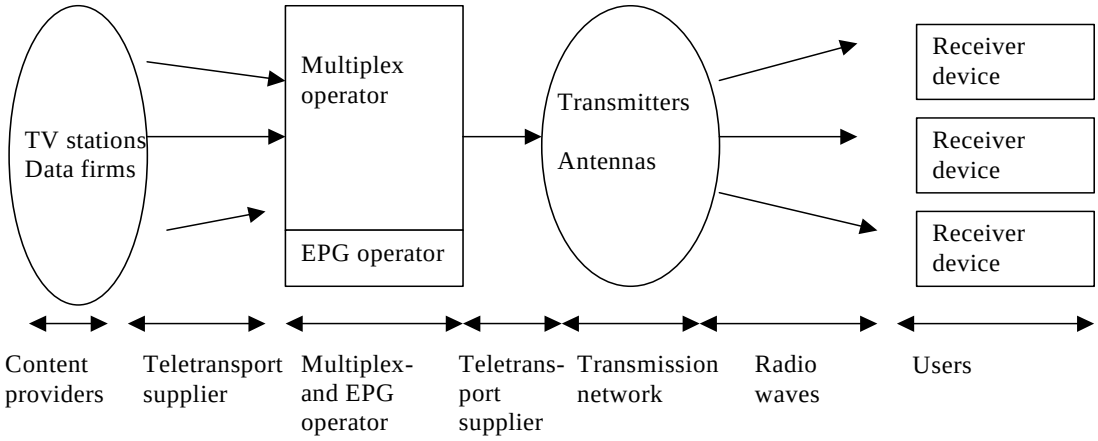


2.3.1 Terrestrial digital TV

Broadcasting analog terrestrial TV requires a single transmission network per TV channel, while a minimum of four digital TV channels can be transmitted using a single network. This number depends on resolution, compression, the number of services in the programmes and the receiver condition, e.g. stationary, portable or mobile[9]. A single transmission network has the capacity of a single multiplex. Within the multiplex a number of TV channels can be broadcasted and the surplus capacity can be used for services, interactivity, enhanced content or sold to data transmission (Skouby, 1998). Since the multiplex can contain more than one channel, a transmission network can be shared between different TV stations and the role as multiplex operator could be separated from the TV stations. As a result the broadcast structure for terrestrial digital TV could be split into various functions, see Figure 2.

[9] Stationary reception with a fixed outdoor antenna eases the requirement for error correction and allows for multiple channels per multiplex. Portable reception with a fixed indoor antenna sets higher requirements for the transmission network and mobile reception reduces the possible number of channels due to error correction. However, it has to be decided from the beginning what kind of reception should be possible since mobile reception means loss of capacity in the network.

Figure 2 Terrestrial digital TV broadcast structure



Source: Adapted from Skouby (1998)

The multiplex operator receives the programme content from the content providers and broadcasts it via the transmission network to the users. The broadcast structure for digital TV makes possible a new division of the tasks performed compared to analog TV. The functions can be combined in different ways or separated depending mainly on policy decisions. The content providers have traditionally been TV stations with several suppliers, but firms specialised in data services can also emerge depending on the distribution of capacity. The multiplex operator is multiplexing the content from the content providers and organises the surplus capacity that can be sold to other services, i.e. the operator becomes a broker. The role of the multiplex operator depends on the role of the public service TV stations, since these might occupy a large predefined share of the capacity. The EPG operator can be a part of the multiplex operator and is collecting the information from the TV stations and presenting the combined TV programme guide. EPG is a political requirement in digital TV. The transmission network with antennas and transmitters is a technical function that also can be performed independently. Various telecommunications service firms could undertake transport of signals from the content providers to the multiplex operator and from the latter to the transmission network (Skouby, 1998).

The digital TV broadcast structure can be divided into several operators, but a total separation might not be attractive, since many of the separate functions in Figure 2 are technologically connected and dependent on each other. This is, however, a political decision with emphasis on competition, culture, economics, regulation, technology and power. The EPG operator is reliant on information from the TV stations and the multiplex operator is depending on the capacity demand of all programmes to maximise the use of the capacity surplus to be used for data casting. The level of competition depends on decisions on which TV channels are to be transmitted (e.g. only the public service channels or also commercial channels), the convergence between the TV infrastructure and the Internet network structure. The culture political issues are related to the transmission of public service TV

compared to commercial channels. Regulation is important since the broadcasting structure can be divided into different functions in which the power relations are not equal and still unsettled. The regulation has to be changes since the traditional regulations by the distribution of frequencies cannot be used in digital TV. New problems emerge since data casting is under the Telecommunications Act and not under the Radio and TV Act. Pay TV and other payment services also create new problems for regulation. Regulation regarding the transmission and receiver devices is very important to avoid that programmes and services use different standards and create proprietary receiver devices. The use of the MHP platform standard for interactive services and enhanced content is supposed to increase competition in the receiver market and drive prices down.

The terrestrial digital TV market is highly dependent on policy decisions and the future broadcast structure is determined by policy decisions. In countries with license fee financed public service TV, the government will most likely secure that these TV stations will not be in a worse situation when broadcasting digital TV. This could have a double-sided effect on the transition from analog TV. It could speed up the process with a decision of a full transition and boost the demand. It could also slow down the process if the transition would allow for more competition by allowing foreign owned channels to the national network.

Several technical problems in key areas are still to be solved; Set-top boxes based on the MHP platform are still sparse and it still lacks certain features to allow all the services, interactivity and enhanced content that digital TV is supposed to provide.

Multimedia Home Platform

The political interest in digital TV has been on using the open MHP standard for enhanced content, interactivity and other services. The MHP standard was approved by the DVB organisation and made a standard by ETSI in 2000. The MHP platform is a common API (Application Program Interface) that is independent of the hardware platform it is running on. Content from different providers becomes available through a single device that uses the MHP common API. This openness is to increase competition and functionalities for the users. The MHP standard could also be used to transmit digital TV through the Internet. The MHP platform might, however, change the digital broadcasting structure described in Figure 2, since it allows content providers other than TV stations to enter the market. Support of the MHP platform for the set-top boxes has been further complicated since different versions of the MHP platform exists, and only the newer and forthcoming versions can support interactivity and other services[10].

[10] http://www.mhp.org

The set-top box

Since most of the TVs are still analog, set-top boxes are needed to convert the digital signal. The set-top box is very important since it also enables the services that digital TV is supposed to provide. The satellite payment TV stations have dominated the digital TV market and subsidised the set-top boxes. Consequently they have had a lot of power in the set-top box market using proprietary standards, but since the number of satellite users is lower than terrestrial (often the satellite users also use ordinary antennas to access some TV stations), the market for set-top boxes is likely to change. The development of set-top boxes has been slowed down because the digital TV market only has evolved slowly. However, using the MHP platform allows the user to see programmes from different TV stations on the same set-top box, increases competition in the set-top box market and increases the user utility. The large consumer electronics producers have waited for the mass market to develop, which has given the small electronics firms the opportunity to be in the technological front on the market for set-top boxes supporting the MHP platform[11].

Enhanced content gives the user a possibility to change the content on the TV screen e.g. viewing a football game from a different angle or getting information on players etc., but this is not interactivity (even though it is often advertised like that) since the enhanced content is broadcasted continuously like simple text-TV in analog TV. Interactivity requires a backward channel from the user to the service provider. The backward channel allows the user to send information to the service provider and in so doing participate actively in the services. It also allows the service provider to send specific services or information to the user. This is a key feature for many of the new services in digital TV e.g. e-commerce, e-mail etc. The backward channel can be any kind of data transmission connection, which mainly is a telephone modem, but could be a cable modem or a GSM mobile telephone modem. The demand for transmission capacity and speed in the connection should not matter that much for interactive services.

Another problem with the current set-top boxes is the need for storage of data, i.e. a hard disk is needed. Many of new the digital TV services require a hard disk to avoid the problem of using the transmission capacity to transmit the same content over and over again, and to enable new services like e-mail, video mail, service information, video-on-demand etc. The

[11] In the case of the field experiment on terrestrial digital TV by TV2 Nord Digital, they searched the market for set-top boxes supporting MHP and interactivity. The support of MHP was important since they wanted to broadcast digital TV with enhanced content and they found that most of the boxes had severe technical problems and could only display the enhanced content slowly at best. Since the users are 'supposed' to buy a set-top box to receive digital TV, the technological development of set-top boxes becomes important. In Sweden the introduction of digital TV was a failure since the user had to pay more for digital TV than analog while the programs were identical, except for a better quality picture. Many of the new interactive services, enhanced content, data casting etc. that are the main arguments for switching to digital TV rely on the set-top box and especially on features that are not added to the box yet. While the manufactures cannot supply the needed technological solutions, there seems to be possibilities for new entrants to enter the market.

price of storage capacity has declined steadily over the last decades and storage capacity for a couple of movies could be added for a reasonable price today. Since the data transmission capacity in the terrestrial digital network is constant all day, it is possible to use the periods of the day with none or only a few programmes to transmit large amounts of data. With IP by DVB it will be possible to transmit targeted information to specific groups e.g. a video mail. The set-top box still has a limitation in only converting the digital TV signal for one TV set in the household. Since many households have more than one TV in the house, each household would need several set-top boxes. This will increase the price of receiving digital TV and reduce the demand until the set-top box can function as a sort of home server.

The development of set-top boxes is slow, since the demand is low. The producers of set-top boxes seem to be waiting for the diffusion of digital TV before up-scaling the development. The transition from analog to terrestrial digital TV can open a mass market, but it depends on political decisions.

2.4 The emergence of digital TV in Denmark and the role of policy

Broadcasting digital TV by satellite is dominant in Europe, but terrestrial broadcasted digital TV is emerging and transmission via optical fiber to the home is becoming an alternative. The satellite companies have a head start in the diffusion of digital TV, since it is technologically less difficult than terrestrial broadcasting, the regulatory regime is more flexible and the competition is higher. The first introductions in UK and Sweden were unsuccessful because the consumers did not want to buy converter equipment (set-top box) and pay extra for the digital broadcasting. In UK the business model was changed and digital TV has become more successful. In Finland terrestrial digital TV is also broadcasted, but it is only the city-state of Berlin in Germany that has implemented terrestrial digital TV 'fully' by turning off the analog transmitters. The broadcasting of digital TV has, however, mainly been a good quality picture and sound and a better text TV, that is, converting the normal analog signal into digital and not utilising the possibilities for new interactive service and enhanced content. As a result the diffusion of digital TV is still sparse.

In the mid 1990s several European countries were preparing the diffusion of digital TV and transmission of digital TV by satellite had begun in a few countries. An EU directive from 1995 on standards for transmission of digital TV signals had urged the member countries to push forward the development of advanced digital TV services (Skouby, 1998). In 1996 the Danish government decided to allocate the available frequencies of a possible third nationwide terrestrial transmission network to future digital TV services. In Denmark there are two nationwide public service TV stations broadcasting terrestrial analog TV and

several TV stations broadcasting by satellite, but the public service TV stations were not to be in a worse situation with digital TV than before. The Danish government wanted the cheapest and easiest transmission of digital TV with national coverage. It should also be possible to transmit regional programmes, transmit many channels, have the possibility for portable reception, and allow for interactive services. The transmission method should fulfil most of the demands but also be the cheapest possible for the user and the TV stations.

In 1998 a workgroup appointed by the Minister for Culture delivered a report on Future Digital TV in Denmark. The Skouby (1998) report compared the four possible transmission methods with respect to the demands of national coverage, economy, costs and competition etc. The report recommended implementation of terrestrial digital TV, since this transmission method had a wide range of advantages fulfilling the demands compared with the other methods. This method was preferable even though most Danish TV viewers receive the TV signal through cable, followed by terrestrial and satellite. However, the cable network is not one big connected network, but consists of several smaller networks of which some are satellite master antenna TV, that is local cable associations receiving the signal from terrestrial antennas and satellite and providing their members by cable. It is possible for these to transmit the raw DVB-T signal through the cable or convert it, but the latter option will mean loss of the interactivity. The report concluded that national coverage was easily obtainable with terrestrial based digital TV since the users could receive it with an ordinary antenna[12] and they do not have to buy a satellite receiver. Likewise was it possible to upgrade the existing terrestrial analog TV network structure to digital TV. Digital TV by cable was not possible since the costs would explode when providing national coverage in one big cable network. Since the Radio and TV Act regulate terrestrial TV whereas the satellite TV is not regulated by the act, there was a political support for terrestrial digital TV. The public service stations could stay independent of paying foreign international satellite companies for transmission by building a terrestrial transmission network. The government also needed to keep some kind of control of the transmission network since it is a part of the Danish war and emergency alertness. Using satellite transmission the two public service TV stations would have to compete with many channels, while they would have an advantage in the terrestrial transmission. The satellite transmission has a higher bandwidth, but reception of terrestrial digital TV is uncomplicated and could also be portable or mobile. The economic calculation also supported terrestrial digital TV, since it is cheaper for the TV stations and the users. The report recommended the establishment of a third terrestrial digital TV network and a transition period from analog to digital TV of 10 to 15 years. And after the analog transmission was turned off, the existing networks could be used for extra TV channels (Skouby, 1998). First mover advantage for the Danish service industry in digital TV was also regarded as being 'not unimportant'. Competencies and knowledge on DVB

[12] It is said that terrestrial digital TV can be received in perfect quality using a knitting needle as antenna.

services and DVB products could be very valuable, since digital TV was in an early phase and most of Europe was supposed to shift to digital TV (Skouby, 1998). As a result the government decided to implement the recommendations in the report.

But nothing happened until 1999, when the two public service stations in Denmark began a test transmission of digital TV on two transmitters to experiment with digital TV[13]. In 2000 the government appointed a new workgroup to investigate if any of the recommendations and conclusions had changed since the last report in 1998 and examine the possibilities to combine interactive broadband services with terrestrial digital TV. The new report concluded that provision of digital TV by the broadband services available at that time was not the best solution due to the requirement of national coverage and price (Skouby, 2000). Digital TV was, however, seen as a step towards the creation of the information society. The conclusion and recommendations were not changed, but the report stressed the importance of beginning transmitting digital TV with interactive services as soon as possible, not to fall behind the rest of Europe (Skouby, 2000).

In 2000 the government decided to create four digital TV transmission networks with multiplex, thus allowing 15-20 channels of which four were reserved for the public service stations. Negotiation regarding the frequencies began with the neighbour countries and because the first set-top boxes were not expected on the market until 2002, allocation of channels and transmission of digital TV were supposed to begin in 2002. However, there were disagreements between the parties supporting the agreement. Especially problems regarding the economy of the project and the distribution of the 15-20 available channels led to disagreements. The unsuccessful introductions in UK and especially Sweden with very low penetration ratios added to the problems and the decision on when to begin transmitting digital TV was only making slow progress.

In 2002 the new Danish government decided to invite tenders for the new digital transmission network. Existing operators or programme suppliers with a dominating position on the Danish market were not invited to submit tenders and the government wanted to turn off the analog transmission network in 2007. The decision was changed in early 2003 due to the economy in the project and in September 2003 a less ambitious plan was finally accepted[14]. Instead of four multiplex with four channels each, it was decided to build a single transmission network for terrestrial TV with four channels. The four channels are to be divided between the two public service TV stations. There are not to be any new channels, but existing channels broadcasted digitally with enhanced content and interactive services. The TV stations are required to develop new digital programmes and services, but analog broadcasting is expected to continue for another 10-15 years. The digital TV will not

[13] http://www.dr.dk/omdr/teknik/dvb/rapporten.htm
[14] http://www.kum.dk

be payment TV, but the users will have to buy a set-top box. The industry has been invited to a consultation regarding the establishment of a terrestrial digital TV network that is supposed to be completed and ready for broadcasting July 1st 2005 at the latest.

This plan seems to be put into work after seven years of discussion and four decisions to build a terrestrial digital TV network, but Denmark seems to have lost the opportunity to become first mover or even between the first, even though the diffusion of digital TV has been slow all over Europe. The digital TV industry is still in a phase of disruption, which holds some opportunities for the Danish companies, but the home market seems not to be the main demand driver. The new plan is not ambitious and has unfortunately some similarities with the Swedish approach. This raises a question of who will buy a set-top box when the services and TV channels are few for the next many years? The potential opportunities created by being an advanced user seem to be replaced with a reluctant user following behind the lead users.

2.5 Terrestrial digital TV

In 2001 the local affiliate in Northern Denmark of a national public service TV station, TV2 Nord, founded a new company with the purpose to begin broadcasting terrestrial digital TV. The idea behind the TV2 Nord Digital project was formed when the region of North Denmark was selected as a region for the Digital North Denmark (DDN) ICT policy programme in 1999. There were several partners behind the project e.g. a TV station, which was to supply the employees, a large bank interested in the possibilities for e-commerce via digital TV, a science park that wanted to support the local activities in the digital TV industry, the local municipality and several content providers. The project was to begin in early 2001 with the first broadcasting starting late 2001. The partners behind the project believed that a full transition to terrestrial based digital TV had finally been decided on politically in Denmark with the law on the media effective until 2004, which proved not to be the case. The law was changed in 2003 with a less ambitious plan for terrestrial digital TV. But the Danish Minister of Culture allowed the transmission network to be digitalised and the project to begin broadcasting in 2001. The purpose of the project was:

> *"The citizens of North Denmark may be the first to have digital TV available in a version that makes the contents interactive, and creating a convergence between the Internet and Television. … With the digital channel, TV2/Nord will be able to broadcast a lot more regional news than today... In the new digital channel the Internet or parts of it is integrated in the TV set. E-business and home-banking should be made available over the remote control, and it is planned to establish a regional activity and event calendar*

with text supplemented by film and video clip." (Project description on www.detdigitalenordjylland.dk)

TV2 Nord Digital was founded in 2001 and the employees were mainly freelancers or employees on leave from the mother TV station.

2.5.1 Technical problems

Terrestrial digital TV was known from other places in Europe, but not with transmission of enhanced content or other interactive services based on the open MHP standard. Terrestrial digital TV consists of video, audio and enhanced content, but the combination of the three is very difficult. When the project became known, many companies contacted TV2 Nord Digital to sell MHP applications and set-top boxes. These firms did, however, only have equipment and applications based on proprietary standards. As a result of many problems regarding software suppliers the company decided to develop its own basic software tools to be used in developing MHP applications for making TV programmes. New specifications of the MHP standard were released in the development phase, which were improvements compared to earlier versions. In this early phase the development of applications for games, betting, e-business and home banking were given a lower priority. Instead the focus was on creating enhanced content.

TV2 Nord Digital discovered that the promised technical possibilities in digital TV are many and widespread, but at present there are also many limitations in the MHP standard and set-top boxes. Even though the project progressed fairly slowly with delays, it attracted a lot of attention from other TV stations, whereas interest from the large equipment manufactures was sparse. A group of test persons have tested digital TV with enhanced content for six months and a new group received digital TV with interactivity (backward link through a modem). The results show that the users have been more positive than expected even though they experienced some technical errors and omissions, and had high expectations of the new form of TV.

TV2 Nord Digital has been running many tests on their systems and has gained a lot of experience in building and running a digital TV station. The new TV station is running fully digitalised and in the evenings it is unmanned, only controlled by an employee working from home on a laptop[15]. Many foreign TV stations have visited TV 2 Nord Digital to gain inspiration and advise. As a result they have begun consultancy business in helping other TV stations. The broadcasting equipment was not supplied by the big equipment manufactures, but compiled from many smaller suppliers combined with own solutions. It was possible to buy a complete system from the big equipment manufactures, but the price was too high.

[15] The live transmission is supplied from the mother TV station.

The test of equipment has attracted some manufactures and some degree of cooperation has taken place.

