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The role of entrepreneurship in cluster evolution: The case of wireless communication cluster in North Jutland, Denmark

Eunkyung Park
Aalborg University
Department of Business and Management
eunkyung@business.aau.dk

Abstract

Recent empirical studies have shown that entrepreneurship is often a key driver to formation of clusters. Examples of semiconductor industry in Silicon Valley, automobile industry in Detroit, and tire industry in Akron all demonstrate that some firms trigger formation of regional clusters by creating numerous spinoffs. In contrast to ample research on emergence of cluster, little is known about how clusters evolve over time and what role entrepreneurship plays in this process. This paper intends to investigate this issue with a case study of wireless communication cluster in North Jutland, Denmark. The wireless communication cluster, which has existed for the last 40 years, seems to have entered a declining phase since 2003 and we show that the lack of new firm formation has accelerated the decline as it could not compensate for continuous firm exit. We argue that entrepreneurship plays an important role not only in the early formation of cluster, but also in the later stage of cluster evolution.

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The Role of Entrepreneurship in Cluster Evolution: The Case of Wireless Communication Cluster in North Jutland, Denmark

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Eunkyung Park, Christian R. Østergaard

Aalborg University

IKE, Department of Business and Management

1. Introduction

Regional clusters have gained much attention by scholars and practitioners during the last 20 years. Increasing interest in clusters reflects the fact that successful clusters have emerged in a wide range of industries in different countries around the world (Porter, 1998; 2000). Although there is lack of consensus regarding the economic benefits of cluster to the regions (Jimenéz & Junquera, 2010), the prevalent existence of regional clusters provides motivation for researchers to study different aspects of the clusters (Enright, 2001). One key feature of regional clusters is that once they have emerged, they appear to be very resilient to chocks and often continue to exist for many years. Therefore most studies on clusters focus on how successful clusters emerge or identify factors and processes that make clusters grow. However, sometimes technologies and market conditions suddenly shift; firms close down, entry of new firms stops, highly skilled employees leave and clusters decline. The purpose of the paper is to study the role of entrepreneurship in the process of decline or possible transformation of clusters that has been overlooked in the literature.

One of the aspects investigated intensively in cluster research is emergence and development of clusters. Recent empirical studies have shown that entrepreneurship is often a key driver to formation of clusters. Examples of semiconductor industry in Silicon Valley (Klepper, 2010), automobile industry in Detroit (Klepper, 2010), telecommunication industry in North Jutland (Dahl, Østergaard, & Dalum, 2010), and tire industry in Akron (G. Buenstorf & Klepper, 2009) all demonstrate that some firms trigger formation of regional clusters by creating numerous spinoffs. For these cases, cluster formation process by spinoffs can be explained by following rationales: 1) spinoffs tend to locate close to the 'parent' companies, where the founders have worked before they established the spinoffs and 2) spinoffs from superior 'parent' companies perform better than other entrants.

In contrast to ample research on emergence of cluster, relatively little is known about how clusters evolve over time and what role entrepreneurship plays in this process. Despite the progress on cluster evolution research in the last couple of years, the literature still lacks an appropriate analytical framework (Boschma & Fornahl, 2011). Nevertheless, a cluster life cycle approach, which has developed out of product and industry life cycle, has been advocated by some scholars recently (for example, Menzel & Fornahl, 2010; Van Klink & De Langen, 2001). Menzel and Fornahl (2010) assert that clusters go through a life cycle that is different from a life cycle of industries. They suggest a cluster life cycle model in which knowledge heterogeneity among the firms in the cluster and how the knowledge heterogeneity is exploited by the firms drive the movement from one stage of life cycle to another. However, they also acknowledge that further research is necessary to uncover underlying processes and to test the model empirically.

This paper intends to investigate the role of entrepreneurship in the evolution of clusters focusing on a cluster that is in a declining phase. The conclusions we derive are based on a case study of wireless communication cluster in North Jutland, Denmark. The cluster emerged in the 1980s and it grew fast in terms of number of firms and employment during the 1990s along with the rapid growth of mobile communications industry. In the mid-2000s the cluster faced several disruptions in terms of changes in technologies and closure of mobile phone manufacturing firms due to the overall turbulent changes in the industry. The number of firm exits increased, but the employment of highly skilled engineers remained fairly stable since other firms hired laid-off engineers and new firms entered the cluster. A few years later, the entry of new firms stopped while the exits continued and this process of decline was enhanced in 2009 when the two largest R&D firms in the mobile phone part of the cluster closed down within a few months.

The paper is organized in the following structure. Theories of cluster evolution and decline are presented in Section 2. Section 3 describes the methodology of the paper. The evolution of the wireless communication cluster is described in section 4. The role of entrepreneurship in the evolution of the cluster is discussed in section 5. Discussion and conclusions follow in section 6 and 7 respectively.

2. Theories of cluster evolution and decline

The last two decades of research in the existence, functioning and evolution of clusters have revealed that clusters are different in terms of size, geography, age, knowledge base and breath and depth of the value chain. These differences have also affected the theoretical and empirical studies of clusters in the literature and lead to multiple definitions of clusters. An often used and workable definition of clusters is provided by Porter (1998):" Clusters are geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions in a particular field, linked by commonalities and complementarities (Porter, 1998, p. 199)". This definition is, however, also imprecise in delimiting the boundaries of the cluster concerning how the companies are interconnected and how the commonalities and complementarities should be perceived. It is apparent that the firms need to be linked more than just through the same geographical location and labor market. They must be coherent with activities within a limited part of an industry or industries and the same technological knowledge base. Therefore, they draw on a common pool of labor with knowledge and skills from the same technological knowledge base.

Changing the focus of study from the level of individual firms in an industry in a particular region to the collections of firms and other organizations increases complexity. The changes in a cluster are more than the sum of changes at firm level or at the individual level. It is somewhat paradoxically that clusters are not just collections of organizations, but there are no clusters without these collections of organizations. Similarly, changes in clusters depend on changes of single firms, but they also appear to be more than the combined changes of these. Nevertheless, the only way the cluster can change is though the actions of individuals, firms and other organizations. Furthermore, these internal actors are also to a large extent affected by external changes outside the cluster.

The cluster literature have found many causes for the existence and functioning of clusters (see e.g. Porter, 1998, Enright, 2001, and Brenner, 2004). Many of these factors are related to a high level of new firm formation, which is a requisite for becoming a cluster and the traditional Marshallian externalities where firms benefit agglomeration economies stemming from co-location in a cluster, such as economies of specialization, economies of labor pooling and localized knowledge spillovers. Most of these positive factors also have a dark side that often is overlooked in the literature and might be causes of decline. When many related firms are co-located, the congestion effects raise prices and wages. The labor pooling increases competition for specific skills and thus raises wages. It also makes it easier for valuable employees to leave a company and thus the company looses knowledge to potential competitors. In addition the localized knowledge spillovers also lead to a loss of information that could weaken firms' performance. The attraction of other firms to the cluster might therefore hamper the incumbent firms' growth (Falck, Guenther, Heblich, & Kerr, 2011). Higher startup rates also increase local competition for resources and when high skilled employees leave an incumbent to found a spinoff, it could also affect its performance. Sorensen and Audia (2000) find both a higher startup rate and a higher exit

rate in clusters, thus the churn is higher which indicates the existence of negative externalities in a cluster. Similarly, Klepper (2010) finds that it is mainly spinoffs from better companies that performed well and helped building the semiconductor cluster in Silicon Valley and automobile cluster in Detroit while other types of entry performed worse which indicates that agglomeration economies were not very high.

Studies have revealed that the processes and factors that lead to the emergence of a cluster are often different from those that sustain the functioning and growth of the cluster (Porter 1998; Enright, 2001; Brenner, 2004; Braunerhjelm & Feldman, 2006). In addition the factors and processes that were an advantage for the cluster sometimes end up being a reason for decline (Martin & Sunley, 2006). Therefore it becomes inherently difficult to point to single explanations for the decline of clusters, since the changes at cluster level is more than the sum of changes at firm level and could come from the interaction of several factors inside and outside the cluster. As a result it is necessary to look both at the micro dynamics of the cluster e.g. new firm formation and structural changes in the industry and cluster, such as technological change and market demand.

