The Role of Universities in Innovation and Regional Development

Co-creation of Localised Capabilities between Universities and Nascent Industries

The Case of Aalborg University and the North Denmark Region

WORKING PAPER 03/2018

David Fernández Guerrero
Aalborg University ▪ Department of Business and Management ▪ Innovation, Knowledge and Economic dynamics (IKE) group
Aalborg ▪ Denmark
Email: dfg@business.aau.dk

Gerwin Evers
Aalborg University ▪ Department of Business and Management ▪ Innovation, Knowledge and Economic dynamics (IKE) group
Aalborg ▪ Denmark
Email: evers@business.aau.dk

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Marie Skłodowska-Curie grant agreement No. 722295.

Abstract

This paper focuses on two cases of interaction between Aalborg University and science-based industries that have appeared in the North Denmark region in recent decades: the Information and Communication Technology (ICT) and biomedical industries. These two cases provide a unique opportunity to study the mechanisms behind the more or less successful development of localised capabilities through university-industry interaction: while both of them are science-based industries with tight linkages with the university, the outcome of the exchanges with the higher education institution has differed. The feedback loops between university and industry seem to have stimulated the development of localised capabilities favouring the competitiveness, and success, of the ICT industry. However, the university actions supporting the development of the biomedical industry do not seem to have been followed by a growing industrial development, as would be expected if the biomedical industry had developed localised capabilities ensuring its competitiveness. For each case, qualitative and quantitative research methods have been applied: this paper combines desk research on secondary sources with qualitative interviews and descriptive analyses based on data from Statistics Denmark.

Keywords: Universities, Innovation, Industry, Aalborg, Denmark.

JEL: I23; J29; L16; R11; R58

This paper version was presented at the 12th Regional Innovation Policies Conference, which was held in Santiago de Compostela, Spain on October 26th - 27th 2017, and is currently under further work and improvement for becoming a book chapter in the framework of the RUNIN project.

David Fernández Guerrero
Gerwin Evers

Table of Contents

List of Figures, Tables and Boxes

Introduction

Universities are expected to play a role in the ongoing transition to a knowledge-based economy (Etzkowitz & Leydesdorff, 2000). By increasing the absorptive capacity of organizations in their environment through the provision of graduates (Charles, 2006; Marques, 2017) and the creation and transfer of existing knowledge (Drucker & Goldstein, 2007), universities can shape the regional economy. However, the local economic actors (e.g. firms) can also influence the development of a university by creating a demand for specific kinds of knowledge and graduates. As a result of this interaction, firms and universities can modify the localised capabilities of a region (Maskell, Eskelinen, Hannibalsson, Malmberg, & Vatne, 1998). That is, regional characteristics that are difficult to replicate in other locations, supporting the sustainable competitiveness of regional firms.

The existence of localised capabilities, nevertheless, requires feedback loops between the actors involved. This implies that an actor modifies its strategies in response to the actions of other actors within the same region, and that the interactions between different actors lead to the co-creation of localised capabilities (Maskell et al., 1998). In this paper we argue that this line of reasoning also applies to the role of universities in stimulating regional development: universities can support the creation of localised capabilities in their home regions with a wide range of activities, yet this is not a unidirectional process. It is, instead, the result of feedback loops between university actions and industry developments, and the intensity of university-industry feedback loops will influence the extent to which localised capabilities are formed. This argument also implies that industry developments will influence the intensity of university-industry feedback loops.

This paper will study the mechanisms affecting the co-creation of localised capabilities between universities and nascent, science-based industries (Pavitt, 1984) at the regional level, focusing on the feedback loops that lead to, and result from, the following university activities: the generation of human capital, the creation and transfer of knowledge, and the technological innovation produced at the university, operationalised as the incubation of university spin-offs (Drucker & Goldstein, 2007). Science-based industries are also expected to rely to a greater extent on the scientific research developed by universities than other, more traditional businesses. Because of this, the industries chosen for this paper provide an excellent opportunity to study the co-creation of localised capabilities between university and industry. These industries, in addition, can provide insights on how university-industry interaction can promote the development of new industrial paths in regions dependent on traditional industries (Isaksen & Trippl, 2014a, 2014b).

The goal of this paper is to provide an answer to the following research question:

RQ: What are the mechanisms leading to the co-creation of localised capabilities between universities and nascent industries at the regional level?