The set-top box has caused many problems for TV 2 Nord Digital, since they wanted to broadcast with enhanced content in the MHP standard. Many of the set-top boxes did not have the claimed MHP compatibility. These problems also occurred with the broadcasting equipment[16]. TV 2 Nord Digital tested different set-top boxes and only found a few that were able to support enhanced MHP services, but only a single set-top box developed in Poland was able to do it at a reasonable speed. They began a close dialog with the firm concerning correction of errors and future development, and subsequently the company was chosen as supplier of set-top boxes for the test users. They also used a digital TV tuner card for a computer in their tests and have tested a Sony digital TV set that supported MHP.

During the test period they discovered several problems with the set-top boxes and needs for further technological development. Especially the need for a hard disk is urgent, since the lack of it hampers the possibility of many new services. The hard disk will increase the price of the set-top box, but a possible business model could be to subsidise the box through sponsorship by allocating a part of hard disk to commercials, public information etc. A telephone modem is now working as return channel, but it limits the speed, location in the house and use of the telephone line. A different form of return channel such as a mobile telephone modem would be an advantage. It is not possible yet to use a cable modem as a return channel. The problem of the return channel has recently been 'solved' by another North Denmark based company, RTX Telecom working with wireless communication technologies. They have signed an agreement with Australian subscription television provider FOXTEL for the development, production and supply of wireless telephone line extenders[17]. The product uses DECT technology in a special configuration that enables the transmission of modem signals at speeds of up to 56kbit/s. This will simplify the installation of modems and the cabling, and the return channel enables interactive services e.g. pay-per-view.

Terrestrial digital TV can only be received with an antenna, which is a problem for more than half of the Danish households who receive TV through cable. Many of the cable TV providers, however, receive the signal through an antenna and transmit it via cable to the households (satellite master antenna TV). It is technical possible to transmit the DVB-T signal through cable, without converting it to a cable signal, thus making it possible to access with a set-top box. This solution is being tested at present and the price for this arrangement is

[16] These problems occurred despite the firms said that their equipment was working fully functional in Finland, Australia or any other place with digital TV, which turned out to be false

[17] Announcement September 30th 2003 by RTX Telecom, see http://www.rtx.dk or http://www.foxtel.com.au

expected to be a very low[18]. An alternative solution is to convert the signal to a cable signal, where the user needs to have a DVB-C supported set-top box.

The integration of an Internet browser in the set-top box is also a possible future technological development that will push the convergence between TV and Internet. This is a part of the IP by DVB development that might change the role of digital TV and give terrestrial digital TV, DVB-T, an advantage compared to the DVB-C and DVB-S.

2.5.2 Content and business models

Making TV programmes with enhanced content requires a new way of planning and thinking compared to traditional TV. One of the project's experiences is that it is not sufficient to add extra content to existing TV programmes, it has to be thought into the programme from the beginning. After some time they found it feasible to adapt a new way of thinking and it gradually became easier to produce the enhanced content. TV 2 Nord Digital has developed MHP application tools that make it easy to add enhanced content, but is has to be planned before making the programme. Programmes with enhanced content demands more resources to develop and produce, which generates extra costs that have to be financed. This raises questions regarding whether the user wants to pay extra for receiving the enhanced content i.e. does the extra value compensate for the extra cost.

Solid business models are still missing for the terrestrial digital TV industry, mainly because the diffusion of terrestrial digital TV is still sparse, but also because the user has to buy a set-top box before receiving the signal. The price of a set-top box has decreased the last few years and will probably continue this path like other consumer electronics products, when the demand increases. The value of the new digital TV services has to be higher than the cost of the set-top box and also higher than a possible higher license fee (as happened in Sweden). It could be a problem to attract a critical mass of users, especially since the analog signal will be broadcasted simultaneously in Denmark for the next many years. And the extra costs of producing enhanced content and interactive services are a fixed cost independent of the number of users.

Digital TV is a network good as described in Shapiro and Varian (1999) with large sunk costs in establishing the transmission network and broadcasting equipment. Technical problems with the set-top box regarding return channel, hard disk etc. have set back the interactive services that should attract users. Without interactivity or enhanced content the only benefits for the users are a better picture and sound. The delay in launching digital TV combined with the increasing number of high speed and broadband Internet connections has also put pressure on the future digital TV services, since the users are used to high speed Internet services, so they might not want to shift to similar services by digital TV, especially

[18] The costs are approximately 1300 € per local cable network.

if these are slower due to transmission capacity and the telephone modem backward channel etc. There are, however, differences in the situations when using the Internet and the TV, since the user of the computer and Internet is actively participating viewed from 2ft, whereas the TV is often used by more than one, focused on entertainment and viewed from 12ft. But the services can also be complementary, e.g. the TV2 Nord Digital has had a great success with a slimming treatment, where the Internet and digital TV have been used as a complementary combination.[19] Participating in the treatment has been free, financed by commercials and the local county.

The revenue in digital TV is believed to come from games, betting, e-business, interactive commercials and pay per view. Some of these features are possible today, but others await the technological development of the set-top box, broadcasting equipment and diffusion of digital TV. TV2 Nord Digital made an interactive commercial service that was being tested by the users. The commercial was for a nationwide real estate agent and had some similarities with their homepage, where the user could click on extra information and search on available homes for sale. It needed some smaller reprogramming of the enhanced content compared to the information on the Internet and the speed was comparable with an Internet connection with a 56kb/s modem. This raises the question of why making the digital TV commercial if the speed is rather slow compared with the high-speed Internet connections i.e. why should the user use digital TV instead of the computer. The digital TV commercial could be used by people with no Internet connection and should be easier to use and the idea was to combine it with a TV programme on real estates. The test revealed that the users were not interested in using the service, which could be related to the slow speed and problems with the modems. The digital TV could, however, have an advantage in the technical possibilities in the use of pop-up notices e.g. in a TV programme or shortly after, a notice pops up informing the user of some interesting enhanced content or interactive services, that could be reached by clicking on the remote control. Whether digital TV services and Internet services are complementary, supplementary or substitutes remains to be seen, but the rapid diffusion of high-speed Internet connections compared to the slow diffusion of digital TV has allowed Internet services to take a large share of the perceived market for digital TV services.

[19] The users have used the Internet to control the weight etc. and TV programs with enhanced content have been used for recipes etc.

2.6 Compression techniques, TV-tuners and the computer

Flextronics[20] in Denmark is specialised in contract manufacturing of advanced electronics, until recently mostly mobile phones, but to an increasing extent also DVD-players, Bluetooth headsets, set-top boxes and similar products. The company provides total solutions including prototyping, industrialisation/technology transfer, component sourcing, highly automated production, high volume production, total box build concept, worldwide distribution and after sales service. Flextronics is producing a DVD player for a small Danish company, KiSS Technology[21]. This DVD player was the first player in the world, that could play movies in DivX compression format and it also has a built-in Internet connection. This market appears to have very big opportunities. The huge consumer electronics giants are apparently locked-in in their more "TV-based" approach at the moment, but that may change, and if/when so probably with dramatic speed.

KiSS Technology has a contract with a Silicon Valley based company providing them with chipsets that can decode all kinds of compression formats and also the MPEG 4 standard and the substandard DivX. The compression formats and related programmes are becoming better at compressing large amounts of data and the computers are becoming more powerful in terms of speed and RAM, which is needed since the unpacking of compressed data demands a lot of power. Combined with high-speed Internet connections it is possible to download movies, burn it on a CD-ROM, put it in the DVD player and watch in on the TV. Many of the movies that can be downloaded are, however, not legal (pirate copies), but new services are popping up with legal downloads and video-on-demand. The improvements in the various technologies makes it easier to download, copy and share movies and TV programmes.

The computer world and the TV world are converging, but have different properties. The computer users have control of their own network and computers and can add anything they choose, which gives the user many choices, whereas the TV world is closed with carrier control. Free file sharing on the Internet is competing with pay per view on TV[22]. KiSS has been the only firm with a DVD player on the market with support of DivX and the multinational consumer electronics companies seem to be stuck in a 'traditional DVD world', where the consumer rents or buys a DVD in a store. The KISS players also have a network plug, which allow the DVD player to be connected to the Internet, at present it only support emails and Internet radio, but this is changed in the new models. The current version of the DVD player has a hard disk built in. This allows the DVD to be connected directly to the

[20] In June 2004 Flextronics decided to close down their production facility in Denmark and move the production to Hungary. In September 2004 Orion acquired the buildings and machines. Orion is a Danish manufacturer of LCD displays.
[21] http://www.kiss-technology.com
[22] According to Preben Mejer TDC Innovation Lab, Katrinebjerg

Internet and also function as a personal video recorder (PVR) with many new features such as recording and playing on same time, that allow the user to stop a programme and resume viewing after a few minutes, thus seeing the programme with a short delay. This will change the market for TV ads, since the user can start watching with a few minutes delay and skip all the ads. The next step in the development of the DVD player is adding an amplifier and a dual TV-tuner. The dual TV tuner is for analog and digital TV and makes it possible to watch TV if a screen is connected. This development path seems to indicate that the TV is changing form. The DVD player connected to loudspeakers and a screen could be the combined TV set. This change puts the focus on the development in display technologies, since these easily can be connected to the DVD player. In display technologies there are a move from traditional electron beams screens towards TFT/LCD, plasma and projection or others like organic/polymer LED.

The DVD player is, however, not the only move from the computer world towards the TV world, since it also is possible to receive analog or digital TV with a TV tuner card in the computer connected to an antenna, cable or satellite receiver. Then it is possible to watch digital television on the computer, or on a connected screen or TV. The convergence is resulting in the computer being used as a TV and the consumer electronics set-top boxes or DVD players are turning into small computers.

2.7 Optical fiber direct to the home

The rapid technological development in the optical fiber industry combined with declining prices have made optical fiber direct to the home a real alternative as an Internet connection. Optical communication (transmission via light signals) has usually been used in the Internet and telecommunication backbone, but the increasing demand for data capacity, i.e. speed in the network by the ordinary users, has made it clear that the best development path in Internet connections is to pull an optical fiber cable directly to each home. These broadband connections could then also be used to transmit digital TV signals. Sweden has been among the lead countries in the use of fiber direct to the home. In Denmark the construction of an optical fiber network with fiber to the home has been delayed because of a lack of political support and commitment. The idea is to design an optimal network according to the existing infrastructure, households, firms and public organisations and coordinate the digging of fiber according to the overall plan when telecommunications and other firms are laying down cable or sewer etc.

The information infrastructure is as important as the 'more physical' infrastructure such as roads and power, but the planning of the information infrastructure is not coordinated and controlled by public authorities. This uncoordinated process is creating an enormous waste since nobody knows who is laying down fiber optical cables, when and where. The price of

laying down cable is mainly determined by the digging, whereas the fiber optical cable and an extra empty plastic tube[23] are rather cheap. Especially in the cities, the digging is very expensive. By planning the optimal future infrastructure and coordinate the digging activities it is possible to build a complete optical fiber network with fiber direct to the home at a reasonable price. The combined demand from public organisations, firms and private homes will make it economic profitable for one or more operators to build the entire network or a part of it. The operators could be telecommunications firms, private building associations, district heating firms or power suppliers etc. [24]

Especially the power suppliers have been interested in entering the market for broadband Internet connections. In North Western Zealand in Denmark the power supplier has begun offering optical fiber direct to the home to its customers[25]. At present they only offer the optical fibers to customers in the cities and only in neighbourhoods with a sufficient number of interested customers. They are building a network consisting of several local city networks combined with a larger backbone network. The customers can choose between several subscriptions depending of the services they want, e.g. Internet, telephony and/or TV. The TV customers get a set-top box with a hard disk, which allow then to watch TV (when it is connected to a TV set) and also use different services, e.g. e-mail and video-on-demand.

Optical fiber directly to the home is an alternative transmission method for digital TV, but will probably be more complementary to terrestrial digital TV due to the requirement that the public service channels have to have national coverage. The construction of a national, optical fiber to the home network will take some years depending on the political climate, whereas a terrestrial transmission network relatively easily could be built, since less than 20 transmitters are needed to cover Denmark.

2.8 Discussion

Digital TV represents a disruption of the TV manufacturing industry. Due to the disruption it is possible for new firms and diversifiers from different industries to enter the market. But the digital TV industry may itself be disrupted by Internet technologies, since the features of interactivity and transmission of data/pictures are overlapping. The area of refraction in digital TV is especially characterised by the different approaches in the move towards Digital TV from the traditional TV side as well as from the computer and Internet side. The traditional TV industry is heavily regulated, while the computer industry and

[23] With an empty plastic tube it is possible to lay down extra fibers when the capacity is needed, without digging, since the cable can be blown or pulled through the empty tube.
[24] See also http://www.nordjysknetforum.dk/
[25] http://www.nve.dk

especially the Internet has been widely unregulated. The interactions of these groups are adding to the disruption in the industry.

The growth of the digital TV industry has, however, been hampered, since the roll out has been much slower than expected. This has slowed down the technological development of set-top boxes, software etc., since the firms seem to be waiting for the diffusion of digital TV before up-scaling the development activity. The large consumer electronics producers have waited for the mass market to develop, which has given the small electronics firms the opportunity to be in the technological front on the market with set-top boxes supporting the MHP platform. The transition from analog to terrestrial digital TV can open a mass market, but it depends mainly on political decisions. However, several problems in key areas still seem to be unsolved. Likewise business models are missing and it is still uncertain if the users want to pay for digital TV.

Several standards have emerged on the different continents, where the European DVB standard seems to be the most successful. Within these standards there are several substandards depending on the transmission methods: satellite, cable or terrestrial. The transmission methods have different advantages and limitations, and the TV companies are competing using different transmission methods, where the satellite companies and subsequently digital satellite TV have had a head start, the competition is harder and the regulations less strict. But terrestrial and cable have more users and are expected to be the most important for the industry especially since most European countries have decided to build a terrestrial digital TV network. The focus on the open MHP platform for terrestrial digital TV also seems be an advantage for the further development and diffusion of digital TV.

The combination of the delay in the roll out of digital TV, the rapid technological development in and falling prices of optical fiber, and the demand for broadband Internet connections have made optical fibers directly to the home to become an real alternative transmission method for digital TV. There is, however, one problem in this transmission method, which is the demand for national coverage. This is also the limitation for cable transmission since it is impossible to supply all households, which is a necessity for the national license fee financed TV stations. The optical fiber will probably be more complementary to the terrestrial based digital TV, but it is also a substitute for some of the services that digital TV was supposed to provide. The problems are the limited speed in the return channel, the missing hard disk, IP over DVB and limited transmission capacity etc. The speed of the interactive services is important since it could easily be a major turn-off factor for the user, this is especially important for the services that also can be found on the Internet e.g. why should the user search for a new home via the TV or use video-on-demand, when similar services can be accessed with a computer at a much higher speed.

The experimentation in the case of TV2 Nord Digital can not create competitiveness for the local industry in itself, but can provide some guidelines for the companies, especially if the Danish government had decided on a full-scale implementation of digital TV. Since the two major TV stations in Denmark are public service channels financed at least partly by license fees, an ambitious plan for a fast transition from analog to digital TV could have created some interesting perspectives on the role of advanced demand and social experimentation. However, the Danish government have lately decided upon a less ambitious plan, which could undermine the entire experiment in North Denmark. Denmark is likely to have lost the opportunity to become first mover or even between the first, even though the diffusion of digital TV has been slow all over Europe. The new plan is not ambitious and has unfortunately some similarities with the Swedish approach (This raises a question of who will buy a set-top box, when the services and TV channels are few for the next many years?). The potential opportunities created by being an advanced user seem to be replaced with a reluctant user following behind the lead users.

One of the main concerns is the price of the shift to terrestrial digital TV. The transmission network and parts of the broadcasting equipment have to be upgraded and more importantly, the users have to buy a set-top box. It is necessary for the users to purchase set-top boxes to convert the signals, but there are still technical problems with the set-top box such as a return channel, hard disk etc. These problems have setback the development of interactive services that should attract users. Without interactivity or enhanced content many of the benefits for the users are missing and in combination with a long transition period it could result in an undesirable chicken-and-egg-situation with the users waiting for services before buying the digital receivers and the broadcasters and regulatory bodies waiting for customers before expanding the networks, and increasing the enhanced content and services. In countries with some degree of licence fee financed public service TV, the government will most likely secure that these TV stations will not be in a worse situation when broadcasting digital TV, which could result in a slow diffusion of digital TV. This seems to be the situation in Denmark.

3 M-commerce

During the boom in Dotcom and telecommunications in the late 1990s, the growing mobile communications industry was searching for new business opportunities. The solution was found in the hype of e-business, which seemed to offer great opportunities. Instead of being locked to the desktop and the fixed line Internet everything should be mobile. By using the mobile handset to data transmission and access to the mobile Internet, e-commerce would become mobile: M-commerce.

The first attempts of creating m-commerce by WAP were failures from the beginning and the second round of attempts were delayed by the financial crisis in the telecommunications sector. However, the mobile operators and content providers had success with a simple form of m-commerce in the increasing use of texting (SMS), furthermore the growth of mobile subscribers had continued creating more mobile subscribers than fixed line subscribers. Competition is fierce in the mobile communications industry both for manufactures and operators. The operators are competing with other operators and non-network operators in a market with continuously declining prices. As well as competing they also have to increase revenues since they spend much money on licenses for new 3G mobile communication networks and on upgrading the existing 2G network to 2.5G i.e. GPRS. The new market for the operators was (and still is) expected to be data transmission, mobile services and m-commerce, but the existing services are sparse and the users are missing. M-commerce seems nevertheless to be moving out of a laboratory research phase and the terminals are improving technologically, but there are still many problems regarding m-commerce such as solid business models, content, services and a mobile payment system. The role of the operators and the financial system, and the extent of integration between platforms, applications and hardware are unsettled in the m-commerce industry.

The actors in m-commerce are the operators, non-network operators, manufactures of mobile phones, financial organisations, content- and platform providers (including diversifiers of the mobile platform), retailers, users and regulatory bodies. In the case studies we find different problems when these actors are being combined. The case studies are[26]: Operators and the financial system in The Digital Mall; platform, content providers and the operators with Mobital and Mobile Gatekeeper; the operator and the functionalities for the users in Personalised Mobile Broadband Services (PMBS); the content providers and service

[26] The case studies are made from desk research and interviews with John Lundsgaard and Michael Skriver, Spar Nord Bank (The Digital Mall); Peter Balling, DCE (Mobile Gatekeeper, Mobital); René Rolander Nyggard, Net-Mill International (The mobile employee); Henrik Bruun, IT-Akademiet (Mobile Content); Yousef Jasemian, L.M. Ericsson (Remote monitoring of cardiac patients); talks with Alf Præstgaard, Sonofon (PMBS) and Kjeld Jensen from the Digital North Denmark (DDN) secretariat. Likewise is information used from more informal talks with participants and formal presentations in the DDN policy program during the DDN project partner seminars in 2001-2003 and the DDN healthcare conference in 2002.

for the content providers (platforms) with MobileContent; diversification of the mobile phone platform and content providers focused on other applications with The Mobile Employee and Remote Monitoring of Cardiac Patients.

3.1 Platforms and the move toward m-commerce: WAP in Europe and i-mode in Japan

In Europe the standard for access to and use of the mobile Internet or alternatively mobile reformatted 'normal' Internet pages, was Wireless Application Protocol (WAP). As analysed in Fransman (2002) the industry in Europe as well as Motorola (US) believed that in order to create new mobile Internet services it was necessary and sufficient to create a de facto standard protocol. An organisation, the WAP Forum was formed to create the standard, but it mainly consisted of mobile phone producers, while the service providers only had a small influence (Fransman, 2003). Soon the mobile service providers ran advertising campaigns for mobile access to the Internet and the large manufactures of mobile phones added to the hype of WAP. However, the development and production of WAP enabled phones was delayed and the market introduction was subsequently postponed[27]. When the WAP enabled phones finally were introduced in sufficient numbers, they had, at least initially, very little success. The consumers showed little interest and the early users were scared away by slow speed[28], no instant access[29] and a pricing model letting the consumer pay per minute. The first step in building the mobile Internet and its content was no success in Europe. WAP was early on declared a fiasco, but the simple service of text-messaging SMS that had some quiet years after its introduction in the mid-1990s has been a great success for the service providers. The number of WAP pages has been rather limited and potential possibilities for location-based services where the user is offered different services and targeted content, based on their geographic location have only been used sparsely. Mobile payment, which was believed to take off together with WAP, has also been delayed, partly due to problems between the operators and the financial system about control and division of profits.