The population concept of resilience can be quite useful in providing a conceptualization of the shift from a functioning cluster to a declining cluster. Walker et al. (2004) defines resilience as: ”the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain the essentially the same function, structure, identity and feedbacks (p. 5)”. Resilience is the amount of disruption and stress a system can take and still function before it starts to break down. This implies that there is both a quantitative and a qualitative part of resilience, which has made it difficult to investigate empirically and apply to evolution of regional economic systems (see e.g. Simmie & Martin, 2010, and Holm & Østergaard, 2011). Cluster resilience is the amount of internal and external disturbance a cluster can absorb and still function before it turns into decline. Clusters often have a high level of resilience. The positive factors and processes that sustain clusters also make it resilient. When a company experiences a crisis and downsizes or closes down, the laid-off employees often are able to get a job in another firm in the cluster, new spinoffs emerge or new firms enter the cluster since they can get entire teams of highly-skilled labor. Thereby the knowledge and skills are kept in the region and the cluster and employment thus seems to be fairly stable to internal and external events. However, if the cluster’s resilience is weakened by various internal factors then negative external events may become disastrous and the cluster starts to decline. The function of the cluster then breaks down, the knowledge base shrinks when companies close down and high skilled employees leave the cluster and get a job in other industries or regions. When the number of firms and employees decline, it also reduces the chances for future spinoffs and the agglomeration economies. Thus it is necessary to look at both internal and external effect when analyzing the decline of clusters.

In the literature, a cluster is considered to be in decline when the number of firms and employees decreases and when revenue and output drop. Causes for decline can be both internal and external. Internal causes stem from cluster itself as it forms rigidities that diminish productivity and innovation. For example, union rules, regulatory inflexibility, cartels can deteriorate productivity. External causes originate from developments or discontinuities in external environments. Technological discontinuity can arise as competitive advantages shift to other locations. Buyer needs might also change which poses a threat to cluster’s survival (Porter, 1998). Belussi (2006) explains that the emergence of negative externalities such as congestion, cut-throat competition in final markets, increased prices for inputs and property, too much embeddedness of the institutional context, and locking-in into obsolete and/or ineffective innovation and learning system might lead to cluster decline. The author suggests that some positive reasons can also induce decline of clusters by encouraging re-location of local firms in other

countries. These positive forces could be 1) the need to access a different pool of knowledge, 2) the need to develop new markets, 3) the desire to gaining access to valuable assets that are embedded in other locations, and 4) the use of wage differentials (Belussi, 2006).

Enright (2001) postulates that clusters fail when their strengths such as localized routines, geographically impacted information, and ties between local firms and institutions become their weaknesses. According to the author, five basic failure modes can be observed. First of all, falling demands for a cluster's products can cause failure. Then, what can be called as organizational obsolescence could dissolve clusters as small firms in a cluster sometimes merge into one or a few firms. Cluster can also be displaced by similar clusters in other locations. The fourth mode is loss of cooperative relationships within cluster. Lastly, clusters can fail due to loss of dynamism through ossification, also called as 'lock-in.' 'Lock-in' concept, first applied in the cluster context by Grabher (1993), explains factors that diminish cluster's ability to recognize and make adjustments to changes in their environment. Grabher (1993) defined the failure of old industrial districts into three kinds of lock-ins. The first is a functional lock-in, which refers to hierarchical inter-firm relationships that hinder suppliers from developing critical functions such as marketing and R&D that are instead practiced through personal relationships within clusters. Cognitive lock-in means that clustered firms share a common world view or mindset that makes them hard to respond to changes outside the region. Political lock-in concerns institutional effort to keep existing traditional industry structures which might damage the development of creativity.

Despite the longevity of clusters, they are not static, but evolve gradually over time. The technological knowledge base continuously evolves depending on the actions of the organization in the cluster and the changes in the industry and market. Market growth creates opportunities for new firms to enter the cluster and for market broadening and application broadening, while declining markets increase the exit rate and hinder entry in the cluster. Change in demand is often coupled with change in technologies. Technological change might lead to cluster growth but is also a challenge because technological developments in clusters often have a degree of path dependency. Disruptive technologies that change the underlying knowledge base for an entire industry can easily lead to decline of clusters especially if the cluster firms are not able to move to the new technology or suffer from a technological or cognitive lock-in (Storper & Walker, 1989; Christensen, 1997; Dalum, Pedersen, & Villumsen, 2005). The firms in a cluster might suffer from group think that reduces the heterogeneity of knowledge in the cluster, which reduce the resilience and could lead to decline.

In the cluster literature, there has been a tendency to link cluster evolution with technology–industry life cycle. For example, Ter Wal and Boschma (2011) explain how clusters co-evolve with the industry and its technological properties at the macro-level, with the firms at the micro-level, and with the knowledge network of firms in the industry. Dalum et al. (2005) found that evolution of a cluster in an industry with fast-changing technologies is closely related to the shifts in technological life-cycle. Nonetheless, some empirical studies suggest that cluster life cycles are different from industry life cycles (Menzel & Fornahl, 2010). Menzel and Fornahl (2010) argue that different growth paths of the computer industry in Boston and Silicon described in Saxenian (1994)'s work indicate that the cluster life cycle is not the local representation of the industry. The authors argue furthermore that empirical findings on performance of clustered firm compared to non-clustered firms also prove this point. Audretsch and Feldman (1996) found that clustered firms perform better than non-clustered firms in the early phase of the industry life cycle and perform worse in the later phase which implies that the life cycle of clusters differs from that of industries.

Researchers supporting the notion of cluster life cycle introduce different phases which typically include the process of emergence, growth, maturity and decline. Although the early phases like emergence and growth seem to be represented similarly in different life cycle concepts, the later phases are described rather differently, indicating the lack of empirical evidence on mature clusters to establish more generalized concepts for these stages. On the other hand, it might just imply that clusters show such different development paths that it is hard to establish one universal track for their development.

Van Klink and De Langen (2001) distinguish four different 'development states' in a cluster's life cycle, namely, development, expansion, maturation, and transition. In their cycle, declining conditions are expressed in the state of transition, which, according to authors, can be brought by changes in the market or changing strategies of dominant cluster firms. In the transition state, the number of firms decreases as there are few entrants, but many exits. However, cluster in this state do not always end in cessation as it can develop a new path by organizing new capabilities and co-operation among cluster firms. Without being explicit on this, they suggest that the cluster can either 'die' or go through transition in the end. In an attempt to shed light on the full range of cluster cycle stages to compensate for current focus on the early stages, Bergman (2008) adopted three phases, existence, expansion, and exhaustion, which are originally suggested by Maskell and Kebir (2006). According to Bergman (2008), exhaustion phase arises "when maturity itself poses a clear threat to continued cluster viability (p.112)". In this phase, a cluster faces two directions to follow. Either it is 'locked-in' in the pause or it experiences a renaissance. While some clusters undergo extended pause over a long period of time, some clusters succeed in going through restructuring which involves the replacement of agents (firms), infrastructure, and institutions, and the reactivated appreciation of external ideas, innovations and technologies among others (Bergman, 2008). These clusters recover from exhaustion and therefore experience 'renaissance'.

Recently, Menzel and Fornahl (2010) suggested a four-staged life cycle going from emergence, growth, sustainment and decline. Size (quantitative dimension) and heterogeneity of knowledge (qualitative dimension) change over the course of maturity. They argue that the heterogeneity of knowledge within the cluster provides foundation for the cluster's development. This life cycle presents several development paths for a cluster. Clusters in sustainment stage face two paths, decline and adaptation. By generating new heterogeneity and shifts in thematic boundary, clusters can go one step back to the growth stage. When a cluster reaches the decline stage, there are three possibilities for its ending. One is to continue with the course of decline and diminish in the end. The second possibility is a renewal of the existing development path by, for example, applying new technologies from outside. Lastly, the cluster can transform itself into totally different fields.