We suggest that the feedback loops between a university and a nascent industry at regional level are key for the creation of localised capabilities benefiting the competitiveness of the nascent industry. However, we also suggest that the size of the nascent industry (measured by the number of jobs it hosts) during university-industry interaction will also influence the extent to which these feedback loops lead to the co-creation of localised capabilities.

The university might dedicate some of its activities to support the nascent industry, proactively or in response to business demands. The larger the size of the industry, the higher the demand coming from its businesses, and the greater the extent to which the university might decide to dedicate resources to support activities related to the industry. In other words, the greater the extent to which university-industry feedback loops will lead to the formation of localised capabilities benefiting industry competitiveness. However, if the size of the nascent industry is small, the intensity of industry demands could be smaller. Even under such circumstances, the university might decide to devote resources to support activities related to the nascent industry, for reasons other than the demands of its businesses. Nevertheless, in that case the effect of university actions could be smaller, because the industry would be less able to benefit from university actions. Hence, the intensity of the feedback loops between university and industry would be more limited, and the same would go for the co-creation of localised capabilities benefiting the competitiveness of the latter.

The research question will be addressed by focusing on two case studies of nascent science based industries (Pavitt, 1984) in North Denmark, a region that has historically relied on traditional industries such as shipbuilding and construction (Nilsson, 2006; Østergaard, 2005):

Case 1: the interaction between Aalborg University (henceforth AAU) and the Information and Communication Technology (ICT) industry, since the foundation of the university in 1974 (Dalum, Østergaard, & Villumsen, 2005).

Case 2: the interaction between AAU and the biomedical industry, since the start of university involvement in a cluster initiative related to the industry, since 2000 (Stoerring & Dalum, 2007).

These two cases have been chosen based on the extent to which the nascent science based industries have developed localised capabilities. We operationalise this by looking at the growth of the industry (measured as growth in the number of jobs) over the period studied (that is, from the start of university involvement to the latest year for which we include quantitative data on the number of jobs, 2010). If the industry has grown over time this might be a proxy for the formation of localised capabilities that have ensured its competitiveness, and thereby its expansion. While the ICT industry has enjoyed a considerable growth until the early 2000s, and is still a large employer in the North Denmark region, the workforce of the biomedical industry has not grown to the same extent of its ICT counterparts.

The findings suggest that the situation of the ICT and biomedical industries during university-industry interaction have influenced the different fate of the industries: the size of the ICT industry supported a series of feedback loops between businesses and university, stimulating the formation of localised capabilities and thereby the strengthening of the industry's competitiveness. Meanwhile, the number of workplaces in the biomedical industry was smaller when AAU started supporting activities related to its businesses, and the industry has not grown since then.

Admittedly, the choice of cases entails a set of limitations in the generalisability of findings: the regional context plays a key role in shaping the phenomena studied (Welch, Piekkari, Plakoyiannaki, & Paavilainen-Mäntymäki, 2011). In addition, university-industry interaction often goes well beyond the regional setting, spanning to the national and international level (Drejer, Holm, & Nielsen, 2014a; Laursen, Reichstein, & Salter, 2011; Rodríguez-Pose & Fitjar, 2013).

The next section will discuss the theoretical background of this study, and will devise a model operationalising the creation of localised capabilities out of the feedback loops between university and regional industries. A subsequent section will expose the research methods applied in the paper. This is followed by an analysis of the two cases, paying attention to the feedback loops between AAU and businesses. Finally, a last section will discuss the differences between the two cases, summarising the findings and drawing some conclusion and policy recommendations.

Theoretical Background

In order to study the mechanisms through which university-industry interaction can reinforce the competitiveness of nascent industries at the regional level, the concept of localised capabilities becomes fundamental. Maskell et al. (1998, p. 51) define them in the following way:

> *"Firms become competitive, and retain their competitiveness, by conceiving and implementing strategies which utilize – directly or indirectly – a number of* valuable *traits and properties of their place of location. (...) All such regional or national traits and properties influencing the competitiveness of a firm or an industry are referred to as the 'localised capabilities' of the area in question. In a knowledge-based economy, valuable localized capabilities will primarily be those which increase the ability of firms to create; acquire; accumulate; and utilize knowledge a little faster than their cost-wise more favourably located competitors"* (emphasis from the original text).