In Japan the mobile Internet has been a huge success, the number of i-mode users, based on the 2G standard PDC, is more than 20 million and is still growing along with the first 3G services. Contrary to Europe the Japanese mobile Internet has a lot of content and many external content providers. In Europe the mobile communication service providers had introduced a pricing model for external content providers that let the former keep the larger

[27] The mobile communication industry seems often to be delayed in the introduction of new products. When the GSM network was up and running, the phones were delayed and the media made a big fuss about the missing phones. The WAP acronym was known as "Where Are the Phones?". The history keeps repeating itself in respect to the introduction of MMS enabled phones and 3G.
[28] The speed of data transmission using GSM is 9.6 Kb/s
[29] The customers had to set up their WAP access themselves

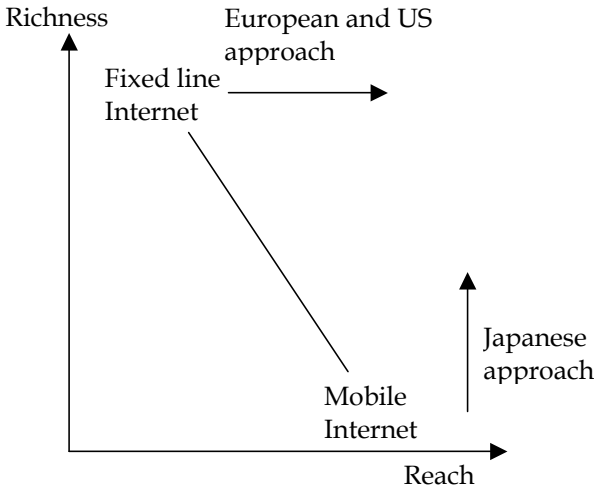
share of the money (30-40%). A pricing model that they also are using for logos, ring tones etc. and also seems to be applying to the 3G services. However, in Japan both the service provider and the external content providers earn money on i-mode. The consumer has to pay a monthly fee for I-mode access and data transmission to the operator and also a monthly subscription fee for each site they want to access. The operator collects the money and pays the external partner minus a handling fee[30]. This model seems to have had an important effect on the prevalence of mobile Internet in Japan. Due to the proprietary mobile network structure in Japan[31], the external content providers have to be approved by the operator and they can only offer content to its customers. The way of implementing I-mode has been different from WAP. It was not institutionalised in a forum and is much more directed at delivering a service. It has one-click access and is in that respect fulfilling a customer demand of entertainment or 'something should happen' all the time. The technical solution is not better than WAP, but the content and the management of the 'user experience' has been better, resulting in an immense success. The long transportation time to work in Japan combined with a lesser share of internet access via PC's are likely to be important factors for the success of i-mode. However, in Funk (2002) it is argued that these factors are only of minor importance, whereas the business model seems to be a perfect match with more cultural oriented phenomena.

Funk (2002) argues that the tradeoff between Richness and Reach for fixed line Internet and the mobile Internet holds some explanation in the different approaches to mobile Internet services, see Figure 3. The European and US approach has taken point of departure in the richness of fixed line Internet with a focus on business users and popular fixed line Internet contents. This has started negative feedback loops since the service providers are offering services that only a few customers want, resulting in poor perception of the mobile Internet leading to little investment in content and the infrastructure (Funk, 2002). By applying popular fixed line Internet services to the small, until recently non-colour screens, with slow speed a lot of the richness is lost and the mobile phone is more or less in direct competition with the PC, that has high speed and large colour screens. The Japanese approach has been different focusing on simple services and content. They started with entertainment and focused on young people. The major application is email and the main content is still entertainment. Only small parts of the Japanese services and content are available on the fixed line Internet and are not very popular since they are too simple compared to the normal richness of the Internet (Funk, 2002). This has, however, created positive feedback loops, where functionality for the user has created a demand for better content, services and phones e.g. colour screens, cameras and other functionalities.

[30] NTT DoCoMo charges a 9% handling fee

[31] The mobile phones are operator specific and cannot be used on other networks.

Figure 3 Japanese versus US and European approaches to the mobile Internet



Source: Adapted from Funk (2002)

The initial failure of WAP and thereby the failure of m-commerce, was also hit by the prolonged crash from the summer of 2000 in Dotcom and the successive turmoil in telecommunications and mobile communication in 2001. Since e-business no longer was a buzzword, it affected m-business negatively. The European telecommunications operators had spent €100 billion on licenses to run 3G networks and had huge debts, and saw the financial market turn against them with dropping share prices. The technology that they had agreed on was harder to implement than expected, which caused delays in the roll out and in expected revenues. As a result the operators began focusing on their core business and somehow kept their non-motivating pricing mechanism for any potential m-business.

3.2 The state of m-commerce – hurdles and success

The operators had an unexpected success with the platform of text messaging (SMS) in the late 1990s. The technology and service had existed on the marked for a few years, when the users began texting and the number of SMS skyrocketed. The troubled operators, however, tried to capitalise on the success of SMS by overpriced text messages. The overpriced text messages consists of a text message that is priced higher than the normal price since it is providing a service by enabling the user to example get new ring tones, logos or to participate in competitions or let the user vote in TV shows and other forms of entertainment. This business has evolved to be an important revenue creator for the operators, although it is a very simple form of m-commerce. Some non-operator content providers have entered the marked and there is some competition, but a major share of the overpriced text message still goes to the company collecting the money and not the content

provider[32]. Since the price is high and mainly targeted towards young people, the possible demand for these services is of a limited size.

M -commerce is still at an early stage and there seems to have been a confusion of 'what is possible' and 'what people need'. There has been a mismatch of consumer demand and the expectations of people downloading movies to show on a mobile phone with a small screen or using WAP. The new technology and devices where not socially accepted and adapted as soon as they were introduced to the market. The industry has in some degree neglected the customers desire for social connectivity in favour of an anonymous world of data. The m-commerce services are still very much like research in a laboratory and the technology and services need to be socially shaped and the users need to be somehow "educated" in or made familiar with using the services. The strategy of the Danish operators seems today to be taking a starting point in the success of SMS, where they hope to persuade the consumer to begin sending picture messages (MMS) with their camera enabled mobile phones. By letting the user send pictures the operator hopes that the users will evolve to use future services of 3G and 2.5G (GPRS). The MMS technology was, however, less simple to adopt technologically than expected which caused delays. The networks needed updating and the phones were not compatible as promised, resulting in problems sending a MMS from one phone brand to another phone brand and from one operator network to another. The phones were missing or few, but expensive and the operators had problems in pricing models and agreements regarding pricing and transfer between different networks.

The m-commerce has been in a laboratory research phase with no applications and no users, with a missing social connectivity. But even if m-commerce initially has been a failure, the ongoing technological improvement of the mobile phones e.g. colour screens and data transmission combined with the social shaping of the use of mobile phones, might reveal that the 'fact' of m-commerce being a failure only is an 'opinion' and not a fact. In relation to direct m-commerce there is an increased diversification of the mobile phone platform. The phone is being used to different services and tasks that are not 'perfect m-commerce', but exploring the *always-on* feature of the mobile phone. The diversification is bringing wireless into existing business and also changing and creating new business. This is interesting since the shift from voice only to data transmission and m-commerce raises the demand for content. No users will use the mobile Internet if there is no content and the content providers have a hard time entering a market with no customers. Individual customers, firms and operators seeking growth in data transmission will demand content. That is a demand pull and a supply push.

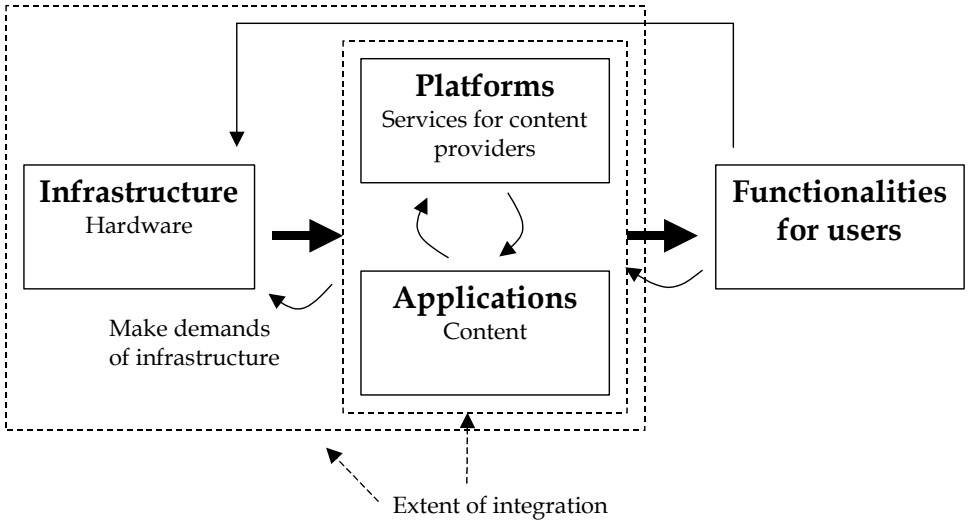
Content is a generic term and consists of different types of applications:

[32] The typical price is 1.35 € of which 20% is value added tax, 30% goes to the operator, 30% to the aggregator, and the rest should cover development, burn rate and profits. The net cost of a SMS sent by a non-operator is approximately 0.018€.

- Real content production e.g. news, movies, text, information etc.
- Games and other animated entertainment
- Other applications

The content builds on different platforms that enable access to the content. The platforms are ranging from the more generic types like WAP and SMS, to platforms building on these i.e. within the WAP standard. The platforms also consists of services for the content provider or a content 'infrastructure' that is the technological shell for presentation of real content such as software code to content management, streaming and billing. The platforms and the content are interrelated make demands of the infrastructure and leads to the functionalities for users. The m-commerce industrial environment is shown in Figure 4.

Figure 4 M-commerce industrial environment



The extent of integration between platforms, applications and infrastructure is still not settled in the m-commerce industry. All of the three can be integrated, where the hardware manufactures define and develop the platforms, and also supply the content. That was the situation until recently, before the introduction of WAP, in which the manufactures delivered the mobile phone with preinstalled applications. Infrastructure and platforms can be integrated with applications separated. The last situation is all three separated, where the industry is divided between several suppliers of hardware, software, services and content. The extent of integration depends on the actors and the demand from the users, which is depending on the functionalities. The manufactures want to be suppliers of total service with infrastructure, platforms and applications, but the operators also want to control the market for platforms and applications with a minor role to the manufactures. In the same time many new actors enter the market for platforms and/or applications. There are, however, several hurdles before m-commerce can move out of the laboratory research phase and evolve.

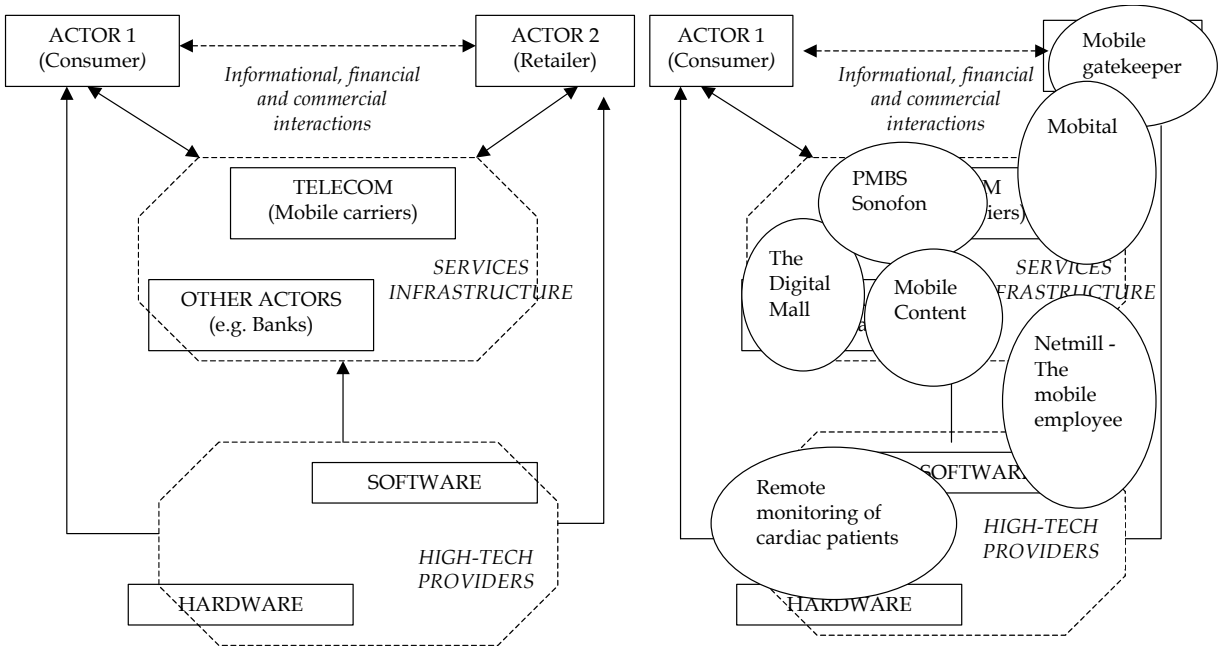
Two of the initial hurdles in m-commerce seem to be business models and payment systems. Before it becomes commerce, some kind of payment or money transaction is needed, except from sponsored services. This payment can take various forms either on the monthly telephone bill to the operator, subscription fees or direct mobile payment etc. The operators have had a head start in m-commerce, since they have easy access to the customer and have a lot of information about the customer and his location. The operators also have a functioning payment system and with the initial price model for access to the mobile Internet – paying per minute – they had a lot of control of the market. GPRS and other systems with always-on data transmission facilities make it cheaper to access the mobile Internet, by paying per byte of data transmission, but the payments for the services or goods are still unsolved questions of how much, who and how.

3.3 Industry structure

The actors in m-commerce are the operators, non-network operators and manufactures of mobile phones, financial organisations, content- and platform providers (including diversifiers of the mobile platform), retailers, users and regulatory bodies. These are connected in a wide variety of ways in which everybody have contact with the users. This contact has, however, so far not been used to create a successful mobile Internet focusing on value added for the users.

In García and Steinmueller (2003) the m-commerce industry is described as being formed by a service infrastructure supporting mobile transactions between different groups of actors and high technology providers that supply service providers and actors with technology that makes the mobile transactions possible, see Figure 5. The high technology providers both provide hardware and software. The service infrastructure contains mobile operators, financial and other organisations. The actors can be consumers, users and retailers i.e. firms selling ring tones, logos, and information services directly to the consumers.

Figure 5 Case studies in the M-commerce industry structure



Source: Structure adopted from García and Steinmueller (2003).

Figure 5 is focused on the actors and their possible interaction, but since they are connected in a variety of ways, it has limited explanation power regarding the interesting complex of problems in the industry. Many of the problems in the development of the m-commerce industry relate to the combination of these actors and the extent of integration between infrastructure, platforms and applications. Especially within the m-commerce service infrastructure the extent of integration between platforms and application is unsettled. The control of and access to the users are creating unsolved problems, since all the actors: operators, non-network operators and manufactures of mobile phones, financial organisations, content- and platform providers, retailers, users and regulatory bodies are connected to each other. In the case studies we look at different cases where the different actors are cooperating or competing. From the case studies we find various problems when these actors are being combined.

3.4 Operators and the financial system: The Digital Mall

In the late 1990s and early 2000s the operators and the financial system were looking for new business opportunities and markets. The operators, in this case a large local based mobile communication service provider with more than 1,000 employees, wanted to enter m-commerce, but had problems since regulations prevented operators from being a bank, that is, they where not allowed transferring money between different users and let the user have an account. The operator could, however, collect the money on the telephone bill. The financial system, in this case a large local bank, wanted to make money on the Internet and

had customer accounts and systems for transferring money, but regulations did not allow them becoming an operator making mobile payments. Cooperation between the two sectors is still missing in general, partly because of hesitating operators, difficulties in deciding on sharing of costs and profits, and control of the payment system.

The bank had in cooperation with the operator introduced WAP banking in 2001. The WAP bank was integrated in the bank's home banking system and allowed the customers to see balances and transfer money. The bank and the operator wanted to push the use of WAP banking and offered all the bank's more 1,000 employees cheap WAP enabled phones and subscriptions. The service did never become a success and was closed in August 2003, while their Internet based home banking has been very successful.

In 2000 and 2001 the operator and the bank had very good relations. The bank wanted to use its bank engine to create new projects on the Internet and the operator was very interested in telephony, payments and creating traffic on their network. The bank had the idea when the Digital North Denmark (DDN) ICT policy programme was launched. They used their social network and contacted the operator that was interested. A logistics company, a supermarket chain, and a software company also joined the project. The bank was supplying the financial transaction system; the operator was involved in the network and Internet side together with the software company; the transportation company was to do all the transport and the supermarket chain was to deliver the goods, but also contribute with knowledge regarding the very complex logistics of groceries. By combining the competences of the members a digital mall was to be developed, which should be the electronic shopping site on the Internet preferred by citizens of North Jutland.

The mall was intended to attract "Business-to-Consumer" (B2C), "Business-to-Business" (B2B) in the industrial sector and to be the site where the state, county and municipalities would undertake their purchases. "The Digital Mall" was developed with a focus on North Denmark but later the concept could be extended to the remaining parts of the country. The philosophy in the project was: Think big and keep expanding your market continuously - with a focus on a future use of the Mobile Internet. It was planned to enable mobile access and mobile payment. The main idea was to create a common portal where different shops were collected. The idea has also been used in other places. To overcome some of the problems with e-commerce such as trust, payment and return policy, they wanted a single standard payment system and a single return and complaint site. Thus signaling that e-commerce is simple, the partners and the payment system can be trusted and if anything goes wrong the return policy is shared and easy. They wanted well-known brands and high security.

The project, however, ended shortly after the start basically because a focus group approach based series of interviews with potential customers clearly indicated that consumers were not willing to pay the extra costs for the new services. One of the problems

is that the revenue on groceries is quite low since the market is very competitive and even though the potential customers would like to use the Digital Mall and also pay extra for the service, the expected revenue was not sufficient to make the project profitable. Other problems were related to creating a high volume to cover the marketing costs, which did not seem possible in the short run without a combined effort in the region from both public and private organisations

As a spinoff idea from the project the bank and the supermarket chain launched payment by the mobile phone in the supermarket. The system is working fine (a update of payment terminals in the shop is needed), but is only reaching a very limited number of users. The mobile payment system has a major competitor in the widespread use of a common Danish debit card system Dankort[33]. This system has existed for 20 years and has been free to use for the customer. The card has had a huge success with the number of transactions growing every year and a total of 3.3 million cards existed in 2002[34]. It can be used in most shops (102,000 in 2002) and approximately 98% of the transactions were made through electronic terminals.[35] The card is also being used to make payments on the fixed line Internet for many pay-as-you-go mobile operators. The high diffusion of the card combined with the frequent use has made it a routine for the customers, and the pricing model has made entry for alternative systems very difficult. The mobile payments system probably needs to seek other markets than the larger transactions in shops. The forthcoming introduction of a new upgraded version of the Dankort might, however, offer some opportunities for mobile payment systems, since the customers have to pay a small fee for every transaction and the existing terminals have to be replaced.