As it is discussed above, various evolution paths are suggested in the cluster literature. It seems like more longitudinal studies on regional clusters are needed in order to establish a more comprehensible framework for cluster evolution. While it is true that development of clusters is subject to contingency arising from unexpected events (Popp & Wilson, 2007), some regularity can be derived from the patterns of development of different systems. Without being a deterministic model for evolution of cluster, life cycle framework can be useful for understanding each stage or phase in detail and questioning generalizations of clusters observed over different phases (Bergman, 2008). Critics of the life cycle approach claim that the concept implies a deterministic and smooth evolution that does not fit with empirics (Martin & Sunley, 2011). The emergence or growth of a potential cluster might be stopped and turn into decline at any point of the life cycle. There are also examples of clusters that start with a very homogeneous knowledge base and end up with a very heterogeneous knowledge

base (Dalum et al., 2005) or clusters that emerge from a single company with many employees that then follow an inverted u-shape evolution in the number of employees (Buenstorf & Fornahl, 2009).

One of the processes that are important for emergence, growth and decline of clusters is new firm formation. New firms often increase the heterogeneity of the knowledge base and bring variety to the cluster. In addition Holm and Østergaard (2011) find that the level of new firm formation has a positive impact on regional industrial resilience to changes in the business cycle. According to Helfat and Lieberman (2002), new firms can be divided into 1) diversifying entrant, 2) parent company venture, and 3) de novo entrant. Diversifying entrants are existing firms entering new or established market. Parent-company venture includes joint venture, franchise and parent spinoff. De novo entrants can be further divided by pre-entry experience. Firms established by entrepreneurs with experience in existing firms in the same industry are called entrepreneurial spinoffs and the others without prior employment in the industry can be distinguished as inexperienced startups. Among the types of new entrants, spinoffs have especially gained much attention in the cluster literature. Empirical studies show that spinoffs have some regularity in their characteristics, which contribute to formation of regional clusters.

Klepper and Sleeper (2005) found that spinoffs in the U.S. laser industry tend to start out by producing the same kind of laser that the parent company produced. This indicates that the founders exploit specific knowledge gained from the parent company and organize their activities in the same or related market. Buenstorf (2007) analyzed the German laser industry and found the similar patterns. He concluded furthermore that knowledge on market opportunities and customer needs is a more important determinant of firm success than technological capabilities. Prior experience in incumbents does not only enable the founders to capture business opportunities in the same industry, but it also has an affect on performance of entrants. Analyzing the disk drive industry in the U.S., Agarwal et al. (2004) found that spinoffs survive at a higher rate than any other types of entrants. Buenstorf and Klepper (2009) find that successful industry incumbents become training grounds for prospective entrepreneurs. In this way, relevant skills and knowledge are transferred from the incumbents to the new organizations, providing advantage to spinoffs in performance compared to other entrants in the industry. Similarly, Dahl and Reichstein (2007) argue that spinoffs from surviving parents are more likely to survive than spinoffs from exiting parents and other start-ups. Spinoffs from exiting parents have even less likelihood to survive than other start-ups, implying that it is type of experience that is important rather than the level of experience.

Spinoffs also show a certain pattern in their location choices as they tend to locate close to the parent companies (Buenstorf & Klepper, 2009; Parwada, 2008). Dahl and Sorensen (2009) argue that entrepreneurs choose their location based on emotional reasons. The authors found empirical evidence that proximity to family and friends matters more than economic attractiveness of the regions when founding a new company. Applying this to spinoffs, the founders are likely to establish the new organization close to the parent company because they are ‘socially embedded’ in the region where the ‘parent’ company is located. Sorensen and Audia (2000) studied geographic concentration of footwear production in the United States and found that the current distribution of production shapes the opportunity structure for future entrepreneurs. Entrepreneurs establish new firms in already dense areas as these locations allow individuals to accumulate knowledge about the industry, social ties and confidence to start a venture. This also explains the rationale that the founders of spinoffs tend to start new ventures close to other incumbents, including the ‘parent’ company.

Summing up, entrepreneurial spinoffs enter similar industry as the one the parent company is active in while they pursue market or technological opportunities that are often not exploited by the parent firm. The entrepreneurs tend to locate their startup in proximity to the parent company. Then, once established, spinoffs outperform other entrants in the industry and survive longer. Following this logic, we can assume that the spinoffs will create successful second-generation spinoffs in the area. Thus superior 'parent' companies and their spinoffs drive the clustering of firms in certain regions. This pattern has been observed in different regional clusters (Klepper, 2010; Buenstorf & Fornahl, 2009, Dahl et al., 2010).

However, if new firm formation for some reason stops, then the cluster loses an important source of knowledge heterogeneity. The stop in entry also lowers the resilience of the cluster and makes the cluster more sensible to firm closure or external chocks. It might lead to decline in the number of firms if the exit rate is persistent (Sorenson & Audia, 2000). Furthermore, the spinoff literature finds that some firms are better training grounds than others and make more spinoffs, while other companies never produce a single spinoff (Klepper, 2010). If the first type of company closes down, it could also mark the beginning of the decline of a cluster. Therefore, the level of new firm formation (especially spinoffs) seems to be either one of the main causes of cluster decline or a symptom of the beginning of the decline.

3. Methodology

The data on our case, the wireless communication cluster in North Jutland, was collected in the following ways. First of all, we started with archives from earlier studies on the emergence and development of wireless cluster in North Jutland (e.g. Dalum, 1995; Dahl et al., 2003). The list of all firms that have been active in the cluster until 2003 had been compiled by Dahl et al. (2003) with the founding and exit year (if any), the names of founders and their previous workplaces, and the main events in the history of the firma such as acquisition and bankruptcies. Then, we identified new entrants from 2003 and onwards by consulting cluster organization's archive on member companies and searching in the various online databases for newspaper articles, media reports and corporate information. After updating the list of firms, we identified the founders of the new companies and their former employers in similar ways, relying mainly on online corporate database, corporate websites, online network platforms and newspaper articles. Each firm has been researched thoroughly for main events including ownership change and closedown mainly on internet sources.

The next step was to collect data on the number of employees of each firm for the last two decades. The early employment data until 2002 came from earlier scholarly work on the Norcom cluster (Dalum, 1993, 1995, 1998; Dalum et al., 1999; Pedersen, 2001; Dalum et al., 2002). The numbers from 2002 and onwards are collected from diverse corporate databases, depending on the time periods that the firms existed. For the firms that still exist now, an online corporate database was used to track the number of employees up to five years back. We used a different corporate information archive to find the numbers for the firms that have already exited the cluster before 2011. Since not all firms are covered by those databases, newspaper articles and media reports were used additionally to find the numbers that are missing. When we finished this step, there were still some numbers lacking. Then, we took estimation by taking the average of the numbers before and after the missing period, assuming that the number of employee grew or decreased linearly.

The last part of our data includes a list of former Motorola and Texas Instruments employees who were laid off when the two firms exited the cluster in 2009 and their new workplace, including the location and the new job function. The data for the former Motorola employees came from one employee who kept track of where his colleagues found new jobs. He collected information directly from the colleagues or from an online network platform. The list of former TI employees was compiled by the authors by searching on the same online network platform. It is hard to find the accurate number of employees who were affected by the closure of the two companies as many employees changed job before the date of official exit. However, comparing the number of fired employees officially reported in the media and the number of employees we identified on our list, we can conclude that our data is rather complete. Furthermore, we have identified spinoffs established by former Motorola and TI employees after the company closure by searching on online media sources. Then, this list was double-checked with the data on new jobs of the former employees.

4. Evolution of wireless communication cluster (Norcom) in North Jutland

History

The history of wireless communication cluster in North Jutland (named Norcom) started with the success of the leading producer of maritime communication equipment, S.P. Radio. S.P. Radio (established in Aalborg in 1942) produced consumer electronics until the early 1960s when the founder decided to produce radio communication equipment for maritime use for small and medium sized vessels. The company had huge success by diversifying into this area as there was almost no competition in the market and its equipment was technologically more advanced than those of the few competitors. A couple of successful local spinoffs have sprung up from S.P. Radio in the 1970s. In 1973, three engineers including the head of R&D from S.P. Radio established the first spinoff company, Dancom. Dancom also produced maritime communication equipment and competed with S.P. Radio in the same markets. A few years later, two engineers from Dancom started Shipmate which also produced radiophone for maritime use. In the 1980s, Shipmate developed a satellite navigation system which became one of the company's main products together with the radiophone.