Localised capabilities are mainly the natural resources of the region, the structures built in there, the formal and informal institutions that regulate business behaviour, and the knowledge and skills created by the regional public or private actors. As the concept suggests, the special, (quasi)non-replicable nature of localised capabilities offers an advantage to the firms that have emerged in the region that is endowed with them. Competitors in other regions might try to replicate these conditions, but this might be a difficult task, in particular for assets marked by their tacit character, such as informal institutions. Moreover, the complementarities between these assets suggest that a business external to the region cannot simply transplant, say, an institution from another region, with the same degree of success as the competitors located in the region where the institution originated (Maskell et al., 1998). Similarly, policies that attempt to replicate the competitiveness of other regions, without taking into account the role of informal institutions, are likely to end in disappointing results (Rodríguez-Pose, 2013). An example might be the complementarity between the education and training system, and other institutions that regulate the economy, as illustrated in the Varieties of Capitalism literature (e.g. Hall & Soskice, 2001).

Localised capabilities, however, are the result of a history of interactions. The key mechanisms here are the feedback loops between the economic agents populating the region. That is, how does each actor react to what other actors have done. Maskell et al. (1998, pp. 56–64) use industry agglomerations as an example of this phenomena. The region where one or few businesses settle might provide no advantage to these firms at the beginning. Nevertheless, the spin-offs emerging from these pioneers might prefer to locate nearby, in order to maximise the use of the industry-specific qualifications they already possess, or to benefit from a regional network of social contacts. Over time, the interaction between these businesses (and others that might add to the regional pool in successive rounds) might generate a set of unique, localised capabilities, such as informal institutions, or an industry-specific knowledge.

A similar process might occur between universities and businesses, in particular for science-based industries, since these are more dependent on the knowledge produced at universities, and hence on university activities (Pavitt, 1984). Drucker & Goldstein (2007, pp. 22-24; see also Drejer et al., 2014a, pp. 5-10) group these activities in a set of outputs:

- The creation of knowledge, that is the basic research developed by the university. The novelty of this knowledge, however, might make its interpretation difficult, requiring the use of knowledge transfer mechanisms (see below);
- The creation of human capital: graduate employees help increasing firms' absorptive capacity (Charles, 2006; Marques, 2017). In some cases, moreover, social ties between business employees/managers and universities are associated to a higher likelihood of university-industry interaction (Drejer & Østergaard, 2017);
- The transfer of existing know-how, that is the application of knowledge already available to solve a problem. This activity entails the application of basic university research, and can encompass a wide range of university-industry interaction channels, from informal consultation and contract research to long-term university-industry partnerships (Abreu & Grinevich, 2013; D'Este & Patel, 2007; Perkmann & Walsh, 2007);

- Technological innovation, that is "the creation and commercialisation of new products and processes at the university itself" (Drucker & Goldstein 2007, p. 23). This can include the formation of university spin-offs (Drejer et al., 2014a, p.8);
- The investments of the university in physical capital. This does not only include its own buildings, but facilities shared with businesses, such as research parks;
- The regional leadership of the university, as an organisation aimed at supporting the region;
- The knowledge infrastructure of the region: this includes the knowledge accumulated by regional education and research institutions, and regional businesses. The different channels through which the university contributes to the region help increasing this knowledge infrastructure;
- The influence of the university in the regional milieu, by stimulating the inflow of creative professionals;

Hence, the presence of a university in a region might provide an opportunity for the development of localised capabilities supporting the expansion of a new, science-based industry. This process would be geared through the feedback loops between the university activities mentioned above, and the demands coming from the nascent industry. We argue, however, that the extent to which university-industry feedback loops lead to the creation of localised capabilities will be affected by the size of the industry (in number of businesses and employees) during university-industry interaction. The next subsection discusses how this process could take place.

Mechanisms behind the co-creation of localised capabilities: the role of feedback loops

A conceptual model (figure 1) shows how university-industry feedback loops could lead to the formation of localised capabilities. Due to the interest of this paper in university-industry interaction at regional level, the conceptual model focuses on regional feedback loops. The analysis centres on the effect of educational, knowledge creation and knowledge transfer activities, and the creation of university spin-offs. We have chosen to focus on these university activities because the literature suggests that they represent a key part of the university activities aimed at supporting the ICT and biomedical industry (eg. Nilsson, 2006; Stoerring & Dalum, 2007).