3.5 Platform, content providers and the operators: Mobital and Mobile Gatekeeper

The pricing mechanism set by the operators has limited the number of content providers and m-commerce. The overpriced SMS with logos and ring tones and other services have, however, been successful, but the high pricing with the major part going to the operator has hampered entry. These conditions have lead companies to find alternative ways around the operator. Thereby they are adding to the fear of the operators that they would be 'excluded 'from the potential lucrative content market, like it happened to many Internet Service Providers (ISP).

[33] The payment with the Dankort can by done by sliding the card through an online terminal in the shop and using a four digit pin code as 'signature' or using a mechanical device or online terminal where the user has to sign on a bill.
[34] There are some restrictions before acquiring a Dankort e.g. the user must have a bank account, be older than 18 etc. It is possible to have more than one card.
[35] In 2002 the cards were used in approximately 477 million payments. See www.dankort.dk

Mobital is a small company founded in 1999. It started with the rationale that WAP was made by web designers and not phones designers. They developed an Internet portal, financed by banner commercials, allowing the customer to create logos and ring tones by use of the fixed line Internet and then download (SMS) them to the mobile phones. These ring tones and logos also became accessible to others once created. From the beginning the service was free and the company paid the cost of the SMS. The revenues for the operator were only the price of SMS and not the extra charge for the payment. Without commercials the company grew rapidly and costs exploded, which lead the company to put restrictions on access. The user had to sign in and give some personal information. As a result the growth rate stopped for a moment, but continued afterwards. Then they introduced a point system where the points could be used to pay for logos etc. The points are paid by debit/credit cards on the fixed line Internet[36], but there are several ways that the uses can earn point through competitions and it is still cheap compared to overpriced SMS. Gradually the portal increased the number of services offered and grew into a community with chat functions, games etc. Community building has become very important for the company and they are trying to stay in the overlap of community, content and development i.e. not developing technical solutions without relation to both the content and the community. The firm also sells user specific commercials to its customers. It allows different firms to make a targeted advertisement campaign to its users[37].

In two years the company has evolved from portal services to development of mobile IT solutions and multiple related services. They have a large share of the young mobile phone users as customers - almost 300,000 users in Denmark and their success has lead to contact with operators who want to buy various software solutions. The success is built on close contact with users, where user demand for services has directed the development. Bypassing the operators is also being used in the introduction of MMS services. By sending the pictures using GPRS data transmission to a network host, place it on the Internet and SMS the receiver a password or a link to the site, then the receiver can decide to download the picture to the mobile phone using GPRS data transmission. This is much cheaper than a MMS and resolves the possible problem of a receiver not having a MMS enabled phone.

The company has been successful in developing platforms and applications, which has attracted the attention of firms wanting to enter the m-commerce industry, but also from the operators. They are selling platforms to the operators and also to content providers, which could indicate less integration of platforms and applications in the industry. It also is an

[36] It is also possible to pay by the mobile phone, but it is more expensive for the customer.
[37] An example is a burger chain that only has very few customers some hours during the afternoon. The campaign is targeted users of Mobital living in the area who receives an SMS saying: 'show this SMS at the counter, and get a discount on a burger'.

example of a platform provider not being an operator, which also allows for the content providers to be separated in some degree from the operators.

3.5.1 Tourism and content

Mobile Gatekeeper is a project in the DDN policy programme. The participants are Mobital, an operator, entertainment/content providers and firms from the enabling technologies e.g. Java and data compression techniques. The general purpose of the Mobile Gatekeeper is to enable users to search, process and receive predefined cultural information from any technological platform. For example, prior to a visit in North Jutland, users should be able to retrieve information and define the type of information required via the Internet. During the actual visit to North Jutland, data and information is to be available for subsequent processing and use. The project focuses on the use of mobile phones. Much of the information is existing information made by existing non-mobile content providers. The information is being made user specific with easy access focused on events and offers within a given time period. The service is not offering mobile access to existing web pages, but creating user specific content adjusted to the mobile phone. The project and content are thus created with the purpose of keeping and attracting tourists to North Jutland. Access to the content will be free except from the data transmission charge and the financing partly based on commercials such as sending a SMS to some users in an area, giving discount to entrance fees in amusement parks etc. The success of this project is still to be seen, but it signals that the platforms and content can be separated.

3.6 The operator and the functionalities for the users: Personalised Mobile Broadband Services (PMBS)

Sonofon is the second largest mobile communication service provider in Denmark and was founded in 1991 as a joint venture between GN Great Northern (DEN) and Bell South (US), now owned by Telenor (NOR). Sonofon participated in the DDN programme with a project trying to be in front with personal mobile broadband services in 2001-2002. The other partners in project on PMBS were Nordjyske Medier (a local media company running a radio station, a TV station, newspapers etc.) and AM Production Multimedia (ICT company working with various software solutions and production of TV programmes etc.). The two latter companies are subsidiaries of the same holding company. The companies were all working on the idea of delivering content to the consumer marked on larger mobile terminals with a high bandwidth. The test was supposed to be using front line technology and creating and testing the future home mobile broadband services. It used newly developed small portable monitors (PDA's and web-pads), which were computers operated by the finger touch, combined with state-of-the-art wireless network technology and the control of news and other information to create a strong personalised tool. The project used

the latest facilities for the wireless transmission of large volumes of information like GPRS and FWA[38]. The project was from the beginning technology-driven, but the idea was to include many different kinds of content to the user and introduce a billing system. The content and different services were to create a demand-pull for the solution. The technology used was expected to be state of the art and the content plentiful, but already in the early phase of the project the ambitions were scaled down.

The role of the partners was very clear from the beginning of the project. The operator was to supply a central server on which the test users could sign on with their mobile terminals through the wireless network. The server was running a general PMBS platform. AM Production Multimedia was to connect the systems of the content providers with the operator and develop a user-friendly user interface and software for presentation of content on the various terminals. The media company and other external partners were to supply the content.

The companies made the experiment with technologies and equipment that were new and had many early service-life failures. The terminals were almost nonexistent even though they were on display from the manufactures. The delivery was delayed and when they arrived they were less capable than promised. The project started in February 2001, but was delayed and the test did not begin before mid-November 2001. The terminals were Web-pads and PDA's, which were connected to a PMBS server by FWA, GPRS or cable TV[39]. The PDA is a personal terminal compared to the web-pad that could be used by the entire family. In the test families each member of the family had their own personal logon allowing them to personalise the setting and content.

The terminals used a common PMBS interface running on an application server that also was used for security, passwords, personal profiles etc. The platform was combined with applications like video compressing and web-clipping software (removing graphics and adjusting web-pages to the PDA). A variety of content and services were collected and added to the PMBS portal, but it was also possible for the users to surf on the Internet. The services, content and applications on the PMBS portal were news, sport, weather, traffic, shopping, food recipes, games, calendars, TV-guide, cinema guide, e-mail and a website for searching telephone numbers and addresses etc. The project partners had to develop a lot of the software themselves, since the available software was insufficient. They developed an application for gathering of content from many different content providers running on various systems and converting the content from one platform to another platform. In this

[38] Fixed Wireless Access is a terrestrial system for radio access in the 4 GHz and the 25 GHz frequency bands. It is the use of wireless technology to replace copper to connect subscribers to the telephone network and the Internet. It consists of a single parabolic antenna in the house connecting the household to the FWA operator.

[39] The web-pad has a large finger touch sensitive screen and has a wireless connection with a base station in the house, which is connected to the Internet via FWA at 1Mb/s. The PDA has a smaller screen and is connected to the mobile communication network via GPRS and has subsequently a wider range.

process they had to secure that the users experienced a stabile and quick responding system. The users could access the content on the PMBS portal, but also on the Internet. They had personal logon and profiles, which allowed them to personalise the settings and have easy access to the preferred content. The personalised content and profiles were created to increase the use of the terminals and create user-friendliness.

The use of the terminals was very high in the beginning of the test, but decreased slowly during the period. Especially the users with a large screen terminal were the most active users and the content on the portal was the most used. The web-clipping software was found very useful for accessing content from the PDA's. It was also necessary for the entire system to be stabile to create a positive user experience because if a user had some problems with the hardware it seems that the entire system was failing from the user's point of view. The simplicity of the system, interface and applications were considered very important for the user-friendliness and thus the success. They found that the users had fewer problems with the three buttons web pads compared to the nine buttons PDA. The arrangement and simplicity of the content were also important for the success e.g. the use of web clipping remove most of the conspicuous content (flash, commercials and colours etc) from the Internet web pages, but it enhanced the user experience, since it made it more visible on the small screens. The users liked the mobility of the terminals and the preferred content in the test was news and e-mail.

The project apparently did not have any major impact, but was still considered to be a success. The participants accepted the project as an exploratory test of a vision, with a focus on gaining experience on the future personalised mobile broadband services. However, many problems blurred the test such as even if the technologies and services seemed to exist and were supposed to be working, they were still full of errors and had many limitations. There seems not to be a demand for the PMBS services at present. Many of the problems were on the technology side, since it did not fulfil the user needs and behaviour, and a solid business model is missing. The users focused on simplicity, user-friendliness and stability in the network, terminals, content and functionality. These experiences are similar to the general m-commerce experiences and problems. In relation to the daily use and the consumer marked, the users did not find the terminals and services a 'must have', which set extra requirements for the PMBS services since they have to compete with routines and habits.

The operator has not continued to pursue the PMBS services in its present format, but the cooperation with the content providers and the experiences were considered to be positive. However, to what extent the experiences and the test of personal mobile broadband services have been adopted in the development of activities like m-commerce in the company is uncertain. The content provider and the software developer have used the application allowing them to present content regardless of the receiver device and across platforms in

the launch of a new TV channel transmitting mainly local news 24 hours a day and a free daily newspaper. The application allows them to transport and adjust the content to different media types e.g. newspaper or TV.

3.7 The content providers and service for the content providers (platforms)

L.M. Ericsson (mobile phone manufacturer), Sonofon (operator), NOVI (science park) and IT-Akademiet (ICT consultancy firm) created MobileContent with the aim of positioning and developing North Denmark as the content centre for the mobile Internet. North Jutland was renowned for its manufacturing of hardware for the telecommunications industry. MobileContent wanted to be the environment for focusing on what the mobile phone can be used for. There is quite a leap from producing hardware and content for the Internet to producing content for the mobile Internet. MobileContent wanted to facilitate this change by making the resources needed available to the firms. The work will be carried out by knowledge sharing and collaboration, primarily initiated by establishing fora for this purpose, creating networks, a innovative environment, test facilities, and education. MobileContent wanted to be an international qualification centre consisting of ICT firms via a close collaboration with operators, manufacturers of mobile phones and infrastructure as well as content providers.

The company was founded in early 2001 and was soon hit by the crisis in mobile communication. There were plenty of firms and persons with ideas related to mobile technologies, but only a few firms who wanted to invest. MobileContent focused on two activities: entrepreneurs and helping existing firms developing their business with mobile technologies. Due to the crisis the company focused mainly on the latter and also found a niche as a network initiator by bringing firms with ideas of m-commerce or content together with firms creating the services. MobileContent did also run tests of content on 2.5G and 3G networks, but the slow development of m-commerce and 2.5G and 3G technologies has made the company work with more simple services e.g. using SMS technology. The role of the partners in the project has both been technological, but also as advisors. They were all a part of a business advisory board that evaluates the ideas after an initial selection by MobileContent. The advisory board selects prospective ideas and begins cooperation with the people behind the idea and helps them with the next steps of developing the idea. The company has thus found a business in servicing and testing possible mobile content companies.

A big problem is that to write content for early generation devices one has to be quite technologically knowledgeable, but technological knowledge may come at the expense of media savvy, so the problem is how to integrate 'style and fashion masters' along with 'technology gurus' – the very different standards for judging are important. This also relates

to the problems experienced with the early attempts at m-commerce, which mainly where technology driven. The MobileContent project tried to overcome this problem by allowing content providers to concentrate on the content and support them in creating business models and solving technical problems. The business plan for the company was targeting a role as an aggregator for mobile technology solutions i.e. platforms and applications. They also worked as an aggregator selling and implementing applications developed by other companies e.g. E-mail2SMS that makes it possible to send SMS messages from the normal email programme, mobile marketing and terminal management etc. The company is a part of the service infrastructure as displayed in Figure 3 and could perhaps get an important role in the development of m-commerce, diversification of the mobile phone platform and mobile technologies by being a kind of a broker and selling standardised product solutions, but this still has to be seen.

After the end of the project period, the project was closed down as an independent business unit since it was not profitable. The activities continued as a part of the mother company IT Akademiet. The project succeeded in creating networks between content providers, software developers and operators, but never created a sufficient number of tests of applications. It was hit by the crisis that reduced the number of mobile applications. Likewise the operators put requirement of the test being run on their own network.

3.8 Diversification of the mobile phone platform and content providers focused on other applications

The high penetration of mobile phones has lead firms to seek in diversification of the mobile phone platform. The mobile phone is integrated in the business, through applications that increase service and minimise costs or support knowledge sharing. These are using the advantages of the mobile phones' long reach and 'always on' feature. The functionalities for the user are the main driver, but the target is not the mass marked, but more narrowly defined groups. The market seems to be somehow neglected by operators, but it offers many opportunities.

3.8.1 The Mobile Employee

Net-Mill[40] was founded in 2001 as a subsidiary of a North Jutland based firm Lyngsø Industry. They wanted to work with the mobile Internet and began making WAP-portals, but there were no market for these, so they diversified into making mobile solutions for logistics. By using a scanner for a GPRS enabled mobile phone and barcodes, they have developed a system for online and mobile time registration, stock control and other logistic related services. The application is browser based and can be used on various mobile devices

[40] http://www.denmobilemedarbejder.dk/dmm/index.jsp

e.g. laptop, PDA etc. In this case study the focus is on the solution including a mobile phone. The mother company Lyngsø Industry's main area of activity is logistics solutions for industry, airports, postal and parcel post. The activities of Net-Mill are combining the competencies of logistic solutions and adding the knowledge base of mobile Internet or mobile data communication. The company participates in the DDN programme with the project 'The Mobile Employee'. The product was to make the working procedures easier for both the company's mobile employees and for its office staff. The traditional, manual time sheets were replaced with bar codes, and the registrations automatically transmitted to the company's financial system, when the employee used the scanner. Mobile stock management, immediate invoicing and planning are also a part of the system.

It is a problem in the small and medium craftsman firms that the registration of the work is often faulty. The craftsman is usually doing all the administrative work regarding specifications of bills etc. in the evenings, which is problematic, since they often only have insufficient handwritten notes to complete the registration work. This is time consuming and the craftsman looses money on wrongly time registration and on forgetting to put the used spare parts on the bill. Another problem is stock management, since the employee is mobile he has to carry all the spare parts in the van, but it is often a problem that he runs out of certain parts and has to drive back to the firm and get it. Using the system can solve these problems.

The product consists of a mobile telephone with a small bar code scanner attached. The scanner is developed by a L.M. Ericsson spinoff in Sweden and was originally designed for the consumer market. It can easily be attached to the mobile phone. The mobile phone is running on the GPRS network, which allows the user to be always online. The idea of using a barcode scanner for logistics is well known, but the systems are quite expensive and the new scanner attached to the mobile phone has several advantages since it is online, cheap and mobile. The mobile scanner is not limited by the memory of the scanner, which is a problem with traditional handheld scanners since it is online it 'knows' the entire list of commodities. The mobile phone is logged on to a server at Net-Mill, which is connected with different actors depending on the wanted service. It can be connected with the computer system at the firm, the warehouse, and the wholesale supplier.

Net-Mill has developed the platform and the database, but they are also developing the applications. The platform is the most important part of the system since different applications can be added depending on the user need. The main issue is user friendliness and the system is kept as simple as possible. The platform is fixed, but the content can be changed between different business segments e.g. carpenter or plumber, but also within the segment such as the master and the apprentice and according to the access device, i.e. desk top PC or mobile device. Using a scanner whenever a task is done or a spare part used collects data. The data is automatically continuously transferred to a server where the data is

computed and presented in a browser programme for the user. When the user verifies the data, it is automatically transferred to the firm's financial system. Since the application is browser based, all users with an Internet connection, username and a password have access to the application. The application is build up in various modules that cover different user needs, which also allow the firm to put together the needed modules to an individual system. When the system is online it is possible to adjust the individuals units to the individual user in the company. User-friendliness and user adjustment is very important for the success. If the system is not easy to use and seems complicated, the user will stop using it or loose productivity. As a result the application is adjusted and the users do not see the same on the screen. This feature is important since the screen size on the mobile phone is very limited and the user do not want to be confused by functions and options not needed in the daily work. The system is flexible and can be adjusted if the user needs a more complicated system.

The platform is flexible and can be adjusted to different industries, but the first application has been targeted at the small craftsman firms. They have cooperated with a large wholesale of metal products company. The cooperation has been focused on the small or medium plumber firms that are customers in the wholesale company. The system has been tested on some of the experienced and demanding customers, who want to have their vans organised and to have stock control. The wholesale company is contributing with industry experience and customers. After the test period the wholesale firm is going to sell a standard package of the system to their customers. They can install the system and modify it for the customer. Many of these are small firms that can use a standard solution.

The main idea behind the system is using barcodes and data management to organise the work for the plumber. Barcodes have been added to all the work functions and the user just has to scan the barcode, add a number or some comments if needed, and verify the action. When the plumber leaves the home/firm he scans a barcode named 'start' from a list where the work functions are specified. The mobile phone displays the selected work function and he controls the time and presses verify. When he reaches the customer he scans the barcode 'beginning work' and verifies. All this information is now stored in the system and at home in the firm they always can see where the worker is. The worker is not under constant surveillance since it is only possible for the boss to see what the worker has registered after the worker has verified the bill. If the job takes longer than expected it is possible to warn the last customer that day or reschedule etc. The system requires some reorganising in the plumbers van, since the equipment and spare parts have to be in order. A barcode is attached to the different boxes with parts (they also have a book with all the barcodes) and when the plumber uses a spare part he scans the barcode and it is registered in the system. The user does not necessarily have to scan the individual parts during the work, he can also do it afterwards. When the job is finished the employee either scans the barcode for finished

job and he can see the total work time and the used parts, which he has to verify or add changes. It is now possible to get the bill faxed to the customer or let the customer verify the bill on spot. The system can be integrated with the firms' existing financial system. The collected data can be processed in different ways depending on who is connected to the system. The worker can later on sit at home at the computer and control the work of the day and the manager or the financial department can control the number of work hours and use it for calculating wages. If the system is integrated with the wholesale supplier it is possible to keep control of the parts used and stock in the van, and order new supplies if needed.

Several different applications can be added to the platform. Their first customers are in the plumbing business, but they are developing new applications for other businesses, e.g. carpenters and lately for a large producer and distributor of alcohol. The system is on the market and the direct competitors are few, because of the complexity of the platform. Many of the competitors are focusing on single markets with very narrow solutions that are not online.

Since the system requires a higher level of organisation in the daily work of the user and also of the equipment in the van it is not all tradesmen who can use the system and get productivity gains. The user needs to be willing to adopt the changes in the work routine. Tests of the system have shown that the users consider it to be an advantage in the daily work and user-friendly. The system, however, has some disadvantages or limitations when it is necessary to fill out more complex documents that are easier completed with a ball pen. The solution has been to include an electronic pen together with the mobile phone in the system. The pen recognises the document and the individual boxes, and is transmitting all the registrations electronically via the mobile phone to the server. The pen still functions as a ball pen and the worker can immediately see the result of the physical paper. The pen also allows for the customer to sign for packages that automatically become registered electronically.

3.8.2 Remote monitoring of cardiac patients

Modern health services seek to put resources to efficient use by the improvement of existing methods of diagnosing and treatment. Today diagnosing and treatment are often performed during hospitalisation. These days of admission are costly to the health budget and it is found attractive to assess the scope of moving treatment from the hospitals into the patients' homes. The general purpose of the DDN project on "Remote monitoring of cardiac patients" is to establish a new telemedicine method of examination of cardiac patients to reduce the demand for hospital bed-days, to bring down the costs of the health sector and, in some cases, to optimise the treatment of the patient. The project includes design and development of an intelligent and reliant mobile teleelectrocardiography system for patients with hearth rhythm disturbances using mobile phones with GPRS and Bluetooth technology.