In the 1980s, a range of the next generation spinoffs came from Dancom (restructured and renamed to Dancall Radio in 1983) and Shipmate. These companies diversified into a related area of personal mobile communication equipment which was led by the introduction of new technology – the common Nordic standard for mobile telephony (NMT). Inheriting capabilities within maritime radio communication from the parent companies, the spinoffs were well equipped for this diversification. One example of the next generation spinoffs is Cetelco that was established as a parent spinoff by Shipmate with the purpose of exploiting the promising business opportunity in mobile communications, the overlap between maritime communication technologies and mobile telecommunication technologies, and the possibility of economies of scale in production. Cetelco developed its first NMT phone in 1986 and began to produce mobile phones for several European and East Asian countries. Another example is T-com. Seven engineers from Dancall disagreed with the company's overall market strategy and founded T-com, which focused on R&D part of mobile phone production. Their strategy was to be an R&D subcontractor for other mobile phone producers, which then produced and sold mobile phones under their names. At the end of the 1980s, there were 15 firms in the industry and the majority of the firms were spinoffs. In the late 1980s, the common European standard for mobile telephony (GSM) was introduced and the leading

producers of mobile phones competed to be the first one to develop a GSM phone. Dancall and Cetelco formed a joint venture company, DC Development, to develop the basic modules of a GSM phone together with the Department of Electronic system at Aalborg University. DC Development succeeded in developing the modules and the parent companies were among the first to produce a GSM phone. In the 1990s, more spinoffs were founded within telecommunication, producing mobile phones, chips, and components, or other supporting technologies. This development, however, was not smooth since several companies in the cluster went into severe financial and technological problems following the shift from analog NMT (1G) to digital GSM (2G) mobile communication technology. As the cluster was resilient in this period, some of the troubled companies and laid-off employees were taken over by other companies in the cluster and new companies entered the cluster.

By the end of 1990s, the number of firms in the wireless cluster has more than doubled. The high increase in the number of firms was mainly due to entry by spinoffs. Among 20 entrants in the 1990s, seven of them were entrepreneurial spinoffs, whose founders had experience in the cluster before the start-up and six of them were parent spinoffs, which were newly established subsidiaries of foreign companies. For example, Analog Devices, Lucent, Infineon, and Nokia entered the cluster by establishing a new branch. In this period, the ownership structure of the cluster has changed significantly as many multinational corporations (MNCs) entered the cluster either by creating a new organization as mentioned above or by acquiring local firms. The latter happened as the local firms experienced financial trouble due to declining markets or general lack of R&D funds for new technologies while large multinational players in the industry were looking for the new locations in order to access competences of local development engineers (Lorenzen & Mahnke, 2002). Maxon, Bosch Telecom, Telital and Texas Instruments are examples of MNCs that entered the cluster by acquiring already existing firms.

The cluster experienced the first external shock in the early 2000s when the telecommunication sector was hit by stagnating sales after the burst of dot-com bubble. The MNCs in the cluster changed their strategies and either collected R&D units in the home country or reduced R&D expenses in the subsidiaries. Consequently, many of the MNCs downsized and sacked local engineers. Some local firms were able to absorb the released work force from the MNCs and some engineers even created their own companies, e.g. Futarque, Wirtek, EB Denmark and PI Engineering. Despite the downsizing of MNCS, the number of companies grew in the same period as there were many new companies entering the cluster, indicating that the cluster was still resilient. During the last half of the 2000s, turbulence in the cluster continued as many firms closed down or downsized. The number of employees and firms began to decrease after the peak in 2003. One of the big companies in the cluster, Flextronics, closed down with 500 employees in Pandrup in 2004. The company has lost a big order from the major customer Siemens and the headquarters in Singapore decided to move the production to low cost locations. Flextronics had its root in Dancom which has gone through restructuring several times with new owners since 1980s. Dancom firstly changed its name to Dancall Radio in 1983 and then renamed again to Dancall Telecom in 1993. Dancall Telecom was acquired by Bosch Telecom in 1997 which lasted 3 years before it was split into two companies, Flextronics and Siemens. As Dancom was the cluster's second oldest company which created many spinoffs, close-down of Flextronics was considered as a catastrophic event for the cluster.

Between 2004 and 2006, there was no entry in the cluster, whereas exit continued to occur. Recently, two more central players in the cluster, Motorola and Texas Instruments (TI), ceased their activities. Motorola entered the cluster by acquiring BenQ which had taken over Siemens' activities in 2005 but closed down all the operation in Europe the very next year. Motorola's Aalborg division had focused on development of new mobile telephones

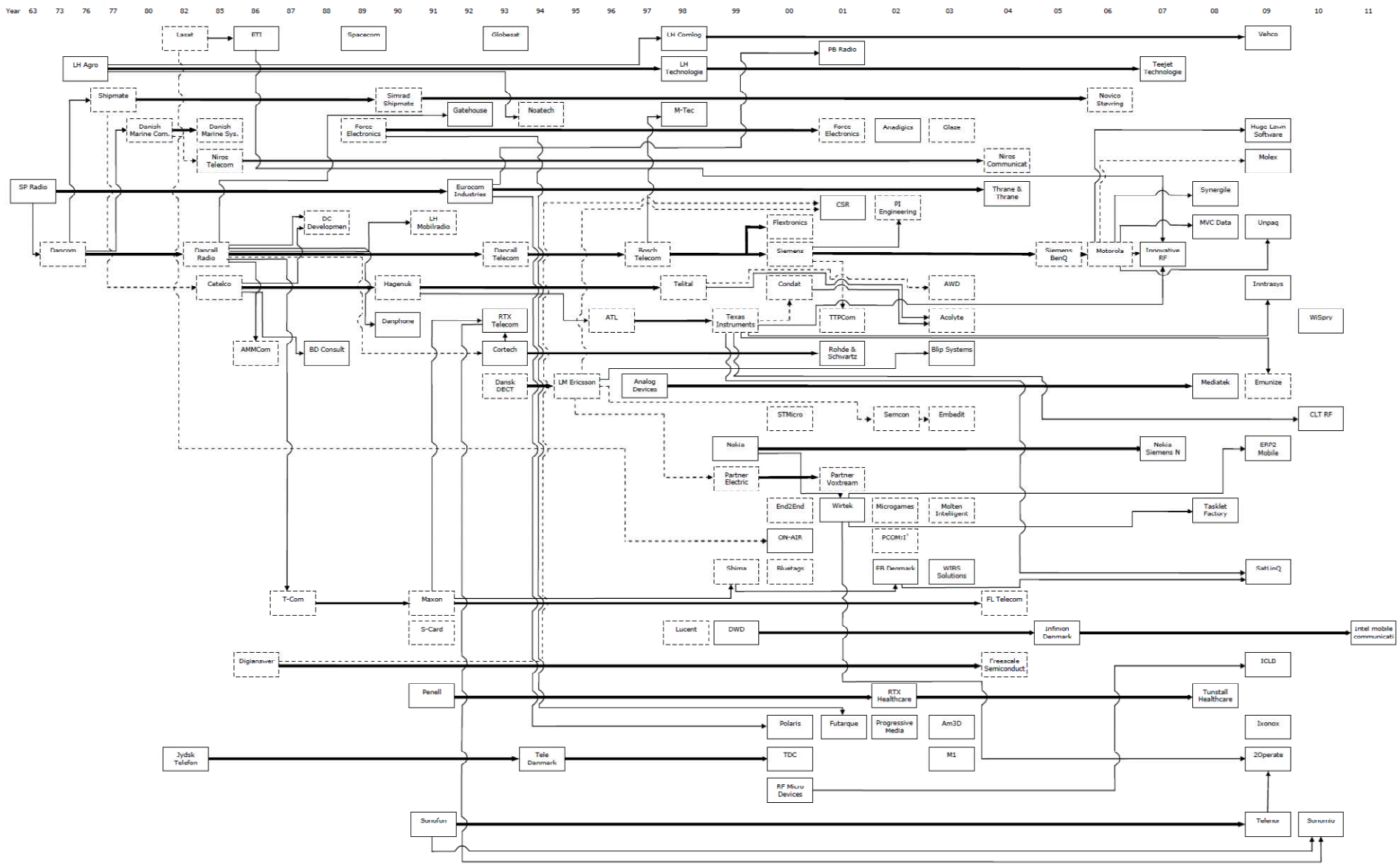
until the headquarters decided to pull out of European mobile market and reduce the number of newly developed models. TI acquired local ATL Research which was established as a spinoff from Cetelco in 1997. TI suffered from focusing on chipsets to EDGE/GPRS phones instead of 3G phones. Motorola and TI had to lay off respectively 275 and 75 employees in 2009 which worried the local actors in the industry. Unlike the former incidents where MNCs laid off many engineers at once, the industry could not take in all the engineers as it was not in the growing phase any longer. This resulted in work force migration to other regions in Denmark and to other industries. At this point, the cluster appears to have lost the resilience.