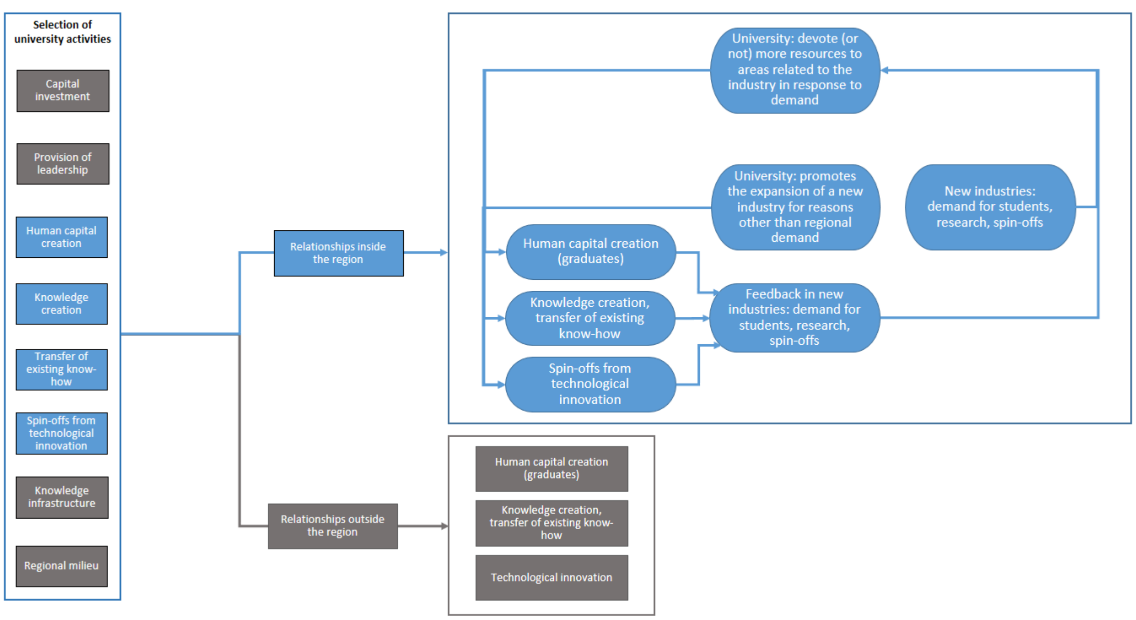


Figure 1 - Conceptual model of the creation of localised capabilities through university-industry interaction in science-based industries (Pavitt, 1984), based on Drucker & Goldstein (2007) and Drejer et al. (2014a). The boxes of interest for the analyses are marked blue.

Here the size of the industry might be key: the larger it gets, the larger the number of graduates that might demand from the regional university, even if they do not hold a degree that matches the needs of the industry[1]. The hiring of graduates by the growing industry might stimulate the university, in turn, to devote an increasing amount of resources in training more graduates, preferably with skills closer to the ones required by the industry. Hence, a series of feedback loops would take place between the university and the industry: more graduates would be hired by the industry, and the university would dedicate more resources to the educational programmes that suit more closely the needs of the industry, in order to tackle the demand coming from its businesses. These feedback loops would support the development of localised capabilities by the industry, and thereby its

[1] This might be particularly the case, if more than one science based industry grows in the region. The higher the variety of these industries, the tighter the competition for graduates, and the less intense their qualification requirements. Businesses might devise retraining programmes, in order to adapt the qualifications of the new recruits to their needs.

competitiveness (operationalised as the growth of its workforce), as well as an increasing presence of graduates from the regional university in the industry's graduate workforce. Conversely, the university might decide, by motivations different from those that might emerge as a result of regional industry demand (for example, to train graduates for a national or international labour market), to educate graduates in programmes related the industry. The extent to which this process stimulates the expansion of the businesses will, again, depend on whether the industry is growing during university-industry interaction.

A similar dynamic could take place, concerning the impact of the university as a creator of new knowledge, and as an agent capable to transfer this knowledge through university-industry interaction. A nascent industry might be interested in accessing the knowledge generated by university research, and this interest could increase with the growth of the industry. The university could, in turn, be interested in devoting more resources to research collaboration with the industry. This process could run in the opposite way as well, with the university taking the initiative and approaching the industry[2], and the latter responding to this stimulus by devoting more resources to collaboration projects with the university. In any case, the feedback loops between the university and the growing regional industry would stimulate an increasing number of collaboration projects between them, provided that the industry grows during university-industry interaction. The expansion of this interaction would, in turn, facilitate the development of the localised capabilities that benefit the growth of the nascent industry.