By using Bluetooth and GPRS the patient becomes mobile and there is no installation and no need for a visit by a technician. The Bluetooth technology is safe by encryption and the frequency hopping is limiting possible interference and increasing stability and security. The aim is to build a telemedicine system for the continuous wireless transmission of cardiological signals from the patient's home to the Cardiological Department of the Hospital of Aalborg. This prevents or cuts down admissions and the number of bed-days, and the effect from the treatment can be assessed under the conditions normally experienced by the patient. The patient will probably experience a better quality of life since it reduces uncertainty and the number of hospital days, and improves the treatment. The existing treatment system also has a two-month waiting time and further delays in the processing of results etc.

The participants are L.M. Ericsson (mobile phone manufacturer), Sonofon (operator), Danica Biomedical (manufacturer of electrocardiogram (ECG) equipment owned by General Electric), the Hospital of Aalborg and the County of North Jutland. L.M. Ericsson delivers the mobile communication technology and owns the software platform and the research, development and design, Danica Biomedical implements the module in their ECG equipment and is also doing the integration and design with regard to the ECG processes. The hospital is testing the equipment and the role of the operator is to provide a stabile and reliant GPRS mobile communication connection, which is crucial for the success of the project. If the connection is not stabile it will effect the reading of the signals, but more importantly giving the patient a feeling of it not working probably and not being as secure as staying at the hospital, which will make the project a failure. This has set some technical requirements for the operator and has given the operator the opportunity to test the network with an advanced user.

The traditional treatment method of patients with heart rhythm disturbances has been monitoring with short-range telemetry in the hospital for two to five days. The continuous monitoring is important due to the registration of tendencies to pause in the hearth beat, too high or low average hearth rhythm in a minute, warnings of virulent hearth rhythm disturbances and short-term very fast hearth rhythm frequencies. The treatment is rhythm-regulating medication. The hospitalisation procedure requires many resources and it can take many days to determine the appropriate treatment i.e. medicine. The effect of the medicine has proven to be affected by the patient's activity level[41], which makes correct medication problematic, since it is only possible to monitor the patient in a non-active position at the hospital. The remote monitoring gives the opportunity to evaluate the effect of the medicine in daily live activities and ensure the long time effectiveness of the treatment.

[41] The medicine is very effective for patients with a low activity level i.e. the situation in the hospital, while the effect is more uncertain during activity. When the patient leaves the hospital and returns to the daily life the activity level rises, which effects the medication.

The quality of the treatment improves by monitoring of the effect of the medicine, but also the length of the continuous monitoring.

The known technology for outpatient treatment is recording with a tape recorder, and mailing the tape to the doctor. The doctor analyses the recorded heartbeat and prescribe medicine or hospitalise the patient. If the patient has to be admitted, it has to go via the administration that contacts the patient. The process is very time consuming, error related and has a long response time. Competing systems using the mobile phone do exist, but these are not online, and only recording for a few seconds at the time and then transmitting the recording to the hospital.

The remote monitoring of cardiological works by using small electrodes placed on the patient's chest to register the hearth beat. This information is transmitted online to the mobile phone via Bluetooth signals and sent via a GPRS network to a server at the hospital. The system registers information on the hearth rhythm, blood pressure and the amount of oxygen in the blood. The hospital personnel analyses the data and remotely monitor the patient's condition. The patients put on the electrodes themselves, get the medicine and the monitoring can begin. The doctor confers with the patient over a telephone and a health visitor visits the patient occasionally. The system is still being tested, but it is estimated that 50% of the patients can be monitored from home with the new system. The medico electric monitoring system is an existing system that has been technologically improved by using the mobile phone and thus been giving a much longer range and has become more flexible.

As a numerical example on the possible effects, the hospital serves approximately 200,000 people and has 900 cardiological patients with hearth rhythm disturbances hospitalised every year[42] in two to five days. The average costs is approximately 400 € per patient per day and the estimate is that half can be kept at home. The hospitalisation days per patient can be reduced (expected 1.5 days on average) and scaled to the entire country the savings will be considerable even with the extra costs taken into consideration (e.g. mobile communication and mobile phones). The technique could also be applied for other monitoring of hearth beat situations, e.g. to transfer ECG data from ambulances to the cardiology department.

3.9 Discussion

M-commerce seems to be moving out of the 'research lab' and into the market. Many of the new applications are, however, not directly m-commerce in the sense of buying via the mobile phone, but diversifications of the mobile platform. The use of and penetration of mobile phones keeps increasing. The mobile phones are becoming more technologically advanced in terms of colour screens, higher speed, cameras, higher speed and memory etc.

[42] Approximately 40% of the cardiological patients in the hospital have hearth rhythm disturbances.

The operators are also introducing new 3G mobile technologies, with high bandwidth allowing more advanced services, with more or less success, but the m-commerce is still lacking. The process has mainly been technology driven, where user education and social shaping of technology has been neglected. This is closely related to the extent of integration of infrastructure, platforms and applications and the role and power of the actors in the industry.

Two of the initial hurdles in m-commerce seem to be business models and payment systems. Other problems in the development of the m-commerce industry relate to the combination of the different actors and the extent of integration between infrastructure, platforms and applications. Especially within the m-commerce service infrastructure is the extent of integration between platforms and application unsettled. The control of and access to the users is creating unsolved problems, since all the actors are connected to each other. The operators are still controlling the access to the customers and are not willing to allow others into the market. A common mobile payment system is also missing, mainly due to disagreement between the operators and the financial system. While these problems are unsolved, m-commerce is only evolving very slowly and new entrants and existing firms are working on systems bypassing the operators.

The m-commerce is, however, in spite of all these problems still evolving very slowly through more simple applications based on the SMS technology, but also in combination with Internet based solutions. Diversification of the mobile platform can also play an important role in the development of m-commerce by creating successful application and platform, and educating the users. A future killer application can maybe be found in this area, but it seems doubtful that m-commerce will become successful without an improved effort to increase interaction between the actors in the industry and further 'education' of the potential users.

4 The future IT infrastructure: More liberalisation or more planning?

The increasing use of IT in society has created an ever-growing demand for network access and faster Internet connections. The traffic on the Internet is said to double every nine months and the yearly growth in network access speed to be almost 25% (IT Kommissionen, 2003; Knudsen and Madsen, 2004). The diffusion of IT has been fueled by the rapid technological development in IT equipment and subsequently decreasing prices. During the 1990s application of the PCs in private homes and the Internet gave rise to the increasing use of IT and created demand for IT infrastructure.

IT infrastructure is a network good that has network externalities in which one user's utility for the good depends on the number of other users who consume this good. The network good has positive feedback created by demand-side economics of scale (Shapiro and Varian, 1999). Infrastructure often requires large initial investments and has low variable cost. Thus, it has the properties of a natural monopoly. As a result, infrastructure is often controlled and planned by the public sector or claimed to be a universal service that should be universally provided. By claiming a good to be a universal service, the government can use various policies to support universal access to the good. Basic telephony service is often considered to be a universal service (Shapiro and Varian, 1999). E.g. the incumbent service provider in Denmark has the universal service obligation that everybody should be able to be connected to the telephone network on equal terms and costs.

In many European countries the IT infrastructure is owned and controlled by private firms as a result of the wave of liberalisation of the incumbent telecommunications operator monopolies in the 1990s. The purposes of the liberalisation were to introduce competition in a market formerly controlled by the government and reduce the price of telecommunication. The IT infrastructure was from the beginning identical to the telecommunication network and access to the Internet was provided by telephone modems. The boom in IT during the 1990s and liberalised telecommunications markets led to large investments in building IT infrastructure by various actors. These investments were mainly in building IT backbone infrastructure based on optical fibers connecting the large cities and countries. Furthermore, actors in the IT infrastructure industry were building parallel networks, thus increasing the capacity in the network greatly, but mainly along the same geographical lines. However, the last mile from the optical fiber network to users (access network) primarily continued to be via traditional cobber telephone line controlled by the incumbent service provider.

This liberalised building of networks created an infrastructure with too much capacity (dark fiber) in rather similar backbones, but did not reduce the bottleneck of the last mile. The last mile in the access network often continued to consist of the old telecommunication

network. The overinvestment in infrastructure also caused the manufactures of optical network equipment and the service providers to be hit hard and among the first, when the IT bubble burst in 2000, which also reduced investments in the following years.

The demand for access to the Internet and speed in the network access has, however, continued to increase and does not seem to slow down in any foreseeable future. The information society is becoming increasingly dependent on a well functioning and safe IT infrastructure since a growing number of functions are based on IT and access to networks or the Internet. In any foreseeable future, the existing IT infrastructure will become insufficient in terms of structure and capacity. As a result it is necessary to establish a new IT infrastructure based on optical fibers to the home. But how is it possible to secure the building of a new, better and future-proof IT infrastructure? Do we need more liberalisation or planning?

This section draws on a project in Denmark that aims to *plan* a future-proof IT infrastructure with Fiber To The Home (FTTH) that also will allow for increased *liberalisation*.

It is structured as follows. Section 4.1 presents infrastructure in economic theory. IT infrastructure policy is analysed in Section 4.2 and the basic of IT infrastructure is described in Section 4.3. Section 4.4 analyses the DDN IT infrastructure project. The conclusion and discussion is presented in Section 4.5.

4.1 Infrastructure and economic theory

A traditional macro economic approach to investments in infrastructure is the Keynesian multiplier by which the building of infrastructure is a fiscal expansion that increases the income and reduces unemployment through an increased public consumption. This role of building infrastructure has been an important part of government policies. However, infrastructure also has other characteristics that can be described by microeconomics.

Infrastructure is a network good that has network externalities in which the value of the network for the user increases with the number of users connected to the network. As additional users get connected, it creates a positive feedback, i.e. demand-side economics of scale (Shapiro and Varian, 1999). To obtain the positive feedback it is necessary to achieve a critical mass of users. As a result, the infrastructure often requires large initial investments while the variable costs are comparably low. This feature also points at creating a natural monopoly since parallel infrastructure does not increase the value for the user e.g. the added utility of an extra parallel road is very low (if the capacity on the first road is sufficient).

Government policy from a network good perspective could then be to create a critical mass of users. The argument could be that the added utility of the network good is hard to internalise for the firm. Another policy is that of universal services. By claiming that the

infrastructure is a universal service it is possible to design policies that ensure that the service is universally provided. This happens often on the expense of competition by creating monopolies. In this situation, the government often regulates the price of using the infrastructure (Shapiro and Varian, 1999). The government could also 'own' and 'build' the infrastructure as can be seen in many of the traditional physical infrastructures such as sewers, roads, water and electricity.

Telecommunications service has been regarded as a universal service good that requires deliberate policies to ensure universal access at the expense of competition (Shapiro and Varian, 1999). The competition in the market is reduced since there is only one network, and the owner controls the access to users. This company is not necessarily blocking access to the network for other companies. Interconnection issues are often part of government policy, but the infrastructure company may keep its dominant market position by a strategy described by Shapiro and Varian (1999):

> *The economic lesson is timeless: if you control a key interface or bottleneck you should open it up, but on your own terms and conditions. These include technical conditions necessary to preserve the integrity of your product and economic terms that compensate you for any foregone business. (Shapiro and Varian, 1999, p. 214)*

4.2 IT infrastructure policy in Denmark

The Danish telecommunication market was liberalised in 1996, thus allowing other firms to enter the market. In 1998 the government sold their part of the incumbent service provider TDC. From 1998, the competitors to the incumbent (TDC) were allowed to create and sell their own services at TDC's nationwide network. By liberalising the Danish telecommunication market and selling the incumbent telecommunication provider, the government lost control over the network, and also lost knowledge about the network since the research and education of IT infrastructure planners was a part of the privatised company. The government also lost the control of the future planning of the infrastructure.

Today, the debate of universal service concerns IT infrastructure and providing access to the Internet for all users. To increase the penetration of high speed Internet connections in Denmark several policy measures have been used, such as tax credits and price regulations for using the access network. In 1996 the government also considered Internet access for all households as a part of the future digital TV network, but it was considered to be a technically inferior solution.

The Danish IT and telecommunication policy is based on the principle that all users should have access to advanced communication technologies, pricing (best quality at lowest prices) and a competitive market. In 1999 the most important political goals were to stimulate the

access to the network society and increase the level of competition in the access market[43]. In 2001 a new political strategy was set for fast, cheap and secure Internet to all of Denmark (Ministry of Research and Information Technology, 2001). The basic principles were that the building of the Danish IT infrastructure was a market driven task for the private sector, while the government role was to secure competition through regulation. The public sector was to create demand-pull in use of the Internet though development of new services. In a report from 2003, the government continued the IT infrastructure policy of low prices and best quality by a marked driven process. The government role is to secure better coverage of access to the Internet via the telephone network (Ministry of Research and Information Technology, 2003). Thus, the IT infrastructure policy in Denmark has been dominated by liberalisation and market driven development, but as discussed in the theory of network goods, this policy is not necessarily optimal in building a new IT infrastructure. The government has mainly focused on the price of Internet connections, and to a lesser extent are the availability and quality (stability and speed). The price in the market for access to the Internet is regulated. Since the incumbent carrier owns the last mile of the network to most of the users, the government regulates the price for access to this network using several indicators. But TDC still has a market share on 66% in broadband connections to the Internet[44](Danish Competition Authority, 2004).

The diffusion of Internet connections in Denmark has been fast during the last four years. The number of Asymmetric Digital Subscriber Line, ADSL[45], connections has grown from 26,000 ultimo 2000 to 562,000 medio 2004, and the number of cable modem connections[46]) has grown from 41,000 ultimo 2000 to 249,000 mid-2004[47]. The total number of broadband connections is 913,000 (Ministry of Research and Information Technology, 2004). It should be noted that the definition of broadband in the above numbers uses a connection speed of at least 144Kb/s and not 2Mb/s that generally is defined as Broadband (see e.g. NJNF, 2004). In international comparisons of penetration ratios and availability ratios, Denmark is usually found among the best in Europe (see e.g. Ministry of Research and Information Technology, 2004). ADSL connections are available in all Danish municipalities, and available to 96% of all households and firms. This is expected to increase to 98% in 2007 (Ministry of Research and Information Technology, 2004), while the last 2% of the households will have to use other access technologies.

[43] http://www.itst.dk/wimpdoc.asp?page=tema&objno=95028257
[44] In the report, broadband is defined as Internet connections with a speed of 128Kb/s or more (Danish Competition Authority, 2004).
[45] At least 144 Kb/s
[46] At least 144 Kb/s
[47] Source: Http://www.itst.dk

The above numbers indicate that Denmark is doing well with respect to IT infrastructure, but this is only a partially correct picture, since the existing infrastructure is insufficient for the future demand.

4.2.1 IT infrastructure versus road infrastructure

The IT infrastructure is not treated along the same lines as traditional infrastructure although government reports stress that a public accessible IT infrastructure is considered to be a basic condition for the people and firms' possibilities to use ICT, and that use of ICT is considered to be a growth factor, and a part of the transition to the knowledge society (National IT and Telecom Agency, 2004). There are several similarities between the economics of road infrastructure and the IT infrastructure, but the former is well organised and planned by public authorities, while the latter is uncontrolled and liberalised.[48]

The Danish road infrastructure is maintained and expanded by public investments, and it is supervised, controlled, and planned by public authorities. There is a Ministry of Transportation and several agencies and related research institutes. An example is the Danish Road Directorate:

> *As a government agency, the Road Directorate is the tool used by the public, the parliament, the government and the Ministry of Transport to promote and bring about the desired development of Danish roads and thus road transport in Denmark (http://www.vejdirektoratet.dk/)*

The Danish Road Directorate manages the national roads while local and regional authorities manage the other roads. The tasks are planning, construction, operation, service and maintenance. It also cooperates with various users and producers of the infrastructure. The Ministry of Transport has the responsibility for the overall coordination of Danish road and traffic. It cooperates with counties and municipalities in planning and organising the road infrastructure and has a range of rather well defined tasks.

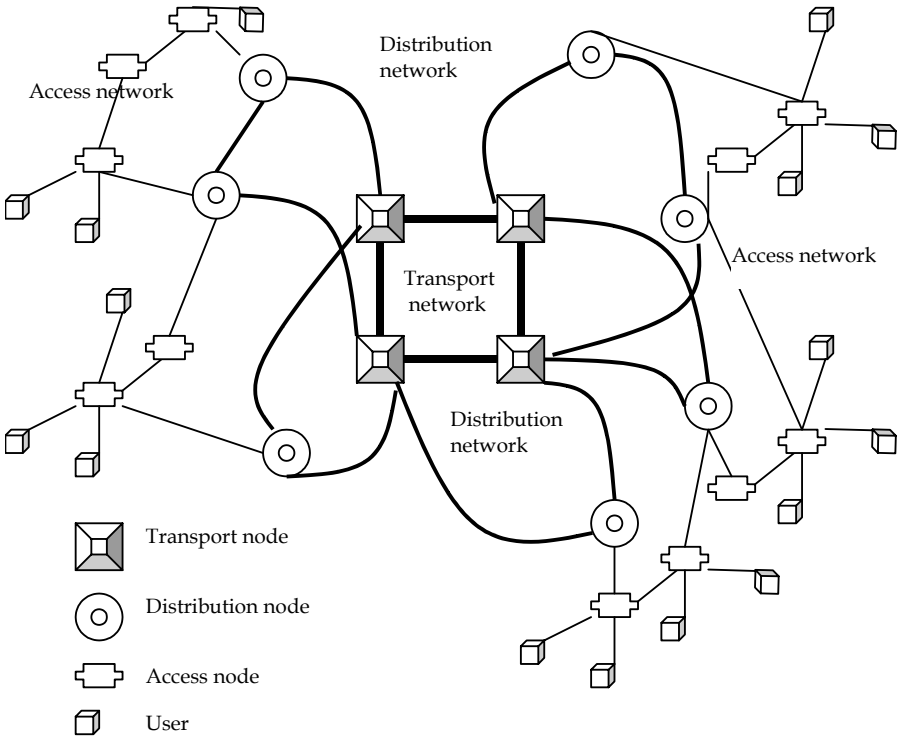
The contrast between policy regarding transport infrastructure and IT infrastructure is quite conspicuous, and indicates that a higher degree of planning and research could be advantageous in the IT infrastructure field. However, this is a political decision, and the Danish government has not found this infrastructure to be a public task that could benefit from a higher degree of public planning and public driven research.

[48] The traditional infrastructure, such as railroads, electricity, water, mobile communications, is planned and controlled in a continuum of degrees by the government, public sector, or users.

4.3 IT infrastructure basics

To understand the problems of building the future IT infrastructure it is necessary to know some basics about the IT infrastructure, which consists of three network levels. The upper level is the transport network. It is the overall network (backbone) that has a high capacity. The transport network is a wide-mesh net that has several nodes. To each of these nodes, the distribution net is connected. The capacity in the distribution net is lower than the transport net, but the mesh of the network is denser, and the number of nodes higher. The lower level network is the access net, which constitutes the common systems of transport between a geographically defined number of end-users (e.g. firms and houses) and the distribution net. The structure of the physical IT infrastructure is described in Figure 6.

Figure 6 Physical IT infrastructure



Source: Adapted from NJNF (2004) and IT Kommissionen (2003)

From Figure 6 it can be seen that the IT infrastructure consists of three independent networks with a number of nodes. These connect the various networks. The network in Figure 6 is an ideal type of network, but the basic underlying principles are also valid for the planning and building of real IT infrastructure.