The genealogy of the cluster

The genealogy of the wireless communication cluster is shown in figure 1. This illustration summarizes the history of the cluster and shows the importance of spinoff activities in the development of the cluster. Fine arrows between firms show that one or more employees from existing firms established spinoff firms. Dotted arrows represent parent spinoffs where the founders or initial management have come from local firms. Bold arrows show change in the original structure of the company including acquisition by another firm and reconstruction after financial difficulties. Firms with dotted box have exited the cluster.

A substantial number of entrants are established by founders with experience in already existing firms in the cluster. It is also possible to identify the firms that created most spinoffs in the cluster and the time periods in which entrepreneurial activities were most active in the history. S.P. Radio, Dancom, Cetelco and LM Ericsson are the companies that created the most spinoffs during their existence. The first three firms can be seen as forefathers of the cluster as they entered the cluster in its early history and generated many offspring. Many entrepreneurial activities are observed in the early 2000s, but the situation changes drastically in the next half-decade, as no entry is observed between 2004 and 2006.

Figure 1 The genealogy of the cluster

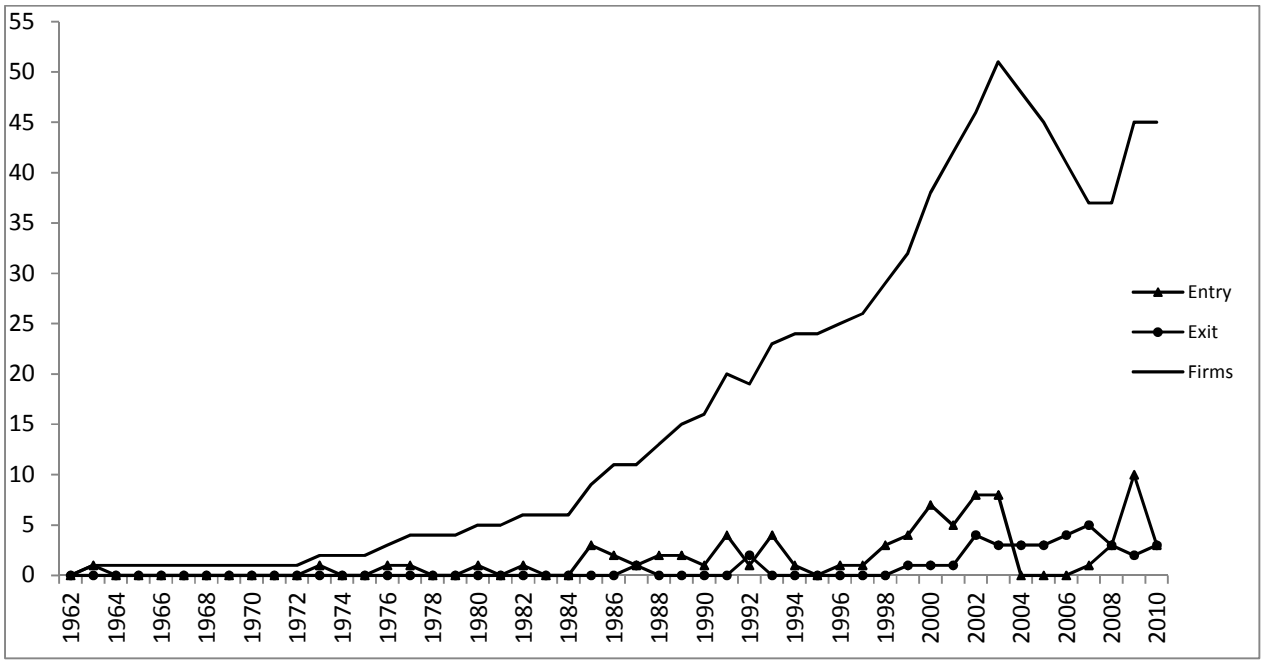


Source: Updated from the genealogical evolution figure in Dahl et al. (2003, p.20)

Entry and exit of firms in the cluster

The more detailed entry and exit trend of the Norcom cluster is discussed here. The change in population of firms is shown in figure 2. The figure demonstrates the turbulence that the cluster has gone through since the early 2000s.

Figure 2 Entry and exit of firms in the cluster

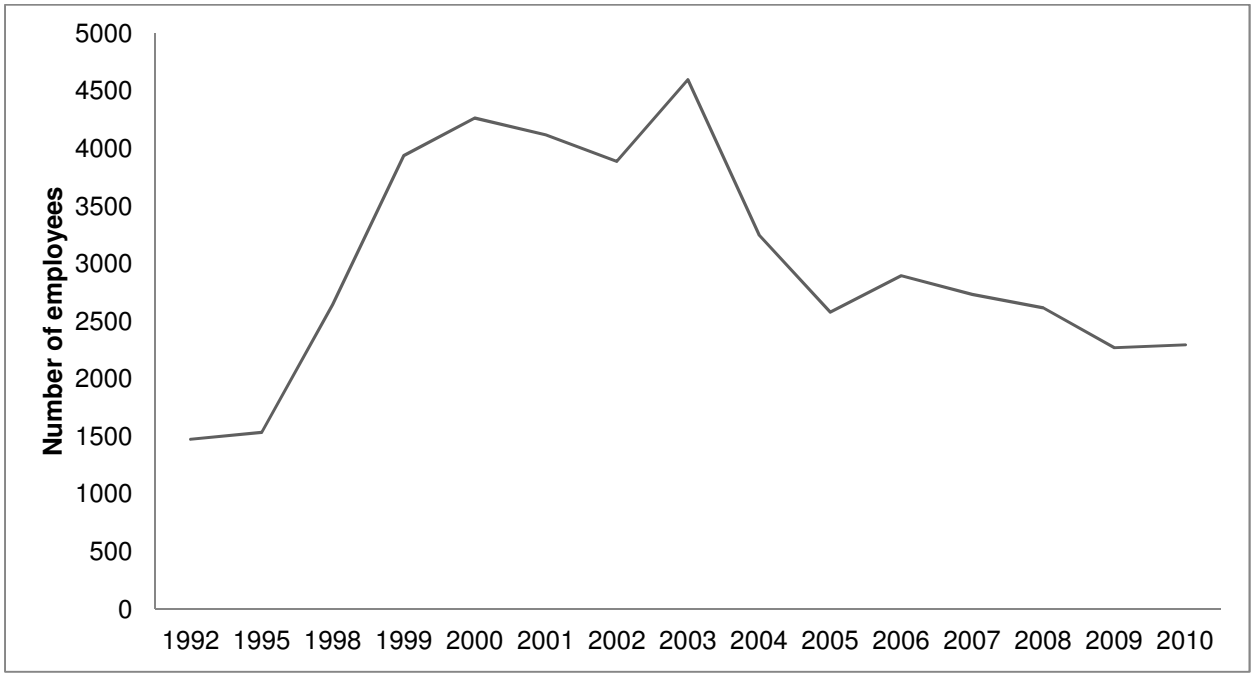


The number of firms had increased steadily until 2003 as there were very few exits but plenty of entries. In this period, some firms were saved from exit by being taken over by other firms, typically MNCs. The different slopes show different phases of development of the cluster. In the 1970s and up until 1984, the cluster grew gently from two to six companies. The next phase until 1996 has a steeper slope as the number grows to 25 firms. From 1997 to 2003, the growth happened even more rapidly and the total number of firms reached 51. Then, between 2004 and 2006, there was no entry at all while firms continued to exit. The cluster started to decline in 2003 and the number of firms dropped quite drastically. In 2008, the number of entry and exit equaled because entry started to grow. In 2009, the number of entry for a year peaked as 10 new firms were established. Although some firms have exited in the same year, the total number of firms recovered to 45 due to the high increase in entry. The majority of the new firms in 2009 were founded by former Motorola and TI employees after the two firms exited the cluster.