Finally, a similar process could be observed for the impact of the university through the creation of spin-offs: in order to support the expansion of a nascent industry, a university might devote resources to stimulate the creation of university spin-offs, and their incorporation in the industry. If these academic spin-offs are successful (hence signalling growth in the industry), the university might devote more resources to these activities, leading to a series of feedback loops that would support the expansion of the new industry. Nevertheless, the university might not simply 'react' to the expansion of a new industry, but also might take the initiative

[2] For example, the university might be interested in stimulating the growth of new industries as part of its regional development mission; or might develop research at the national or international levels, with local spillover effects (Drucker & Goldstein, 2007; Stoerring & Dalum, 2007).

of stimulating the appearance of a new industry by hosting a series of spin-offs. Here, one of the motivations would be the hope that academic spin-offs could provide the basis for the appearance of a new industrial path, revitalising the regional economy (Isaksen & Trippl, 2014a, 2014b).

Methodology

Research Design

The findings presented in this paper are based on two case studies: the interaction between AAU and the ICT industry; and the interaction between AAU and the biomedical industry. In both cases, the unit of analysis is the interaction that takes place between the university and the industries, in the context of the North Denmark region. A case study allows tracing back in time how the development of each industry might have stimulated actions on the part of the university, and vice versa. The case study relies on the combination of qualitative and quantitative research methods. Hence, the biases that one single data source might carry can be compensated with the strengths of other data sources, thereby reinforcing the construct validity of the two-case study (Yin, 2014).

Case Selection

North Denmark has been historically a region specialised in traditional industries: groupings related to construction (quarrying, non-metallic mineral products) or shipbuilding (fabricated metal products) industries have been overrepresented when compared to the Danish average; and the same can be said about industries such as those of food and agriculture, or the manufacturing of tobacco (Nilsson, 2006; Østergaard, 2005). Since its establishment in 1974, Aalborg University (see some context on the university in box 1) has supported actions aimed at creating opportunities for the growth of science based industries (Pavitt, 1984), including the ICT and biomedical industries. The interaction between the university and these industries has, to a certain extent, opened new industrial paths (Isaksen & Trippl, 2014a, 2014b) in a region that depended mostly on traditional businesses.

An overview of the changes in the industrial composition of North Denmark from 1980 to 2005[3] (table 1) depicts a decline in the food producing and textile industries, while the ICT and biomedical industries (as defined in the heading "Quantitative techniques: transformation of the IDA database", in this section) grew until 2000. However, the differences between ICT and biomedical industries are

[3] The table is limited to 2005, because of changes in the EU NACE classification of economic activities.

stark, especially if hospital activities are not taken into account: the former grew to 4.6% in 2000; the latter reached a 0.8% peak in the same year.

BOX 1: GENERAL INFORMATION ABOUT AALBORG UNIVERSITY

AAU is the fourth university of Denmark, based on the number of full-time students (20,506 in 2016), and spreads among three cities from which the Aalborg campus host most of students (81%). The university counts with five faculties (Humanities, Social Sciences, the Technical Faculty of IT and Design, Engineering and Science, Medicine) from which the Faculty of Social Sciences is the largest, with 6,212 students. However, the strong technical character of the university, and the relationship between this institution and the regional industries is still visible (between 39% or 48% of the students are enrolled in one of the degrees of the technical faculties, depending on whether the Faculty of Medicine is included in the calculation (Aalborg University, n.d.-c).

Since its foundation the university has experienced a rapid growth, from 1,635 full-time students in 1974 to the numbers mentioned above. Compared to other universities, a large share of the graduates is moving to other regions: only 54% of Aalborg University graduates (with a bachelor, master or PhD degree) who found their first job after graduation between 2000 and 2010, did so in North Denmark, the lowest regional average. This trend is related to the small size of the local labour market, vis a vis the number of students trained at the university. Moreover, 65% of AAU graduates establishing their first firm do so in the same region, the lowest percentage compared to the rest of higher education institutions. However, North Denmark is also the region with the largest percentage inflow of graduates from other regions (49%), and more than a third of them finds their first job after graduation in the region (Drejer et al., 2014a; Drejer, Holm, & Nielsen, 2014b).