To insure security and stability in the network, it is necessary to build independent networks and redundant connections. This is not a technical requirement, but more a practical and organisational issue. The independence should ideally mean that the network

cables are not located together, but this would drive up costs. In reality, the independence of the networks is secured by using two independent plastic tubes containing bundles of optical fibers. These tubes are co-located, when the transport network and distribution network are following the same geographical line of route. Co-locating of networks will reduce the costs of building IT infrastructure since only one digging is needed. This structure does make the network more vulnerable for somebody cutting the cables when digging, but this problem is solved by redundancy in the network[49]. Redundancy is the principle that there are several routes from one point to another. As a result every network node is connect by separate lines to two different nodes. E.g. a transport node is always connected to two different transport nodes in the network. If the network connection between two nodes is cut, then the traffic can move via the other connection and thus secure the flow of data in the network. This structure is called a ring structure. The alternative tree structure, in which the nodes only are connected to a single node, is much more vulnerable since a break in the network at a key connection will cut off a large share of the network. This instability is not acceptable for a society relying on access to the network and Internet.

The principle behind the ring structure is that every transport node should be connected to two different transport nodes and every distribution should have two different connections to other nodes and thus being connected to two different transport nodes. The redundancy should also apply to the access network, but for practical reasons, the access network is to consist of a mix of redundant and non-redundant connections. Less important access networks (e.g. in sparsely populated residential areas) would have a tree structure to reduce the costs. Being blacked out for hours while the network connection is being repaired is not an option for most companies or public organisations, such as hospitals, but is only a minor problem for residential areas.

4.3.1 Building IT infrastructure

To build an IT infrastructure it is necessary to lay down a plastic tube containing a number of cables (optical fibers). The digging is the most expensive part of establishing new infrastructure, while the optical fiber cables and protective plastic tubes are comparable inexpensive. Digging costs are higher in cities, and lower in rural areas.

4.3.2 Limits in the existing structure and a future-proof IT infrastructure

During the 1980s, the optical fibers were introduced in the Danish IT infrastructure. The transmission network changed from using cobber cables to using optical fibers, and transmission techniques changed from analog to digital transmission. The telephone exchanges were also digitalised. The access network is mainly based on the old telecommunication cobber cables, and the potential connection speed depends on the

[49] An alternative is to lay the transport network tube deeper in the ground than the distribution network.

distance to the exchange and the quality of the cobber in the cables[50]. The speed can be upgraded by forthcoming technologies and equipment, but the above limitations still apply. As the demand for speed in the network increases, the availability of fast connections decreases, and some areas will not be able to get the broadband connections. Larger organisations and firms have optical fiber based Internet connections. It is not possible to investigate the quality and operational security in the existing IT infrastructure since it retains to be business secrets, but the various actors' transport networks mainly follow the same lines[51]. The existing IT infrastructure thus holds several limitations in structure and speed.

In 2000 the Swedish IT Commission described the requirements for a future-proof IT infrastructure; a new infrastructure must be able to support the collected digital communication needs for all organisations and households. It is important that upgrading the communication equipment, and not laying new cables can increase the capacity in the physical IT infrastructure. The transmission capacity must be symmetric (today the connections are mainly asymmetric ADSL). The requirements in the infrastructure for quality and operational security must be high, and several service operators are to be able to use the same network (IT Kommissionen, 2003). To fulfil these requirements it is necessary to build a mesh structured IT infrastructure with Fiber To The Home (FTTH) to every household in the long run. Optical fiber is the only wire technology to fulfil these demands that is economical feasible. By using optical fibers, the speed and capacity decrease only very little over distance, and the speed in an typical FTTH connection is 100 Mb/s[52]. Upgrading the equipment can increase this speed.

The main limitation in the IT infrastructure is the access network, but building a FTTH infrastructure is not profitable for parallel actors. The market has the features of a natural monopoly since building parallel access networks will not increase the utility of the access network for the user or decrease the price. But building a single new access network requires great skills in cooperation between the actors in a liberalised market for telecommunications. However, creating a new monopoly in the IT infrastructure market may not be desirable. A purely demand driven building of IT infrastructure would also led to an unequal geographical development, since the sparsely populated areas are less economically attractive. Today the competition in the market for infrastructure takes place in three levels: The planning, the installations, and use. But the competition benefits the actor in the market who gets the cables laid down first, i.e. the owner of the connection to the customer holds a competitive advantage. A possible solution to these problems could be planning of a future IT infrastructure that allow for competition.

[50] The number of users connected to the cable may also reduce the speed.
[51] For a map of the Danish Internet backbone, see Ingenioeren 22 February 2002
[52] This speed is not a general, but depends on the components.

4.4 Planning the IT infrastructure and The Digital North Denmark

The North Jutland Netforum and KMD Netbroker were two related projects in the Digital North Denmark (DDN) policy programme from 2001 to 2003[53] (The history and intended versus realised implementation of DDN is analysed in detail in Chapter 9). The purpose of the projects were to plan the long term IT infrastructure in North Jutland based on Fiber-To-The-Home (FTTH). Following the above descriptions for a future-proof IT infrastructure, FTTH was considered the long term planning goal of the projects. This goal had become economical feasible by the rapid technological development in optical fibers combined with declining prices during the last years.

Since the exiting IT infrastructure was inadequate, the idea was to design an optimal network according to the existing infrastructure, households, firms and public organisations. Long term planning was considered the only way to minimise the costs, and secure a future-proof infrastructure, designed by the previously described principles, for the entire North Jutland region.

The information infrastructure should be regarded to be as important as the traditional infrastructure, such as roads and power. The IT infrastructure is being build by various actors in an uncoordinated and uncontrolled process. This lack of coordination is creating a significant waste of resources, since no single organisation knows who are laying down optical fibers, when and where. The price of laying down cables is mainly determined by digging costs. Repeated digging could be avoided by planning.

The North Jutland Netforum developed a strategy plan for North Jutland County and a very detailed plan for IT infrastructure for three small rural municipalities in the region. By planning the future IT infrastructure with the goal of connecting every household[54] in the region with optical fibres, the combined demand will drive down prices on each connection, and also allow for households and firms in the rural districts to get a 'true' broadband Internet connection. The planning takes point of departure in the existing structure in the region, such as houses, firms, public organisations, roads, geography, and existing IT infrastructure. Planning for the entire region, and not just one municipality secures that intra-municipality networks are located in a way that allow for connection with 'outside' networks. Likewise, the regional network is planned with strategic nodes that allow for connection with national networks and other IT infrastructure operators' networks. The

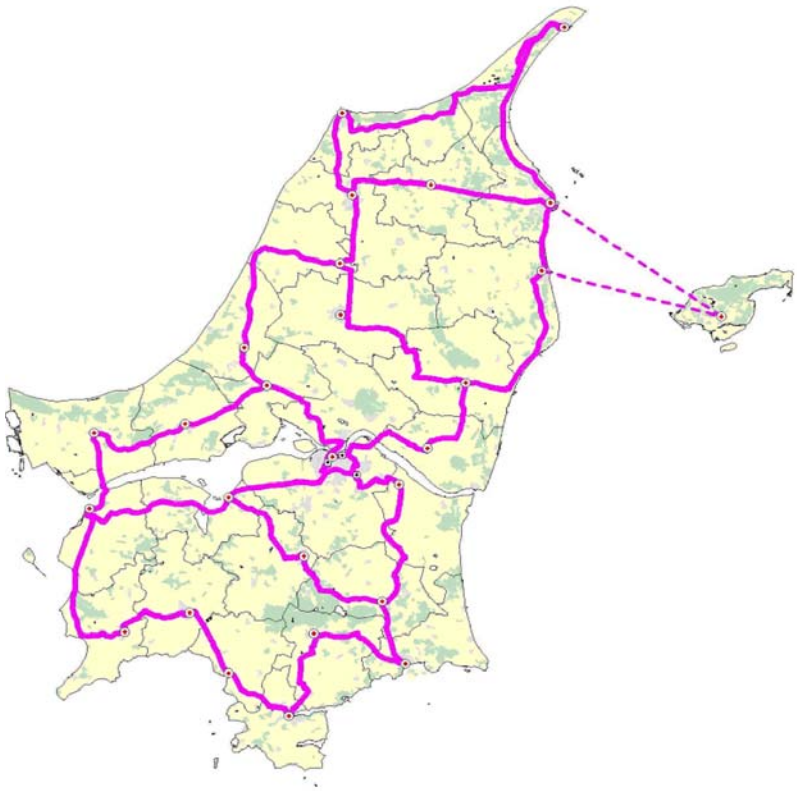
[53] North Jutland Netforum was an independent organisation established in cooperation between Aalborg University, a bank, the North Jutland County Administration, the municipality of Aalborg and an IT firm. The KMD Netbroker was a commercial organisation established as part of KMD A/S in collaboration with the municipalities of Brønderslev, Hals, Frederikshavn and Sæby.

[54] Using other technologies like Fixed Wireless Access (FWA) could be used to connect the most geographically isolated household.

planning is thus a collection of all actors needs. The plan also emphasises the areas in North Jutland that are less economical attractive because of population density and geography[55].

Figure 7 shows the map of the planned transport network in North Jutland. It consists of seven connected rings covering North Jutland, and the network cables follow the shortest geographical route via existing roads or paths according to the overall plan.

Figure 7 Map of the planned transport network in North Jutland

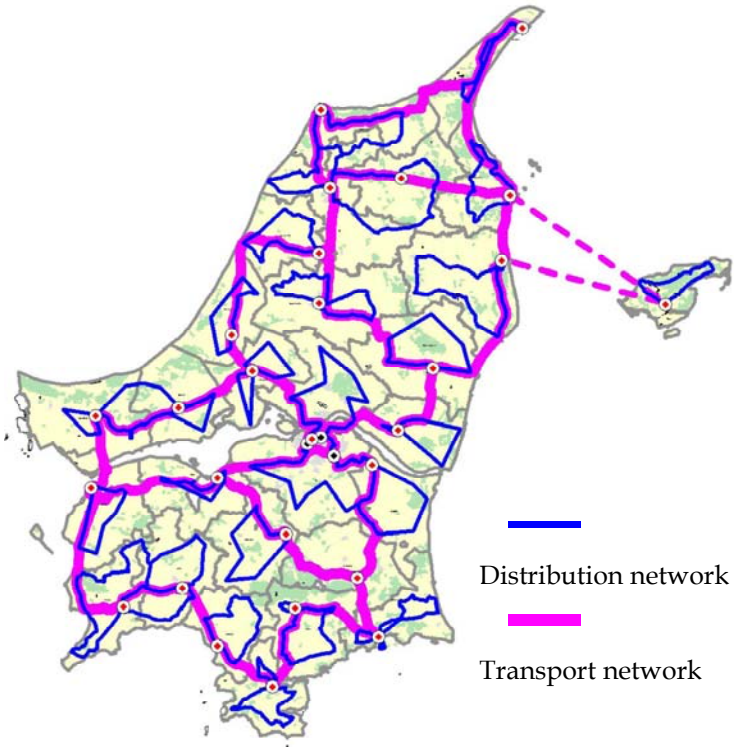


Source: Adapted from (NJNF, 2004)

The distribution networks are connected to the transport network. The finer meshed local distribution networks and the connection to the planned transport network is shown in Figure 8.

[55] TDC has universal service obligations in 2 Mb/s Internet connections on equal terms for the entire country, but the set-up costs vary according to the distance to nearest exchange i.e. it can be very costly (Ministry of Research and Information Technology, 2004).

Figure 8 Map of the planned transport network and the distribution networks



Source: Adapted from (NJNF, 2004)

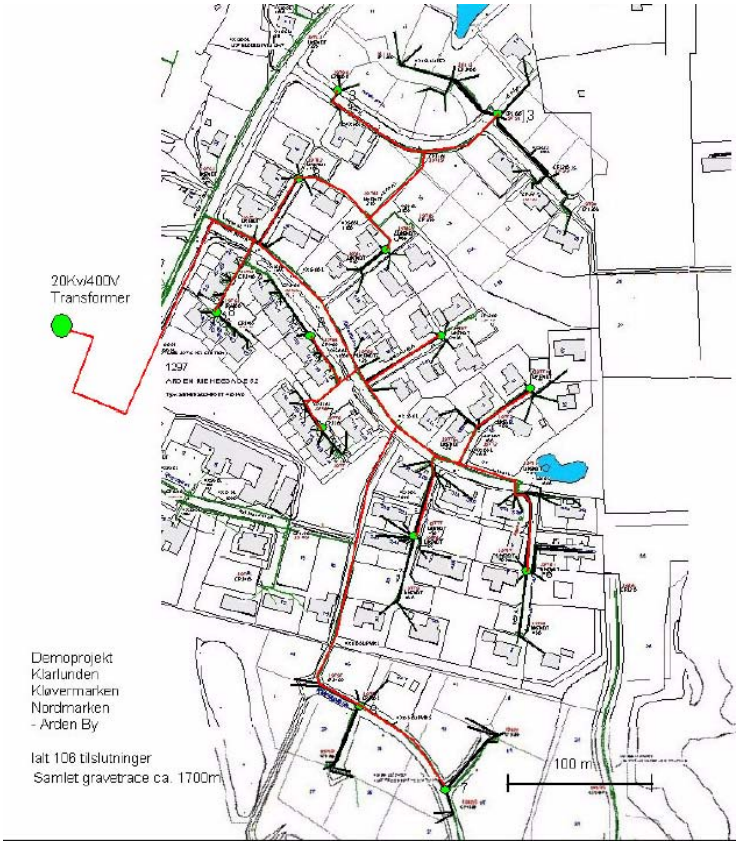
Figure 9 shows the plans for ideal IT infrastructure municipality level for three municipalities in North Jutland.

Figure 9 Map of ideal IT infrastructure at municipality level

Source: Adapted from presentation by Ole Brun Madsen, ICT and Learning in Regions Conference, Aalborg 2 June 2004

An example of planned access network, at a very detailed topological level, can be seen in Figure 10.

Figure 10 Planned IT infrastructure from a demo project in Arden



Source: Adapted from presentation by Ole Brun Madsen, ICT and Learning in Regions Conference, Aalborg 2 June 2004

The plan for the IT infrastructure in North Jutland reveals that only one network is going to be built. But the plans are not aiming for a monopoly (or less liberalisation) in access to the Internet. They recommend that a private company builds and runs the infrastructure, but access to the basic IT infrastructure is to be available to all service providers at equal and fair terms. These restrictions are to secure competition in the market for services (NJNF, 2004). The owner of the infrastructure and the operator of the infrastructure could thus be separated into different companies. This would move the competition in the market from owing the infrastructure to competition in the use of infrastructure.

The North Jutland Netforum has developed detailed plans for the future IT infrastructure in North Jutland. These recommend that the transport and distribution network are to be build first, since they are the foundation for the access network. The building of the entire access network is more independent of the transport and distribution network, and can be built in several stages.

Public organisations are planned to be a demand driver and first movers. The optical fiber based infrastructure is planned to connect all the municipality town halls in North Jutland. The town halls are to house the transport nodes that connect to the distribution network, see Figure 7. Some large organisations are also to be connected directly to the optical fiber

network[56]. The plan includes the distribution network with nodes that connect public organisations, business areas and residential areas. The access network accounts for a large share of the investments in IT infrastructure, and it is less essential for the entire infrastructure (NJNF, 2004). As a result, the IT infrastructure report (NJNF, 2004) stresses that the final building and project planning of an access network in an area will occur, when a share of the potential users accepts to join. The distribution networks are mainly located within existing municipality borders. This planning allows for a stepwise construction of the IT infrastructure. If a municipality decides not to join, empty tubes will be put down when the 'planned distribution network' and the transport network overlap.

The infrastructure is to have sufficient capacity to match demand for many years, but it should also be flexible and allow for upgrading of capacity in the future without digging. This flexibility is obtained by putting down empty tubes. With an empty plastic tube it is possible to add extra fibres when the capacity is needed, without digging, since the cable can be blown or pulled through the empty tube. This planning makes it possible to reduce the costs of building the infrastructure, since digging activities can be coordinated. The coordination requirement is that whenever telecommunication firms, power plants, district heating firms, and public sewer services etc. are digging, there should be put down empty tubes as well. It is, however, not sufficient in building the entire infrastructure.

4.4.1 Building FTTH networks

The construction of the optical fiber network has been delayed because of the lack of political support and commitment. To fulfil the plan, it is necessary to get public and private organisations to cooperate and coordinate. The public sector is especially important to boost the project, to coordinate, and also decide that this is the future IT infrastructure. The relative small size of the North Jutland county could potentially make it more efficient in taking decisions of building an IT infrastructure, and thus establishing the best IT infrastructure in Denmark. But it seems that the national policy of liberalised development of the IT infrastructure also dominates at the regional level. While the North Jutland Netforum project tried to mobilise support for a planned IT infrastructure, various actors continued building IT infrastructure, uncontrolled and uncoordinated[57].

However, several new actors in the IT infrastructure market have been interested in entering the market for broadband Internet connections. The power suppliers have been very interested, and have contacted the North Jutland Netforum. They want to expand their business, and are in a process of converting their overhead power lines to power lines in the ground, i.e. they could save money on digging costs. They are planning to build a FTTH network to their customers. In North Western Zealand in Denmark, the power supplier has

[56] The county administration, KMD, Aalborg Hospital South and Aalborg University
[57] E.g. the county administration built an IT network that connected the hospitals in the county

begun offering optical fiber connection direct to the home to its customers (only in neighbourhoods with a sufficient number of interested customers)[58]. The power supplier in Southern Zealand (SEAS) has built a fiber optical FTTH network in the municipality of Praestoe[59]. Other power suppliers, energy companies, user associations, and (semi) public organisations etc. are also planning fiber optical networks, or building networks in limited test areas[60]. The incumbent service provider TDC is planning optical fiber Internet connections to the most of the Funen County. The price for each connection is, however, several times higher than the calculated price of each connection in the DDN project.

The public authorities in North Jutland have been very slow in acknowledging the benefits of planning the future IT infrastructure for the entire region, since it was considered to be a private task. However, other counties have cooperated with the DDN project, and implemented the planning tools. Recently, the political and organisational mood at the county level seems to have changed towards a more positive attitude towards planning the IT infrastructure. The force behind this change seems to have been pressure from municipality mayors, and the experiences from other counties (using the planning tools).

A power company in North Jutland, HEF, has initiated a demonstration project in the small city Arden with FTTH to 125 households. They are planning to expand their network in the entire geographical area they supply with power. The project is based on cooperation with the North Jutland Netforum and all other power suppliers in the region. This project could be the starting gun for FTTH in North Jutland.

4.4.2 Price examples for FTTH in North Jutland

The estimated cost of construction of the transport network in North Jutland, in total 668 kilometres, is approximately €16.8 million. The optical fiber network has an expected operational life of 30 years (NJNF, 2004).

A loose estimation on the costs of a full FTTH network for all households and citizens in North Jutland is between €130 million to €260 million[61]. This could be scaled to the entire country by a factor ten i.e. €1.3 to €2.6 billion. In comparison, the bridge across the Great Belt between Funen and Zealand had a cost of €3.3 billion, and the planned bridge between Denmark and Germany across Fehmern Belt is expected to cost €5.3 billion. The proposed expansion of the Copenhagen Metro is expected to cost approximately €1.8 billion of which half is expected to be financed by future passenger revenues. The construction of the planned IT infrastructure is to be financed by the users (including the public sector).

[58] http://www.fth-bredbaand.dk
[59] http://www.seas.dk
[60] See Ministry of Research and Information Technology (2004) for a detailed list.
[61] Based on a presentation by Ole Brun Madsen, ICT and Learning in Regions Conference, Aalborg 2 June 2004

The price of a complete FTTH network in Denmark could thus be compared with the price of a large bridge, but the IT infrastructure is not on the political agenda. Roads, bridges, and railroad tracks are subject to political debates and decisions at national level, while IT infrastructure is not being discussed politically. As investigated in previous section IT infrastructure seems to be entering the political debates at municipality or county levels in various parts of the county. Especially Southern Jutland County and Viborg County have put IT infrastructure on the political agenda at county level.