Change in the number of employees in the cluster

Figure 3 shows the change in the number of employees in the cluster over the last two decades. The cluster seems to be in a declining phase when it comes to the development in the number of work force in the cluster.

Figure 3 Employment in the cluster



The development in the last 20 years shows that the cluster was largest in 2003. The total employment data is available from 1992 when the cluster had 19 firms. The number of employees did not change much from 1992 to 1995 and stayed around 1500. From 1995 to 1999, this number increased drastically from 1533 to 3936 while the number of firms increased merely by eight. As the new established firms' contribution to this increase is 128, this means that the existing firms built up their size enormously during this period. When the crisis came in the early 2000s, the total employment decreased slightly from 2000 to 2002, but increased again in 2003 mainly due to expansion by Flextronics. From 2003, the number had decreased quite drastically until 2005 as many firms downsized and exited in this period. Except the increase by 316 in 2006, the number had continued to decline until 2010, when the number increased merely by 24.

From the above analyses, the evolution of Norcom can be explained in terms of a cluster life cycle (Menzel & Fornahl, 2010). Regarding the size in employment, the Norcom cluster had been in the growth phase up until 2000 and went into the sustainment phase for a short while from 2000 to 2003 with minor fluctuation. From 2003 until 2009, the Norcom cluster seemed to be in the declining phase where the number of employees declines as time goes. Although the size continued to decrease, the decline had slowed down since 2005 and the number of employees has been stable during the last couple of years. In terms of the number of firms in the cluster, it seems like a kind of renewal took place in 2009 as a relative high level of entry is observed after some years of very low entry. However, we also observe substantial employee migration from the cluster to other industries or to other regions in 2009 when Motorola and Texas Instruments closed down (Appendix A). Only 27 percent of the former employees from the two companies stayed within the cluster with their new jobs.

Considering that the two companies were R&D units and the former employees were mainly engineers, we conclude that the cluster lost its capacity to retain knowledge workers and therefore is in the declining phase.

Explanation for downturn of the cluster in recent years

Several internal and external factors can be identified to explain the downturn of the cluster. First of all, technological competence in the cluster is an important internal factor that affected the evolution of the cluster combined with an external factor, technology shift in the mobile telecommunication market. As briefly explained in the history, the cluster has its root in NMT (1G) and GSM (2G) technologies. The early startups in the cluster, S.P. Radio, Dancall, Shipmate and Cetelco, all grew with the development of NMT mobile industry. When the next generation of mobile system, GSM, was introduced, Dancall and Cetelco were among the first to produce the GSM phones in the market. Sonofon which was the first private GSM operator decided to build its main operations in Aalborg and there were several other companies in the cluster that continued to develop GSM equipments. The technological competence broadened as some companies founded a joint venture Dansk DECT Udvikling to focus on ETSI standard for cordless phones while others went into the field of Bluetooth standard. Companies like Texas Instruments, Infineon and Cambridge Silicon Radio entered the cluster and focused on development of GSM terminal equipments. However, when UMTS (3G) emerged, the development of basic 3G technologies did not take place in the cluster to the same degree as the development of the 1G and 2G took place in the past (Dalum et al., 2005). 3G proved to be a major technological disruption and attracted some new players to the industry. The technology is vastly more complex than 2G and requires huge investments in R&D that only large companies can afford. Consequently, the technological competences within 3G were mainly developed in other parts of the world (e.g. Asia). Furthermore, the introduction of the Iphone in 2007 led to change in demand from traditional mobile phones to smart phones and 3G telephones have gradually taken over the mobile telephone market. Therefore, the lack of these competences in the cluster influenced some central companies' (e.g. Motorola and Texas Instruments) decision to cease the activities in the cluster.

Another factor that affected the development of the cluster was high concentration of MNCs. Many MNCs present in the cluster had headquarters in other countries and the units in North Jutland did not have much influence on strategic decisions made by the headquarters. Especially when the mobile telecommunication sector had crisis in the early 2000s and the financial crisis hit the economies worldwide in 2008, many of these MNCs had to reorganize their activities to stay competitive in the market. Motorola and Texas Instruments decided to focus on other technology areas and Ericsson gathered its development activities to bigger R&D centers. Lastly, high wage level in the cluster also caused some firms to close down in North Jutland. The wage level of highly qualified engineers had skyrocketed during the 2000s because of the increase in demand for specialized labor. Since many firms in the cluster were involved in the production of mobile phones and components, they became sensitive to high production costs in Denmark. When Flextronics and Navico closed down the production in North Jutland, the companies indicated that the production will be relocated in low-cost locations.

The evolution of the Norcom cluster is a product of several factors affecting the development together. Among the factors, technological and cognitive lock-in could be identified as major causes since the cluster was not active in developing new technological competences within 3G. Focusing on the competences the firms already had (e.g. 1G and 2G), they probably were not able to recognize the trend in the market and acknowledge the need to develop new ones. As a consequence, not only this led to many firm exits in the cluster, but it also limited the opportunities for new businesses, resulting in a very low entry level.

5. The role of entrepreneurial spinoffs in the evolution of the cluster

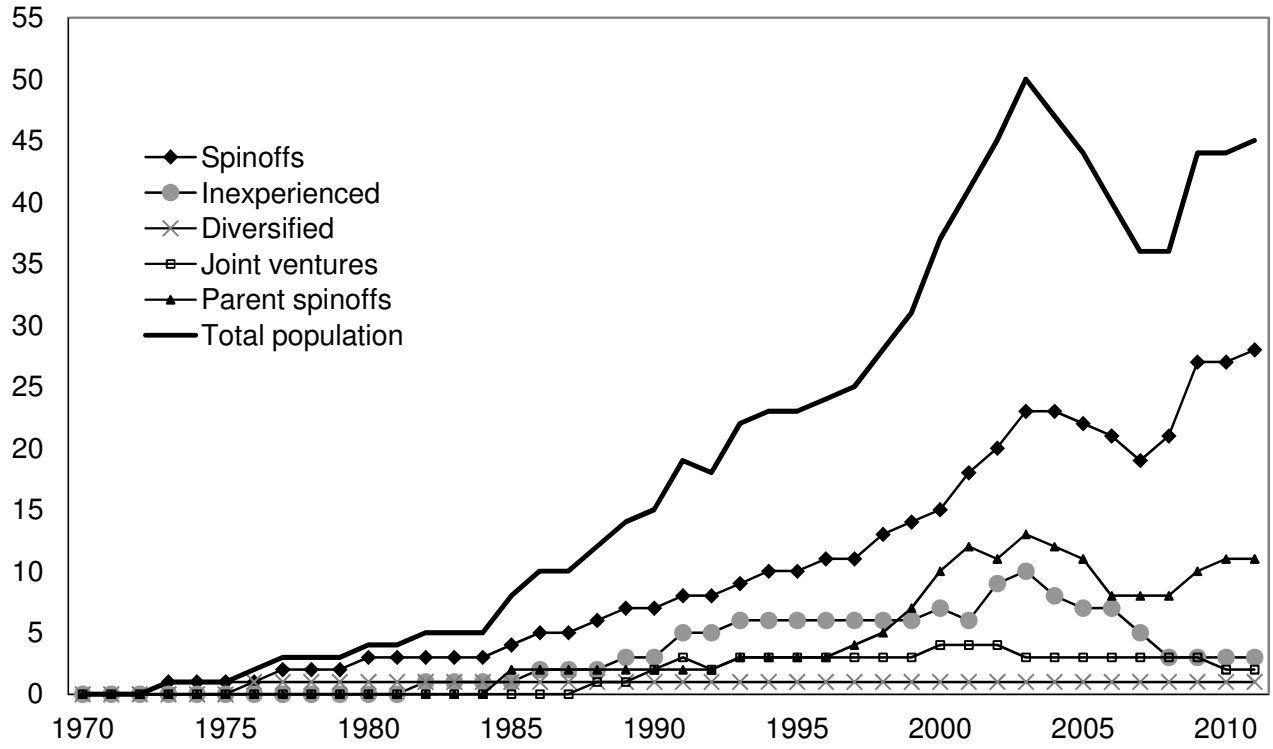
Entrepreneurship has played a critical role in the evolution of NorCOM. In their earlier work, Dahl et al. (2010) concluded that entrepreneurial spinoffs from the existing companies have been the main driver of the formation and development of the cluster until the early 2000s. In their analysis, they divided the entrants into 1) diversifying entrants (firms entering new or established markets unknown to them), 2) parent spinoffs (new entities founded by established firms), 3) joint ventures, 4) entrepreneurial spinoffs (firms founded persons with previous employment in incumbents in the industry), and 5) inexperienced entrants (founded by persons with no previous employment in the industry). It was found that the entrepreneurial spinoffs represented the largest group of all over the whole period. The spinoff process was especially important in the very early emergent phase where S.P. Radio created offspring that diversified into mobile telecommunication. The existence and survival of Dancom and Cetelco, the two seedbeds for many spinoffs later on, was also crucial for further development of the cluster.