Table 1: Share of workforce employed per industry	1980	1985	1990	1995	2000	2005
Agriculture, hunting, forestry and fishing	3.7%	3.8%	2.8%	2.8%	2.4%	2.2%
Mining	0.2%	0.2%	0.2%	0.3%	0.2%	0.2%
Manufacturing: Food, beverages and tabacco	6.4%	6.1%	6.0%	6.5%	5.9%	4.7%
Manufacturing: Textile and leather	1.3%	1.5%	1.0%	0.8%	0.7%	0.5%
Manufacturing: Paper and wood	2.1%	2.2%	2.3%	2.4%	2.6%	2.5%
Manufacturing: Chemicals and plastics	0.9%	0.9%	0.9%	1.2%	1.2%	1.3%

Manufacturing: Non-metalic mineral products	2.5%	2.4%	2.1%	2.0%	1.9%	1.5%
Manufacturing: Metal and metal products	3.0%	3.7%	4.0%	3.9%	3.6%	3.2%
Manufacturing: Machinery and equipment	3.1%	3.4%	3.6%	4.1%	3.8%	3.7%
Manufacturing of electrical and optical equipment	1.7%	2.4%	2.8%	2.2%	2.7%	1.8%
Manufacturing: Transport equipment	4.2%	3.8%	2.3%	2.3%	1.1%	0.6%
Manufacturing: Other	0.8%	1.1%	1.4%	1.7%	1.6%	1.2%
Electricity, gas and water supply	1.1%	0.9%	1.0%	0.9%	0.6%	0.5%
Construction	8.6%	9.3%	6.7%	6.8%	7.7%	8.4%
Wholesale and retail trade	14.5%	12.9%	12.2%	12.6%	12.9%	13.2%
Hotels and restaurants	1.2%	1.2%	1.3%	1.4%	1.4%	1.5%
Transport, storage and communication	3.3%	3.6%	5.3%	5.6%	5.7%	5.2%
Financial intermediation	3.4%	3.0%	3.3%	3.0%	2.7%	2.7%
Real estate, renting and business activities	4.0%	4.0%	3.9%	4.9%	5.5%	6.3%
Public administration and defence	6.6%	7.8%	11.0%	9.2%	7.1%	6.5%
Education	8.6%	7.6%	7.6%	8.6%	8.9%	9.4%
Health and social work	14.3%	13.4%	15.8%	13.4%	16.3%	18.8%
Other	4.6%	4.8%	2.6%	3.4%	3.4%	4.0%
Zooming in on two science-based industry						
ICT industries	1.8%	2.2%	2.2%	3.6%	4.6%	3.5%
Biomedical industries (including hospital and related activities)	5.8%	5.0%	5.9%	6.0%	6.6%	7.2%
Biomedical industries (excluding hospital and related activities	0.0%	0.0%	0.0%	0.6%	0.8%	0.7%

Source: Register data from statistics Denmark.

The boundaries of these cases include the interaction between AAU and each of the selected industries (that is, the interaction between AAU and ICT industry, and the interaction between AAU and biomedical industry). The cases, therefore, are defined according to the phenomena of interest (Piekkari, Welch, & Paavilainen, 2009, pp. 572–573), which are the feedback loops between university and industry. Cases, in addition, are selected according to their outcome: both concern science based industries (Pavitt, 1984) with a strong connection to the local university (Stoerring & Dalum, 2007), yet their success in terms of the formation of localised capabilities ensuring their competitiveness (operationalised as the employment growth over the period) has differed notably. The goal, here, is to understand the mechanisms behind the differing outcomes (Ragin, 2009).

Methods

The case studies rely on a combination of qualitative and quantitative research methods. The qualitative methods include the analysis of secondary sources and two interviews with key stakeholders, which were selected because of the insights they could provide on the evolution of the ICT and biomedical industries. Interviews were conducted with a representative from the BrainsBusiness cluster initiative (an organisation related to the ICT industry), and policy makers from the North Denmark regional administration related to the Biomed Community cluster initiative (an organisation related to the biomedical industry). The goal, here, has been to track over time how the developments in the ICT and biomedical industries might have affected AAU's educational and research activities, and viceversa. The qualitative data allows, for instance, to study university decisions on its educational and research activity, and relate them to the situation of the industries of interest.

As for the quantitative methods, these include the analysis of descriptive statistics. This data is used to give insight in the growth of industries, the adoption of university and AAU graduates in the industries over time, student numbers, and the research performance of AAU. The quantitative analysis has been used to complement the findings from the qualitative methods: whilst qualitative secondary sources allowed following over time the opening of research centres supporting the ICT and biomedical industry by the university, the descriptive statistics included in this paper allow tracking over time the changes in the workforce of these industries, and the employment of AAU graduates. In some cases, in addition, the quantitative information has been used to confirm some of the findings of the qualitative analysis, following a triangulation logic.

Data Sources

This paper relies on qualitative secondary sources such as policy reports, newspaper articles, and publications in academic journals. In addition, the two qualitative interviews (one with three policy makers from the North Denmark Region, and one with one of the coordinators of the BrainsBusiness cluster organisation) conducted have allowed to corroborate some of the data obtained from the secondary sources, while updating part of the information obtained from them.