4.4.3 Education in network planning

The planning of IT infrastructure is done individually by private actors, but public organisations also individually plan and build their own IT networks. When TDC was liberalised, the public accessible education of network planners and knowledge were lost, since this research and education was a part of the incumbent telecommunication operator (NJNF, 2004). This effect of the liberalisation has created a lack of educated network planners in public organisations and also in telecommunication companies. One of the derived effects of the North Jutland Netforum project is the foundation of a Centre for Network Planning as a part of the Centre for Tele Infrastructure (CTIF) at Aalborg University joining the research competencies within wireless technologies with research in wired infrastructure. As a result, Aalborg University has established a master in network planning for engineers. The people involved in the North Jutland Netforum project have backed this education by supplying knowledge and staff.

The joining of research competencies within the wireless technologies with research in the wired infrastructure at Aalborg University might have a positive effect on the ICT sector in the region. This is analysed in Chapter 8 investigating technological life cycles in the mobile communication industry, and the convergence between the fixed and wireless communications.

4.5 Conclusion

This section analyses how the future IT infrastructure in Denmark could be build. The increasing demand for access to the Internet, and dependence on IT in society is expected to make the existing IT infrastructure insufficient in terms of speed and operational security. It is necessary to build a new IT infrastructure or upgrade the existing network radically. The future-proof IT infrastructure is to be based on optical fibers to the home (FTTH). In Denmark government policy has pushed for liberalisation in the telecommunications market (including Internet access), but has regulated the price of using the access network. Thus, the building of IT infrastructure is market driven, but the market for Internet connection is still dominated by the actor that owns the access network. It is discussed whether a continued liberalised building is desirable or if more planning is needed.

IT infrastructure has similarities with traditional infrastructure. It is a network good, requires large initial investments, and has low variable costs. However, traditional infrastructure, such as roads, is primarily regulated, controlled, overall planned and/or provided by the public sector, while the IT infrastructure is a private sector task. The properties of the IT infrastructure suggest that it could be a natural monopoly. Today, the various actors build their own networks, which is creating a waste of resources in parallel digging (digging is the most expensive part of building IT infrastructure). Likewise it is not economic rational to have two parallel access networks since an additional network does not increase the utility for the user. This situation creates a market situation where the competition is on whom gets the cables laid down first, i.e. the owner of the connection to the customer holds a competitive advantage.

The solution to the problem of more liberalisation or more planning is found in a project by the North Jutland Netforum that intends to create increased liberalisation through planning of the future IT infrastructure. The project targets planning and building of an IT infrastructure with FTTH, for all households and firms, in the long run. The competition in the market for infrastructure takes place in three levels: The planning, the installations, and use. Today the owner of the installations has a competitive advantage, but the North Jutland Netforum aims at moving the competition from owing the infrastructure to use of it. Operators are to be allowed access to he network on fair and equal terms, which will create competition in the market for services. However, to fulfil the plan, it requires cooperation between public and private organisations. The public organisations are the key players in this process to coordinate the building of the IT infrastructure, and as demand drivers and first movers. But North Jutland County has been slow in supporting the plan, while other counties have adopted the planning principles. The plans for the IT infrastructure are in the process of being implemented in North Jutland County, and in some of the municipalities. A number of the municipalities in the county are not willing to join the plans.

Recently, several new actors have entered or are planning to enter the market for IT infrastructure by building their own regional FTTH network. Some of these are using the planning principles provided by the North Jutland Netforum, but the increasing number of local initiatives has created a need for coordination to avoid building parallel access networks, and 'negotiating' termination policies.

Applying the plans for building the IT infrastructure would make the Danish IT infrastructure the best in the world, which would create positive externalities and opportunities for Danish industry. Planning would allow of further liberalisation in terms of increased competition. The future IT infrastructure for the entire country needs more planning, but it has only received little attention among public policy makers.

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Chapter 11

Conclusion

Conclusion

The purpose of this thesis is to analyse the development perspectives for the ICT sector in North Jutland. In addition I have posed a range of more specific research questions to be examined. These are analysed in particular chapters that also include the conclusions to the specific questions. The analysis of the development perspectives for ICT sector in North Jutland was done in three parts. Part one was setting the stage by presenting the North Jutland region, the development of the ICT sector in North Jutland, and knowledge flows in the Danish ICT sector. This context was important for analysis of the overall research theme.

The ICT sector in North Jutland had a remarkable growth in employment and number of firms from 1992 to 2002. The growth in employment was almost twice as high as at the national level. IT services experienced the largest employment growth; employment almost tripled. The growth stopped in 2000 when the ICT sector went from boom to burst and employment declined. Especially the ICT manufacturing was hit hard, while ICT services performed less badly. North Jutland is not specialised in ICT employment, but the indicator increased from 0.70 to 0.85, i.e. it has somewhat been catching-up from a rather low level. Compared to the national average North Jutland is specialised in manufacturing, but services account for two-thirds of the total employment. The Danish ICT employment specialisation pattern at municipality level reveals a specialisation and concentration in and around the cities of Copenhagen, Aarhus, and Aalborg. The main share of the total ICT employment was concentrated in the NorCOM cluster firms, while the IT service and software segment was relatively smaller compared to the large cities of Copenhagen and Aarhus. This segment has a branch structure with the headquarters located outside the region. Two large companies dominate the structure of this segment that also includes a range of smaller and medium sized IT service firms of which many are affiliates of national or international companies. The manufacturing segment also includes a group of printed circuit board firms, consumer electronics firms, and medico electronics firms.

In an international context Denmark is one of the most advanced user nations, measured by conventional indicators for user penetration, but it is not one of the major players in the international ICT markets, even allowing for country size. This paradox was examined by studying the structure, strengths and weaknesses of the industry in Denmark. The supply side problems were lack of qualified labour, dominance of foreign ownership in a significant part of the sector[1], and lack of a large 'domestic' multinational ICT company. In some cases

[1] Not least in those sub-industries displaying very fast technological development

the latter problem might have been compensated for by the emergence of small and medium sized R&D oriented firms, but too few have emerged during the 1990s, in spite of rather favourable economic conditions. Policies have been targeting some of these problems at various levels. The intake of ICT related educations has increased, and the government launched the Digital Denmark programme to improve the performance of the ICT sector, but Denmark still has an advanced demand, but a rather mediocre supply in ICT.

North Jutland has traditionally been characterised as peripheral with an unemployment rate among the highest in Denmark. The industry structure has previously been dominated by more traditional industries, such as agriculture and food processing, fishery, tourism, shipyards, textiles, tobacco and cement. However, during the 1980s North Jutland went into crisis fuelled by a recession in the Danish economy and consequently many of the traditional large industries downsized. The 1990s represented a growth phase for the region and it experienced a process of structural change, which made its industry structure more in line with other non-metropolitan regions. But during 1999 to 2002 this process stopped and North Jutland seems to continue on a growth path more similar to the other Danish non-metropolitan regions. However, lately the unemployment rate has increased more than the national average.

The foundation of Aalborg University (AAU) in 1974 has played an important role in the structural change of North Jutland. From its establishment AAU has been very active in cooperation with private firms. It has also several research groups within ICT technologies and has a large production of MSc graduates in engineering and computer science. AAU was until 2000 the one of only two universities in Denmark that offered the MSc in engineering and approximately half of the Danish MSc's in engineering graduated from AAU during the 1990s. Likewise it was also an important trigger for further industrial development of the wireless communication cluster e.g. due to the supply of engineers.

The cluster accounted for the main share of the total ICT employment in the region in the late 1990s. Most of the cluster firms were very R&D intensive, owned by foreign firms, or R&D subsidiaries of well-known multinational companies. It was very successful and attracted a lot of attention. It was one of the main factors behind the Digital North Jutland programme. But the crisis in the ICT sector from 2000 affected the cluster and caused problems. Some firms downsized and some moved away from the region. Meanwhile other local firms hired most of these engineers and new firms entered. The employment of engineers in R&D has been fairly stable, but large downsizing in manufacturing and mobile communication service have made the total employment decline. This turbulence somehow made the policy makers' attention turn away from the cluster and focus on other areas[2].

[2] The lack of attention has had some negative effects on the development perspectives for the cluster e.g. the public policy authorities at the regional level has been very reluctant in supporting the 'North Star' vision. It

However, the development perspectives for the ICT sector in North Jutland are still closely related to the cluster.

Part two on cluster analysis dealt with the more specific debate of localised knowledge spillovers (LKS) and broader issues of the role of spinoffs and technological life cycles in the evolution of clusters.

The analyses of LKS show that informal communication in social networks is diffusing knowledge between firms in a cluster. Some engineers also acquire valuable knowledge from the informal social networks. Even specific knowledge about new products, which is likely to be very firm specific and which the firms are likely to want to protect from competitors, is shared among these engineers. The engineers, which have previously been part of formalised projects with other firms and which are in contact with their former colleagues and classmates, are much more likely to receive knowledge of higher value. The engineers also share more locality-specific information that is hard to value, but it could have an important function in updating and strengthening the social network of informal contacts. This is potentially important for the dynamics of a cluster, since a larger proportion of the engineers who reported that they have social contacts acquired their current job through a social network than those without such contacts.

These micro-level studies of informal contacts between engineers have provided insights as to the existence and value of informal relationships to the individual employee. But new questions have also been raised such as the value of these knowledge flows to the firm, the effects on firm performance, both positive and negative. Future research also needs to ask the individual in question to compare the value of knowledge thus acquired with other sources of knowledge and map how individuals are linked in networks of informal relationships across firms.

The remaining chapters of Part two were focused on cluster evolution from the emergence to the development of mature clusters.

The role of entrepreneurial spinoffs (founders previously employed in the industry) in the evolution of clusters was analysed using detailed information about the founding events and organisational background of the individual entrants in the NorCOM cluster. The dominating cluster theories cannot sufficiently explain the emergence of clusters like NorCOM. The claims about the initial factor conditions, overall regional attributes, and institutional set-up as the explanations do not appear to be satisfactory. These factors cannot explain why this cluster of high technology and research intensive firms emerged in a peripheral region dominated by traditional industries, such as agriculture, food processing,

emphasised a joint effort from the Aalborg University and the cluster firms in gaining new ground in the basic R&D needed to become visible players in the market for solutions for the future wireless technologies and ICT infrastructure.

and fishery. The initial location of first firm in the cluster can at best be characterised as a chance event. A key component in the growth of the cluster has been the early performance of the first entrant that was very successful and provided a good example for the following entrants (spinoffs). Later, when the cluster had entered its initial growth phase, the local university was founded, but the firms still had to rely on internal competence building and 'imported' employees from other Danish regions. In this early phase the 'quality of the parents' played a major role as an early seedbed for innovation and growth and through the 1970s and 1980s a series of new firms was founded as spinoffs. In 1980s and 1990s, the university clearly had an effect through its growing supply of qualified labour and top-level basic research in the wireless technologies of the cluster. In addition parent spinoffs often founded by multinationals have supported the growth in number of firms during the 1990s. Often these have founded subsidiaries by hiring or headhunting experienced local employees to start the new firms. Entrepreneurial spinoffs are an important driver in the evolution of clusters.

The development perspectives for the NorCOM cluster are also linked to the development in cluster's technology base. The relation between technology and the evolution of clusters was analysed in Chapter 8. Many of the wireless communication cluster firms are working within mobile communication technologies and handsets in particular. In the last few years these has been anticipating a new disruptive technological life cycle based on the third generation of mobile communication technology. The cluster has previously experienced two technological life cycles. It has emerged during the first cycle and grown rapidly during the second. In anticipation of the next cycle the firms were applying various strategies to move into it, when the ICT sector went into crisis. This context is quite important, because it adds to the turbulence and increases the role for policy and collective action.

The policy challenge is to combine efforts at experimenting with the consumption structure and support the basic university research. At the regional level there is also room for policy and collective efforts, such as field experiments with the patterns of telecommunications services seen from a user perspective. The aim can be to be prepared for different future trajectories, if not to influence these outright. Even small regions may eventually influence the future development abroad if they may use their potential institutional advantages in terms of organising field experiments that may be visible internationally. The DDN IT infrastructure project has opened opportunities of creating field experiments with an optical fiber based local infrastructure that also contains possibilities for wireless technologies. The opportunity for the entire region is that the present growing pessimism, caused by troubles of the GSM developers to get a foothold in the 3G world, could be changed with a vision focusing of combining some of the existing knowledge assets of the region and the country at large. Aalborg University and the cluster organisation have jointly invested considerable efforts in gaining new ground in the basic R&D background

needed to become visible players in the market for solutions for the future ICT infrastructure as well as in the international academic community in this field. A significant outcome has been the establishment of Centre for Teleinfrastructure, CTIF, at AAU in 2004. The support and commitment from the local players has been an outcome of a 'collective spirit' accumulated among the network of regional players over nearly two decades. The final outcome is a result of efforts from local firms, foundations and university paired with significant contributions from large multinational telecom companies.

The analysis of spinoffs and technological life cycles in the evolution of clusters seems to be connected. Disagreement about strategies for future development could cause more spinoffs. Future research could analyse the link between disruptive technologies and spinoffs.

Part three of this thesis was focused on the Digital North Denmark policy programme. The analyses presented in the first two parts of this thesis make an important background and set the context for which the DDN programme should be analysed.

The localisation of a successful high-tech cluster with several multinational firms in a peripheral region like North Jutland attracted a lot of attention. The attention came especially from policy makers at both the local and national level that wanted to strengthen this process of clustering and broaden the cluster to improve other areas. But the region could also focus on developing different industries. The cluster was one of the main reasons for choosing North Jutland. The local actors, however, faced some tension in the formulation of a goal: Could the successful process of clustering be copied and the programme be used to develop other parts of the ICT sector, or should it be used to promote development broadly in the region? Initially DDN was planned as a policy programme to promote incremental change in ICT sector, but it was initiated as a radical change project focused on the users. DDN was to be focused on user-producer interaction, but mainly targeted the users. However, it might have had an effect on the development perspectives for the ICT sector given the problems of advanced demand, but mediocre supply in the Danish ICT sector, and the technological challenges for the NorCOM cluster. Therefore DDN could have played an important role for the development of the ICT sector in North Jutland by supporting user-producer interaction and engaging in field experiments and research that could provide some insights in future demand and technological development paths.

Analysis of the history of the DDN programme revealed that the profile became broadly user-orientated as a result of a deliberate strategy among the dominant actors at the very early stage of the program. The strong commitment from the leadership of influential public organizations and the missing representatives from private ICT firms lead to the final profile.

On the other hand the industry side could, perhaps, be blamed for not being sufficiently active in this process[3].

The goals of DDN were multiple and lost focus. The winner projects within the IT industry theme included a mix of radical as well as incremental change oriented projects in many different sectors, and at different levels. But the large and 'high profiled' radical-change-like projects have not been realised at a sufficient scale. From an ICT industry perspective DDN appears to have been too broadly formulated and the effects to have been too scattered.

DDN was supposed to make the ICT sector stronger, but the profile was soft and broad, mainly targeting the public sector and many widespread smaller projects. However, it appears fair to state, that there has been some success stories of small and medium sized local IT service firms who have benefited from the program, and many projects where the participation has been positive for the participants, but with no significant impact on the development of the ICT sector in North Jutland *per se*, at least so far.

When North Jutland was chosen to be a part a national ICT policy programme it raised questions about how to broaden the cluster and improve it, or if the region should focus on developing different industries. However, the actors in the region chose neither, but began on a different path by promoting a broad lift in user competencies in the region and applying a let a thousand flowers bloom diversity strategy.

The role of DDN and its impact on the development perspectives of the ICT sector could also be more broadly sketched in a user-producer interaction in a system of innovation approach. The demand side of the NorCOM cluster is global. Likewise the users of IT services are a part of a global system. The local market for wireless communication equipment is very small[4], while some of the IT service solutions still have a Danish specificity. The global market for these parts of the ICT sector puts additional requirements on the advanced users and user-producer interaction, since the pecuniary effect of the local market is small. The IT infrastructure, however, is also a part of a global market, but it also has a clear regional effect. This project was an 'internationally advanced user' that could be used to connect the demand and supply in the region and potentially create user-producer interaction for the cluster firms and the fragmented IT service segment.

A cluster of wireless communication firms and a range of more dispersed activities characterise the structure of ICT sector in North Jutland. The cluster is internationally visible, while the remaining segments are fragmented. There are several international companies, but most seems to be directed towards the home market. On the supply side the university has a series of international research groups and education of engineers. This is an advantage

[3] The strong growth in mobile communications industry – up until 2001 - was likely to make them less interested in participation. The business opportunities were plenty at the time.
[4] Measured by sale of terminals. Some of the cluster companies have customers within the cluster.

for North Jutland compared to many other regions in Denmark. The supply of qualified labour from the university constitutes a possible knowledge flow from the university to industry. But it should be noted that these still need in-house training to gain the specific industry experience, which was found to very important in the theories of spinoffs. The question of the development perspectives for the ICT sector in North Jutland is related to the development perspective for the cluster and the other interesting technological knowledge bases that also holds good performing firms, such as biomedical, logistics software, electromedical etc. and a knowledge base. But these do not produce many spinoffs and lacks critical mass of firms before the self-augmenting processes potentially could create a process of further growth in number of firms.

The existence of a knowledge base in terms of a few firms and university research is not a sufficient condition for clustering. It is necessary with strong self-augmenting processes, local attractiveness and several firms. The supply of qualified labour from a university could support the clustering process in a specific technological knowledge base, but these still need to be employed in firms within this knowledgebase to get industry experience. Then the immobility of labour will induce entrepreneurs (spinoffs) to locate in the region, so they can maintain their social networks. Without firms to employ the qualified labour these would leave the region or start working in another industry with another knowledge base instead. Only a very few are likely to start a successful firm within their field as newly graduates. To get a cluster additional firms are needed and these can be attracted to the region, they could be diversifiers, and come as spinoffs from local firms or the university (public research organisations). Firms from outside could be attracted by the supply of engineers and university knowledge, but they have to train the labour industry specific knowledge. The diversifying firms could come from the existing cluster and the spinoffs have to come from existing firms or university. Thus it takes a long time to develop a cluster in other segments of the ICT sector.

The NorCOM cluster is still a visible high-tech cluster in a peripheral region. It is still the strength of the ICT sector even taking the recent turbulences into account[5]. Specialisation by clusters creates vulnerability and lock-in effects in terms of dependency of a single technological knowledge base, but it is also a sign of strength. That is, NorCOM makes the ICT sector more vulnerable for shocks in markets and technologies, but it has also been the growth driver of the sector. It has created visibility, attracted firms and funds, and more importantly generated a large pool of highly educated qualified labour in a peripheral region. The possible lock-in could create long-run negative effects with lower innovative

[5] A look at the NorCOM history reveals that the cluster has experienced many crises for the entire cluster and individual firms. The doom of the cluster has been foreseen many times, when prominent firms went bankrupt or when multinationals chose to close down their division in the cluster. But somehow it has proven to be very hard to extinguish because of the self-augmenting processes. When companies exited spinoffs entered. Employment declined from 4,300 in 2002 to 2,800 in 2005. The closed-down Flextronics employed 1,500-1,700 in 2002.

activity and revenues etc., and it could raise a debate of how to destroy clusters when they have outlived its performance. However, then it should be possible to measure the point when the negative effects of the cluster were larger than the positive.

The question of the development perspectives could be rephrased to what can be done to copy or start the clustering process in other areas of the ICT sector. The strong cluster could in interaction with other environments create new possibilities for expansion of the cluster or spinoffs in other areas, new technologies or alternative use of existing technologies that are not supported in the mother firm. The lesson from the cluster theory and the evolution of the NorCOM cluster on the development of clusters is clear. It takes many years and effort for a cluster to emerge and the strong technological core competences are not a matter of course. Even when the will to become a cluster and talent within a technological field are present, it requires new firms, spinoffs, and a pool of labour experienced in the specific technology, market and industry segment in question.