Continuing this analysis for the extended period until 2011, we argue that entrepreneurial spinoffs also have high impact on the further evolution of the Norcom cluster. We also employ the division of entrants by Dahl et al. (2010) in this paper as it describes our case well. Looking at the change in the population of firms by these entry types (see figure 4), it is hard to deny that spinoffs, especially entrepreneurial spinoffs, largely account for the development of the cluster over the whole time period. Especially in the most recent years when the downturn began, it is apparent that the evolution of the cluster follows that of the entrepreneurial spinoffs. Considering the large share of entrepreneurial spinoffs, this implies that the dynamics of these firms contribute the most to the evolution of the cluster compared to contribution by any other types of entry.

In discussing the importance of spinoffs, it is important to point out that firms that had created many spinoffs in the history have exited the cluster within the last 10 years. The company which had bred most spinoffs in the cluster was Dancom that had 14 spinoffs before its exit in 2009 and four spinoffs after the exit. Dancom had experienced several occasions with financial difficulties during its existence and therefore changed owners many times. However, the company managed to breed many spinoffs including Shipmate and Danish Marine Communication which became parent to other organizations in the cluster. Cetelco, which exited in 2002, had 5 spinoffs during its life. One of its spinoffs, ATL Research (later acquired by Texas Instruments and exited in 2009), also became seedbed for new firms as total six spinoffs came from this company. In 2003, L.M. Ericsson, which was parent to four firms in the cluster have ceased its activities. This spinoff history over few generations confirms that some firms function as training ground for entrepreneurs who gain relevant capabilities and routines from the parent companies. Therefore, it raises concern that these firms exited the cluster in recent years when the cluster started to show signs of decline. This might explain the low level of entry in the past six years with the exception of year 2009. Klepper (2010) also found that a few companies are major sources of spinoffs while others do not produce a single spinoff. RTX is an example of the latter. RTX was founded in 1993 and experienced a fast growth during the 1990s and early 2000s, growing to 230 employees in 2002. It is known to be an innovative company with a low labor turnover and the strategy to start up new projects in various technologies. It seems like the company's strategy to allow the employees initiate different projects within a broad range of technologies kept them from founding spinoffs until 2010, when the former CEO founded a mobile communication service provider company together with two other entrepreneurs from other imcumbents.

The CEO previously worked as a director of a large mobile communication service provider in the region for many years.

Figure 4 Firm population by entry type



The importance of entrepreneurship, regardless of the type, is shown in the years when entry was absent for 3 years (see figure 2). These three years of no entry have clearly contributed to the downturn, by not compensating for the continuous exits.

6. Discussion – Decline or possible transformation in the future?

Considering the development in the level of employment of the Norcom cluster, we have argued that the cluster is in the declining phase. However, one might contend that the increase in the number of entrants in 2009 (mainly spinoffs from Motorola and Texas Instruments) suggests possible revival of the cluster. We also observe another factor that could perhaps lead to the transformation of the cluster in the future, while it is too early to determine whether the transformation is taking place or not. These factors are discussed in this section.

Merger of two industry organizations, NORCOM and IKT Forum

The wireless communication cluster in the North Jutland had its own industry association, NorCOM, which organized industry-specific activities such as symposia, recruiting events, and plenary sessions. It started in early 1997 as a club of firms and knowledge institutions and was formally founded as association with a board of

directors in January, 2000. The mission of NorCOM was to improve and expand the scope of business opportunities, technological development and innovation in the cluster. The NorCOM activities were organized and financed by the members and NOVI Science Park.

In 2009, after Motorola announced its close-down, NorCOM merged with another local industry association IKT Forum which represented a wide range of firms in information- and communication technology (ICT) industry[1]. IKT Forum was a relatively new organization (founded in 2005) that counted all types of firms and institutions dealing with ICT – from small businesses that sell and service website solutions to municipalities and companies that provide IT-healthcare services. The decision was made while the two organizations were working together to develop a new business platform for ICT industry, BrainsBusiness, which was funded by the regional growth forum. As the ICT industry was converging and creating new ideas, the two organizations did not see the distinction between wireless and non-wireless relevant and agreed that they could serve the existing and new businesses better if they merged together. The new organization is called ICTNorCOM which became the major partner for BrainsBusiness. This official merger also reflects how the two industries are intertwined in their evolution in the region. When wireless communication companies shut their businesses down in recent years, many of the discharged engineers, especially the software engineers, found new jobs in related ICT firms. During the last 20 years, ICT industry in the region has grown significantly as the employment grew by over 40 percent. Therefore, this industry had the capacity to take in some of the employees laid off from the wireless communication firms.

ICTNorCOM's birth indicates the possible injection of new knowledge into the wireless cluster, contributing to the increase the heterogeneity of knowledge in the cluster. According to Menzel and Fornahl (2010), this allows the cluster to renew itself from the declining phase. Similarly, Bergman (2008) asserts that diverse agents and polyvalent technology sources are the assets that could help exhausted clusters through the process of restructuring towards the 'renaissance.' The close collaboration between the two (although very similar) industries might encourage the wireless communication cluster to reorganize its activities and find new business opportunities. There are already some signs that wireless firms are influenced by the presence of the ICT firms. Historically, wireless communication cluster was dominated by firms that produced hardware parts of the mobile phones, but this has changed recently as more and more firms are engaged with software development.

Spinoffs by Motorola and TI employees

A flock of new companies in 2009 stopped a rather drastic decline of firm population in the cluster since 2003. The majority of new entrants were spinoffs founded by former employees of Motorola and Texas Instruments. Eight firms in the cluster originated from the two companies since 2008. In this section, we introduce the spinoff activities initiated from the exit of the two companies and discuss how they might affect the evolution of the cluster.

All in all, 32 firms spun off from Motorola and TI from 2008 onwards (see Appendix B). In terms of industry, eight out of 32 companies were established in the wireless communication industry where the two parent companies also belonged to. 15 companies can be classified as ICT companies and the remaining nine

[1] In the rest of the paper, ICT industry refers to non-wireless-communication-related ICT firms in an attempt to distinguish the wireless communication industry, which the cluster is related to, from the broader ICT industry.

companies are in other unrelated industries. The majority of the founders have engineering background and they founded companies within their own field of areas. As many of them are hardware and software engineers, they established consulting firms dealing with hardware and software development. For example, software engineers started firms developing computer games, web solutions and other software solutions. A greater number of new entrepreneurial spinoffs were founded in the related ICT industry than in wireless communication industry although strict distinction between ICT and wireless communication industry can not be applied for some firms[2]. It can be interpreted that new start-ups did not see new market opportunities in the cluster and therefore positioned themselves in the broader ICT industry where they can reach a wider set of customers. It could also reflect that the merger of the two industry organizations encouraged the founders to position themselves according to the new ICTNorCOM boundary.