As for the quantitative data, this includes descriptive macro-data available from Aalborg University, the descriptive macro-data available online in Statistics Denmark, and the register data from the Integrated Database for Labour Market Research (Abbreviated in Danish as IDA). This database contains interlinked micro data from all Danish firms and inhabitants. The main advantage of the IDA database is that it contains data on the from the whole population of a wide set of objective variables (Timmermans, 2010).

Quantitative techniques: data transformation in the IDA database

The quantitative analysis is carried out within the limits of the North Denmark region, the individuals of interest being those that live and work in a full-time job[4] in the region between 1980 and 2010: the analysis with IDA database ends in 2010 because of restrictions in the information available on full-time/part-time employment status. The variable that indicates the institution of highest completed education is used to distinguish whether someone has a university degree, and whether this degree has been received from Aalborg University. The university is for this analysis constrained to the main campuses in Aalborg. Aalborg University also has smaller campuses in Copenhagen and Esbjerg (in the southern part of Denmark), but due to the focus on the interplay with local industry in North

[4] The analysis is restricted to persons in full-time employment, in order to study the main dynamics of the industry: those individuals that are employed on a full-time basis are more likely to develop their career within the boundaries of the industry, whilst part-time employment might respond to short-term needs (Richards & Polavieja, 1997).

Denmark, these campuses are not included in the analysis. The ICT and biomedical industries are defined using the EU NACE classification of economic activities (Eurostat, 1996, see appendix for the included NACE codes). Although we recognize that firms related to the ICT and biomedical industries can be found in numerous industry groupings, we focused on the main ones, since including all the categories in which related firms are located would insert too much noise into the analyses. Next to that, a focus on the core is likely to give good insights in the general trends of the industries of interest. The ICT industry includes, next to some other small groupings, manufacturers and wholesalers of ICT related equipment, and ICT services. The biomedical industry includes manufacturers and wholesalers of ICT related equipment, and hospital activities (see appendix for a list of all included industry groupings, and how they have been constructed).

Quantitative techniques: data analyses in the IDA database

For the purpose of our analyses, we are interested in the interplay between Aalborg University and the ICT and biomedical industries. This is operationalized by the extent to which Aalborg University plays a crucial role as a supplier of employees with a university background. For this purpose, the number of employees, number of employees with a university degree and number of people with an AAU degree working in the industry are of interest. In particular, the share of AAU graduates among the total employees with a university degree might give an insight in how much the industry depends on AAU. Following the conceptual model included in the previous section, the data allows to indirectly analyse the feedback loops between university and industry, by looking at the overlaps between the changes of the workforce in the ICT and biomedical industries, and the share of AAU graduates over the graduate workforce. A growing proportion of AAU graduates over the total number of graduates in each industry might occur if the feedback loops between university and industry have stimulated a greater interest of the latter in hiring professionals trained at Aalborg University. Without AAU, the industry would have had to do more effort for recruiting highly skilled staff, which would limit the development of the industry. At the same time, a high share of AAU graduates in a particular industry indicates a strong demand for AAU graduates.

Aalborg University: creating and being shaped by localised capabilities

Context: a regional struggle, and a university focused on traditional industries

The very origins of AAU are grounded in the needs of the surrounding region of North Jutland (the northern part of the Jutland peninsula, which is currently under the administration of the North Denmark Region). With 587,335 (211,937 of them in the main city Aalborg) inhabitants in the first quarter of 2017, it is the least populated region in Denmark. Previous to the inauguration of the university (September 1974), some of the main regional actors (employers, unions and the Aalborg municipality) had been lobbying for its creation. One of the key steps in this process was the creation in 1961 of the North Jutland Committee for Higher Education, an organisation composed of representatives from the municipality, the Danish Parliament (an MP from North Denmark) and the business community. The committee was led by Eigil Hastrup, a local bank manager (Nilsson, 2006; Plenge, 2014; Skaarup, 1974). The group succeeded in persuading the Ministry of Education to authorise the establishment of the Denmark Engineer Academy (DIA) in Aalborg. Nevertheless, during the 1960s the Ministry was reluctant to facilitate the creation of a university in the region. Instead, a law draft submitted in March 1969 opted for the creation of a centre for higher education in Roskilde. The government perceived it was necessary to cover the growing need for higher education places in the country, yet preferred to prioritise the regions surrounding Copenhagen (Plenge, 2014).