The DDN programme was not a large financial support programme compared to the EU structural funds. However, it had a possibility to strengthen the cluster or to focus on developing other segments of the ICT sector, but became too broad and unfocused. Unluckily, it was launched at the worst possible time by coinciding with the worldwide crisis in ICT. It has had some positive effects, but it does not appear to have left a visible lasting fingerprint on the development perspectives for the ICT sector in North Jutland.

Chapter 12

Summary

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The purpose of this thesis is to analyse the development perspectives for the ICT sector in North Jutland. This main research theme is investigated in three parts. The first part deals with setting the stage by presenting the North Jutland region, the development of the ICT sector in North Jutland, and knowledge flows in the Danish ICT sector. The second part analyses the wireless communication cluster in North Jutland (NorCOM), and Part three is focused on the Digital North Denmark policy programme.

Chapter 2 analyses the development in the Danish ICT sector from 1992 to 2002. The ICT sector in North Jutland had a remarkable growth in employment that was almost twice as high as at national level. IT services experienced the largest employment growth; employment almost tripled. The growth stopped in 2000 when the ICT sector went from boom to burst and employment declined. Especially the ICT manufacturing was hit hard, while ICT services performed less badly. North Jutland is not specialised in ICT employment, but the indicator has increased from 0.70 to 0.85, i.e. it has somewhat been catching-up from a rather low level. The ICT employment specialisation pattern in Denmark at municipality level reveals a specialisation and concentration in and around the cities of Copenhagen, Aarhus, and Aalborg. Compared to the national average North Jutland is specialised in manufacturing, but services account for two-thirds of the total employment. The main share of the total ICT employment was concentrated in the NorCOM cluster firms, while the IT service and software segment was relatively smaller compared to the large cities of Copenhagen and Aarhus.

The point of departure of Chapter 3 is part of the general worry about the rather weak Danish performance in the ICT sector. The main focus is that, on the one hand, Denmark is one of the most advanced user nations, measured by conventional indicators for user penetration. On the other hand, however, Denmark is not one of the major players in the international ICT markets, even allowing for country size. The nearby and somewhat similar countries of Sweden, Finland and the Netherlands, are living proof that small countries can be very visible in this field. This paradox was examined by studying the structure, strengths and weaknesses of the industry in Denmark. The supply side problems were lack of qualified labour, dominance of foreign ownership in a significant part of the sector, and lack of a large 'domestic' multinational ICT company. Policies have been targeting some of these problems at various levels. The intake of ICT related educations has increased, and the government launched the Digital Denmark programme to improve the performance of the ICT sector, but Denmark still has an advanced demand, but a rather mediocre supply in ICT.

Chapter 4 introduces the North Jutland region and analyses the development in the industry structure from 1983 to 2002. North Jutland has traditionally been characterised as less favoured region with an unemployment rate among the highest in Denmark. The industry structure has previously been dominated by more traditional industries, such as agriculture and food processing, fishery, tourism, shipyards, textiles, tobacco and cement. However, during the 1980s North Jutland went into crisis fuelled by a recession in the Danish economy and consequently many of the traditional large industries downsized. The 1990s represented a growth phase for the region and it experienced a process of structural change, which made its industry structure more in line with other non-metropolitan regions. But during 1999 to 2002 this process stopped and North Jutland seems to continue on a growth path more similar to the other Danish non-metropolitan regions. However, lately the unemployment rate has increased more than the national average.

Part two on cluster analysis deals with the more specific debate of localised knowledge spillovers (LKS) and broader issues of the role of spinoffs and technological life cycles in the evolution of clusters.

Chapter 5 investigates the role of spinoffs in the evolution of clusters. Recent empirical studies have focused on how capabilities of new entering firms are important for the evolution of industries over time. The performance of new entrants appears to be significantly influenced by their pre-entry background. The general impression of the literature is that firms founded by former employees of successful incumbents have shown larger propensities to survive than other categories of new entrants. In Chapter 5 this approach is used to study the emergence and growth over the past four decades of the NorCOM cluster. The aim is to analyse the dominating forces behind its growth using detailed information about the founding events and organisational background of the individual entrants in the cluster. Chapter 5 shows that the technological successes of firms in the region have powered a spinoff process, which can account for the majority of the growth in number of firms in the cluster.

Chapter 6 investigates knowledge flows through informal contacts in a regional cluster. The role of informal networks in the development of regional clusters has recently received a lot of attention in the literature. Informal contact between employees in different firms has been claimed to be one of the main carriers of knowledge between firms in a cluster, while others have argued that the importance and existence these of knowledge flows are unclear. This chapter examines empirically the role of informal contacts in the NorCOM cluster. In a questionnaire survey, a sample of engineers and computer scientists were asked a series of questions on informal contacts. Chapter 6 analyses whether the engineers actually acquire valuable knowledge through these networks. The results show that the engineers do share even valuable knowledge with informal contacts. This shows that informal contacts represent an important channel of knowledge diffusion.

Chapter 7 analyses social networks of informal contacts between employees in NorCOM cluster and analyses the genesis of informal contacts and knowledge diffusion by studying relationships, experience and other characteristics of the engineers. The chapter presents a review of the theoretical ideas that have been dominant in the debate on the role of knowledge exchange through social networks. The purpose of this chapter is to study the factors, which influence the likelihood that the individual engineer will be an active part of the social networks between the local firms. The analyses show that the informal communication is diffusing knowledge in the cluster. Some engineers also acquire valuable knowledge from the informal social networks. Even specific knowledge about new products, which is likely to be very firm specific and which the firms are likely to want to protect from competitors, is shared among these engineers. The engineers, which have previously been part of formalised projects with other firms and which are in contact with their former colleagues and classmates, are much more likely to receive knowledge of higher value.

The relation between technology and the evolution of clusters was analysed in Chapter 8. It analyses how regional clusters may react on the emergence of new disruptive technologies. New disruptive technologies may initiate the emergence of new clusters or create opportunities for further development of existing ones. They may, however, also result in stagnation and decline. The case is the NorCOM cluster that has previously experienced two technological life cycles and is facing a third. It emerged during the first and grew rapidly during the second after experiencing a turbulent, but successfully shift. A special emphasis is given to the study of whether and how a 'collective spirit' may be formed and turned into collective action in periods of major threats and challenges. This again leads to a discussion of the interaction between privately and publicly initiated efforts and policy initiatives.

Part three of this thesis is focused on the Digital North Denmark policy programme. The analyses presented in the first two parts of this thesis make an important background and sets the context for which the DDN programme is analysed. Chapter 9 investigates the history of the programme. It analyses how the profile shifted from focusing on incremental change targeting the producers of ICT in North Jutland, to be initiated as a radical change project focusing on the users. And how it was implemented as a wide variety of projects mainly targeting users, while some of the radical change projects with local user-producer interaction revealed a lack of cooperation between private firms and public organisations or suffered from external events. The analysis is focused on whether and how the program may have long-term consequences for the development perspectives for the regional ICT sector.

Chapter 10 investigates three themes in relation to DDN: Digital TV, m-commerce, and the future IT infrastructure. The focus is on firms from the ICT sector in North Jutland that participated in the DDN programme. It investigates the move towards digital TV, m-commerce, and the future IT infrastructure in North Jutland.

Chapter 11 presents the conclusion and a discussion of the development perspectives for the ICT sector in North Jutland. A cluster of wireless communication firms and a range of more dispersed activities characterises the structure of ICT sector in North Jutland. The cluster is internationally visible, while the remaining segments are fragmented. There are several international companies in these segments, but most seems to be directed towards the home market. On the supply side the university has a series of international research groups and education of engineers. This is an advantage for North Jutland compared to many other regions in Denmark. The supply of qualified labour from the university constitutes a possible knowledge flow from the university to industry. But it should be noted that these graduates still need in-house training to gain the specific industry experience, which was found to very important in the theories of spinoffs.

The question of the development perspectives for the ICT sector in North Jutland is related to the development perspective for the cluster and the other interesting technological knowledge bases that also holds good performing firms, such as biomedical, logistics software, electromedical etc. But these do not produce many spinoffs and lacks critical mass of firms before the self-augmenting processes potentially could create a process of further growth in number of firms. The lesson from the cluster theory and the evolution of the NorCOM cluster on the development of clusters is clear. It takes many years and effort for a cluster to emerge in other segments of the ICT sector.

The DDN programme was not a large financial support programme compared to the EU structural funds. However, it had a possibility to strengthen the cluster or to focus on developing other segments of the ICT sector, but became too broad and unfocused. Unluckily, it was launched at the worst possible time by coinciding with the worldwide crisis in ICT. It has had some positive effects, but it does not appear to have left a visible lasting fingerprint on the development perspectives for the ICT sector in North Jutland.

Chapter 13

Summary in Danish

(Resumé på dansk)

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Formålet med denne ph.d. afhandling er at analysere udviklingsperspektiverne for den nordjyske informations- og kommunikationsteknologi (IKT) sektor. Dette er undersøgt i tre overordnede dele, hvor den første del præsenterer Nordjylland, udviklingen i den nordjyske IKT sektor og vidensstrømme i den danske IKT sektor. I anden del analyseres virksomhedsklyngen indenfor trådløs kommunikation i Nordjylland (NorCOM), mens del tre omhandler Det Digitale Nordjylland (DDN).

I kapitel 2 analyseres udviklingen i den danske IKT sektor fra 1992 til 2002. IKT sektoren i Nordjylland havde en bemærkelsesværdig vækst i beskæftigelse, som var næsten dobbelt så stor som på landsplan. Herunder blev beskæftigelsen i IT service næsten tredoblet. Men væksten i IKT sektoren stoppede i 2000 da konjunkturerne vendte brat med den verdensomspændende krise i IKT sektoren (der startede med IT boblens brist). Dette gik dog især ud over IKT fremstilling, hvorimod IKT service klarede sig bedre. Nordjylland er ikke specialiseret i IKT beskæftigelse, men specialiseringstallet steg fra 0,70 til 0,85, hvor en værdi på 1,0 angiver, at regionens andel er på landsgennemsnittet. Regionen nærmede sig dog landsgennemsnittet som følge af den højere vækst, men havde et lavere udgangspunkt. IKT sektoren har en tendens til at koncentrere sig omkring de store byer, herunder Aalborg, Århus og Københavnsområdet[1]. Strukturen af den nordjyske IKT sektor er forskellig fra sektoren som helhed, idet den viser en specialisering indenfor fremstilling. IKT service udgør dog stadigvæk to-tredjedele af den samlede beskæftigelse. Hovedparten af den samlede IKT beskæftigelse er koncentreret i NorCOM klyngen, mens IT service segmentet er relativt mindre sammenlignet med Århus og København.

Kapitel 3 udspringer af en generel bekymring over den relativt svage internationale performance af den danske IKT sektor. På den ene side er Danmark en af de mest avancerede bruger-nationer målt på konventionelle indikatorer, men på den anden side er Danmark ikke en af de store spillere på de internationale IKT markeder, ikke engang målt i forhold til størrelse. Sverige, Finland og Holland er alle eksempler på, at selv små lande kan være meget synlige på dette felt. Dette paradoks med avanceret efterspørgsel og svagt udbud blev analyseret ved at studere struktur, styrker og svagheder i den danske IKT sektor. På udbudssiden var der problemer med mangel på kvalificeret arbejdskraft, dominans af udenlandsk ejerskab i store dele af sektoren og ikke mindst mangel på en stor dansk

[1] Odense er en undtagelse, idet kommunen ikke er specialiseret i IKT beskæftigelse.

multinational IKT virksomhed. Det Digital Danmark, hvoraf DDN var en del, var et forsøg fra regeringens side på at forbedre sektorens performance, men situationen synes at være uændret.

Kapitel 4 indeholder en analyse af udviklingen i den nordjyske erhvervsstruktur fra 1983 til 2002. Nordjylland er traditionelt blevet karakteriseret som en udkantsregion med en arbejdsløshed blandt de højeste i Danmark, men der er flere faktorer, som peger på, at der er sket en ændring gennem de sidste tyve år. Erhvervsstrukturen har været domineret af de mere traditionelle industrier såsom landbrug og fødevareforarbejdelse, fiskeri, turisme, skibsværfter, tekstiler, tobak og cement. Op i gennem 1980'erne og 1990'erne har regionen gennemgået en strukturel forandring med krise i mange af de traditionelle industrier. Som følge af dette er jobs flyttet fra de traditionelle fremstillingserhverv til service- og højteknologiske erhverv. Selvom virksomhederne i Nordjylland stadig er specialiseret i den primære sektor og metalindustrien, så er de også specialiseret (dvs. har en beskæftigelsesandel, som er højere end landsgennemsnittet) indenfor maskin- og elektronikindustrien. Denne specialisering er blandt de træk, som tyder på, at Nordjylland ikke længere er en udkantsregion, men har en erhvervsstruktur, som er på linie med de andre ikke-metropolregioner i Danmark[2]. Regionen har gennemgået en forandring, men har stadig strukturelle problemer og lider under en arbejdsløshed over landsgennemsnittet, samt indkomster under landsgennemsnittet.

Del to vedrørende klyngeanalyse omhandler de mere specifikke debatter i litteraturen omkring lokaliserede vidensspillovers samt bredere emner omkring betydningen af knopskydninger og teknologiske livscykler i udviklingen af klynger.

I kapitel 5 analyseres betydningen af knopskydninger (spinoffs), der er skabt af entreprenører med industrierfaring for udviklingen af virksomhedsklynger. Nyere empiriske studier har fokuseret på hvordan nye virksomheders nedarvede organisatoriske rutiner er vigtige for udviklingen af industrier over tid. De nye virksomheders præstationer synes at være signifikant påvirket af grundlæggerens erfaringsmæssige baggrund. Virksomheder grundlagt af tidligere ansatte i en succesfuld virksomhed har større sandsynlighed for at overleve end andre nystartede virksomheder. Denne teoretiske tilgang er anvendt til at analysere udviklingen af NorCOM klyngen over fire årtier. Formålet er at analysere de dominerende kræfter bag dets udvikling på baggrund af detaljeret information omkring virksomhedsgrundlæggernes organisatoriske baggrund. Analysen i kapitel 5 viser, at virksomhedernes teknologiske succes har styrket en knopskydningsproces, som står for hovedparten af væksten i antallet af virksomheder i klyngen.

I kapitel 6 analyseres vidensstrømme gennem uformelle kontakter i en virksomhedsklynge. Den teoretiske diskussion har omhandlet betydningen af videnstrømme

[2] Metropolregionerne er Københavnsområdet og Århus Amt.

gennem uformelle kontakter mellem ansatte i forskellige virksomheder. Formålet med kapitlet er at undersøge dette ved hjælp af data fra en spørgeskemaundersøgelse udført blandt højtuddannet teknisk personale i NorCOM virksomhederne. Resultaterne viser, at disse deler selv værdifuld viden gennem deres uformelle kontakter, samt at de uformelle kontakter udgør en vigtig form for diffusion af viden.

I kapitel 7 analyseres sociale netværk mellem ansatte i NorCOM klyngen. Formålet er at analysere hvilke faktorer, som påvirker sandsynligheden for, at en ingeniør er aktiv deltager i sociale netværk mellem virksomheder. Analysen viser, at viden deles gennem sociale netværk i virksomhedsklyngen. Ingeniører, som tidligere har deltaget i formelle samarbejdsprojekter med andre klyngevirksomheder og ingeniører, som er i kontakt med tidligere kolleger og studiekammerater, har større sandsynlighed for at modtage mere værdifuld viden gennem disse kontakter.

Samspillet mellem teknologi og udviklingen af virksomhedsklynger er analyseret i kapitel 8. Fænomenet teknologiske livscykler har stor betydning ikke kun i udviklingen af industrier, men også i udviklingen af højteknologiske virksomhedsklynger. Nye forstyrrende teknologier kan igangsætte udviklingen af nye klynger og/eller skabe nye muligheder for videreudvikling af eksisterende klynger. Men de kan også medføre stagnation og forfald af disse. NorCOM klyngen har tidligere gennemlevet to teknologiske livscykler og befinder sig i dag på skiftepunktet til en tredje. Klyngen opstod i den første livscykel og voksede kraftigt under den anden efter at have overstået et meget turbulent, men succesfuldt, skifte. I kapitlet er der lagt vægt på at studere om og hvordan en fælles bevidsthed kan skabes, samt hvordan denne kan føre til fælles handlinger i perioder karakteriseret ved store trusler og mange muligheder. Dette fører til en diskussion om samspillet mellem private og offentlige igangsatte initiativer.

Del tre omhandler Det Digitale Nordjylland (DDN). De to første dele i denne afhandling udgør baggrunden for den videre analyse af DDN. I kapitel 9 undersøges DDN's historie og analyseres, hvordan profilen skiftede fra at fokusere på inkrementel forandring og IKT producenter til at blive igangsat som radikal forandring fokuseret på den almindelige bruger. Analysen omfatter også, hvordan DDN blev implementeret som et vidtfavnende program med en bred vifte af projekter rettet mod brugere. Udgangspunktet for analyserne er, om og hvordan DDN har haft langsigtede konsekvenser for udviklingsperspektiverne for den nordjyske IKT sektor.

I kapitel 10 analyseres tre emner i relation til DDN: Digital TV, m-handel og den fremtidige IT infrastruktur. Analyserne tager udgangspunkt i en række DDN projekter med nordjyske IKT virksomheder.

Kapitel 11 indeholder konklusionen og en diskussion af udviklingsperspektiverne for den nordjyske IKT sektor. Strukturen af IKT sektoren i Nordjylland er karakteriseret ved en

virksomhedsklynge i trådløs kommunikation samt en lang række mere spredte aktiviteter. Virksomhedsklyngen er internationalt synlig, mens de resterende segmenter er fragmenterede. Der er flere internationale virksomheder i disse segmenter, men de fleste synes at være fokuserede på egne hjemmemarkeder. På udbudssiden har Aalborg Universitet en lang række internationale forskningsgrupper og uddanner civilingeniører og dataloger. Dette giver Nordjylland en fordel sammenlignet med mange andre danske regioner. Udbuddet af kvalificeret arbejdskraft fra universitetet udgør en mulig vidensstrøm til virksomhederne, men det skal bemærkes, at de nyuddannede stadig har behov for 'træning' i virksomheden for at opnå industrispecifikerfaring. Denne er ifølge teorierne om knopskydning meget vigtig.

Spørgsmålet om udviklingsperspektiverne for den nordjyske IKT sektor hænger sammen med udviklingsperspektiverne for delmiljøerne i denne. Herunder virksomhedsklyngen og de andre interessante vidensmiljøer i regionen, som også indeholder succesfulde virksomheder. De sidstnævnte miljøer skaber ikke mange knopskydninger og mangler at opnå en kritisk masse før de selvstyrkende processer potentielt kunne medføre opstarten af endnu flere virksomheder. Lektien fra teorierne om udviklingen af klynger og fra NorCOM klyngens historie er klar: Det tager mange år og kræver en stor indsats før en virksomhedsklynge kan opstå i andre segmenter af den nordjyske IKT sektor.

DDN var finansielt ikke et stort program sammenlignet med de EU midler, der er tilfaldet den nordjyske region. Det havde muligheden for at styrke virksomhedsklyngen eller fokusere på andre segmenter af IKT sektoren i Nordjylland, men blev for bredtfavnende og ufokuseret. Uheldigvis blev DDN igangsat på det værst tænkelige tidspunkt sammenfaldene med den verdensomspændende krise indenfor IKT sektoren. DDN havde dog nogle positive effekter, men synes ikke at have efterladt et synligt og blivende fingeraftryk på udviklingsperspektiverne for den nordjyske IKT sektor.