With the reorganization of industry organizations and the influx of new spinoffs from 2008/9, the cluster might go through a transformation process towards becoming an ICT cluster. However, the survival of the new spinoffs and their influence on the cluster is rather questionable. Four spinoffs have already closed down and ten founders have another regular job other than the start-up. These ten founders demonstrate necessity-driven entrepreneurs, who founded consulting firms while they were between jobs. The majority of the new firms have one or two employees which represent the founders themselves. After a couple of years of operation, most of them do not show growth in terms of employment. Considering that the spinoffs are from exiting parent companies, we can carefully assume that these firms are not likely to prosper. All in all, whether or not the cluster will be able to reorganize itself towards its renaissance is a matter that time will eventually show.

7. Conclusions

The wireless communication cluster in North Jutland is a rather mature cluster that has existed for 40 years in a rapid changing industry. By following its evolution path utilizing the concept of cluster life cycle, we conclude that the cluster seems to be in a declining phase and possibly expecting a process of transformation. Since the number of employees peaked in 2003, the cluster has been in the continuous downturn. As is often assumed, there were multiple causes for the cluster decline. We found that both internal and external factors appear to have led the decline and weakened the cluster resilience. First of all, the cluster's focus on 2G technologies has affected some major companies' decision to close down the operation in the cluster since 3G became the dominant platform in the market. 3G technologies have been intensively developed in other parts of the world, and therefore the whole industry started to move towards the source of new technologies. At the same time, the mobile communication industry has gone through restructuring worldwide as large MNCs either sold their business units to other major firms, ceased operation completely in the mobile market, or changed core technological platforms (e.g. operating systems on the phone). This overall change has also had an effect on firm dynamics in the cluster in North Jutland. Thus, the technological and cognitive lock-in and some external changes in the industry and market needs have altogether influenced the development of the cluster.

Moreover, we also find that new firm formation has been important in the evolution of the wireless communication cluster. Advancing the previous findings on the role of entrepreneurship in the emergence of the

[2] We distinguished the firms based on the target customers identified in media reports, newspaper articles and the companies' websites.

cluster, we argue that entrepreneurship has influenced the cluster throughout the whole evolution path. Especially, the lack of new firm formation in recent years has accelerated the decline as it could not make up for the high level of exit. No entrants in the cluster mean that the diversity of knowledge and competences is decreasing, affecting the cluster's ability to renew itself (Menzel & Fornahl, 2010). On the other hand, the absence of entry also indicates continuous decline of the cluster as it reflects lack of technological and market opportunities within the cluster. Among different types of entrants, entrepreneurial and parent spinoffs have been the most important ones for the evolution of this cluster. The majority of firm population originated from already existing companies in the cluster and the evolution of the cluster to a high degree resembles that of spinoffs. However, a few firms that could be identified as the main seedbed for creating spinoffs have exited the cluster within the past 10 years, which might further deteriorate new firm formation in the cluster.

Appendix A. Employee migration after firm exits – the case of Motorola and TI

TI employees

Geographic distribution	#	%
North Jutland (NJ)	62	82
Central Jutland	10	13
Southern Denmark	0	0
Zealand	3	4
Outside Denmark	0	0
N/A	1	1
Total	76	100

Industry	Total	%	NJ	% NJ
Wireless	30	39	29	38
ICT	16	21	13	17
Other	29	38	20	26
N/A	1	1	0	0
Total	76	100	62	82

Motorola Employees

Geographic distribution	#	%
North Jutland (NJ)	168	68
Central Jutland	44	18
Southern Denmark	5	2
Zealand	17	7
Outside Denmark	11	4
N/A	2	1
Total	247	100

Industry	Total	%	NJ	% NJ
Wireless	73	30	58	23
ICT	68	28	43	17
Other	106	43	67	27
Total	247	100	168	68

For both companies

Geographic distribution	#	%
North Jutland (NJ)	230	71
Central Jutland	54	17
Southern Denmark	5	2
Zealand	20	6
Outside Denmark	11	3
N/A	3	1
Total	323	100

Industry	Total	%	NJ	% NJ
Wireless	103	32	87	27
ICT	84	26	56	17
Others	135	42	87	27
N/A	1	0	0	0
Total	323	100	230	71

Appendix B. Spinoffs from Motorola and Texas Instruments since 2008/9

TI spinoffs

Firm name (Founding year, exit year)	Industry	Jobs	Location	Founder's prior position(s) at TI	Field of activity
CeePro Aps (2009)	ICT	1	North Jutland	System Architect	Embedded system design and SW development
CLT RF Design and Services (2010)	Wireless	1	North Jutland	RF Engineer	RF design
EC Advisory Group (2009)*	Other	1	North Jutland	Nordic Export Control Manager	Export control management and export process optimization
Efficient Project Management (2009)	Other	1	Central Jutland	CCSS Planning Project Manager	Project management/ HR management
Energy-Design (2010)*	Other	1	North Jutland	R&D Director	Project management within cleantech, smart grid and wind energy
enumize.com (2009)*	Wireless	1	North Jutland	Embedded Software Developer	Embedded software and IPhone application
Inntrasys (2009)	Wireless	7	North Jutland	Program manager, Chief Architect	Mobile OnBoard Units for Intelligent Transport Systems
QA Systems (2009)	Other	1	North Jutland	QA Manager	Quality Assurance consulting
SatLinQ Technology (2009)	Wireless	1	North Jutland	Director/ Wireless consultant, PMO Manager	Solutions within Satellite and Software Defined Radio (SDR)
Sequenced Aps (2009, 2010)	ICT	0	North Jutland	Senior Software developer	Next generation system test solution
SSC Solutions Aps (2009)	ICT	1	North Jutland	Development Consultant Engineer	Hardware and software development
TEGA Solutions (2010)*	ICT	1	North Jutland	Baseband Engineer	Unknown

* Hobby start-ups: The founders have a regular job in another company.

Motorola spinoffs

Firm name (Founding year, exit year)	Industry	Jobs	Location	Founder's prior position(s) at TI	Field of activity
3D-CT (2009)	Other	7	North Jutland	Technician, Senior Design Engineer, Metrology Engineer	Measurement center with CT scanner
Arcane labs (2009)*	ICT	2	Central Jutland	SW Engineer/Team Leader, System Engineer	X-box games, Classicard games
Cloud Circus (2010)	ICT	5	North Jutland	MUIQ System Engineer	Software development
Code craft Aps (2008)	ICT	3	North Jutland	MUIQ System Engineer	Software development
Createitreal (2009)	ICT	1	North Jutland	Project Leader Engineering	Developing 3D printing and automated fabrication technologies
Flexmanagement (2010)	Other	1	North Jutland	Director	Management consulting
Full circle design.dk (2009, 2010)	ICT	0	North Jutland	Product Manager User Interface (UI)	Embedded UIs, Documentation of UI Design
Huge Lawn software (2009)	Wireless	5	North Jutland	Quality Manager	IPhone and IPad applications
MVC-data (2008)	Wireless	2	North Jutland	Senior SW Engineer	SW and HW development , solutions with Bluetooth technology
NeoGrid Technologies (2010)	ICT	3	North Jutland	Line manager, RF function manager	Solutions for controlling electricity demand
NordicRefurb (2009)*	Other	1	North Jutland	Department Manager	Electronic test and manufacturing equipment.
North Development Consult (2009, 2009)	ICT	0	North Jutland	Sr. Electrical Engineer	Engineering consulting
OR Pro (2009)*	Other	1	North Jutland	Requirement Manager	Project management
PartDesign (2009)	Other	2	North Jutland	Sourcing manager	Mechanic construction, FEM analysis, Sourcing in China
PBC-support (2009)	ICT	2	North Jutland	PCB Designer	PCB design

Proint s.m.b.a. (2009)*	ICT	2	North Jutland	Project Leader , Program Manager SW	IT consulting
SES IT (2010, 2010)	ICT	0	North Jutland	Software Test Engineer	IT consulting
Synergile (2008)*	Wireless	1	North Jutland	Engineering Lead	RF Engineering solutions
Unpaq (2009)*	Wireless	1	North Jutland	SW Engineer	Software, Mac OSX, IPhone
Utopia Solutions (2009)*	ICT	2	Central Jutland	SW Engineer	Web shops and custom web-solutions

* Hobby start-ups: The founders have a regular job in another company.

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