The resistance on the part of the Ministry of Education to satisfy the demands of Jutland led to the creation, on the part of the Committee, of the North Jutland University Association in June 1969. This position gained further support: 1,000 youngsters from the region demonstrated in front of the Christiansborg palace, the site of the legislative, executive and judicial powers. And, inside the Parliament, the Social Democrats and the Socialist People's Party supported the association plans, in front of the executive at that time (led by the Danish Social Liberal Party, the Liberal Party and the Conservative People's Party) (Folketings-redaktion, 1969; Plenge, 2014; Pyndt, 1969; Statsministeret, n.d.). Shortly afterwards, a new university law draft, submitted in June 1970, included the promise of establishing a higher education institution in Aalborg between 1974 and 1975 (Koldbæk, 1974)). The tasks of the DIA and other higher education institutions present in the region would be integrated in the new-founded Aalborg University Centre, re-named as Aalborg University in 1994 (Nilsson, 2006; Plenge, 2014; "Aalborg Universitets Historie," n.d.).

The resulting institution had, like some of its predecessors, a strong technical character. Although this specialisation was limited by the expansion of social sciences, it still reflected the needs of the regional industries at that time. The information on the student intake of Aalborg University (n.d.-c) shows that the university counted 1,635 students in 1974 (2,241 in 1980, the next year available), 765 of them in the Faculty of Engineering and Science (1,001 in 1980), 681 in the Faculty of Social Sciences (790 in 1980) and 189 in the Faculty of Humanities (450 in 1980). The Aalborg University Centre trained graduates in construction for the building industry; while mechanical engineering graduates were employed by companies such as the Aalborg Shipyard (Nilsson, 2006).

Next to this, AAU pioneered the Problem-Based Learning (PBL) method in Denmark, together with the Roskilde University. This approach to learning entails that students work in project teams on self-defined, interdisciplinary problems, many of them related to challenges faced by local firms. The number of projects grew to the point that in recent years AAU continuously hosts between 2,000 and 3,000 of them. In this respect, PBL offers various advantages for businesses. These include accessing a low-cost tool for solving immediate problems, since projects tend to last for six months; while screening suitable candidates for their workforce (Gregersen et al., 2009). Together with the short time span of the projects (they tend to last for less than six months), other advantages are the adaptability of the project contents to company needs and the potential workload that can be assumed by student teams (Kendrup, 2006, pp. 19).

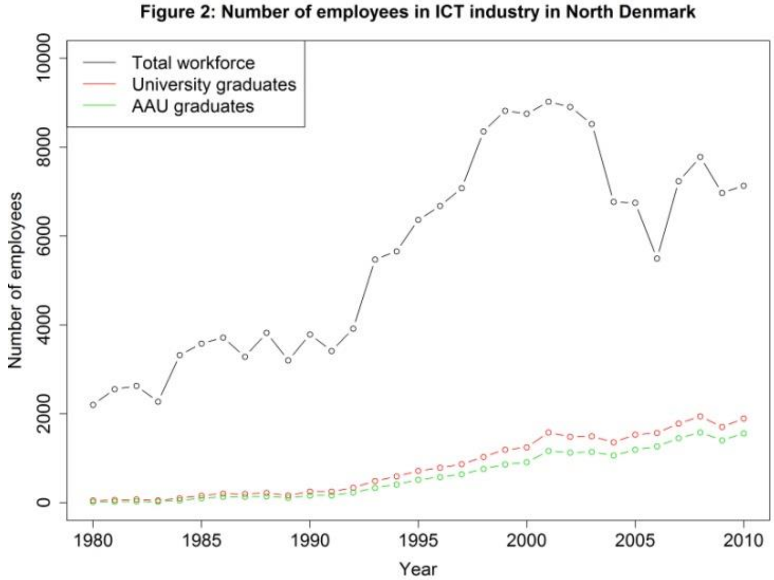
Industries such as construction and shipbuilding continued into the 1980s. Their weight in North Denmark employment was superior to their average share in the Danish labour market. This was also the case of other regional strongholds, such as the food, beverage and tobacco industries (Østergaard, 2005, p. 92). Nevertheless, these industries were under pressure, and the university was perceived as a tool for supporting the industrial transformation of the region

(Kendrup, 2006). Employment in agriculture, fishing and forestry was halved between 1983 and 1999 (from 28,000 to 14,300 jobs); and shipbuilding experienced a major crisis, together with the rest of the industry in Denmark: in 1982 the Danish shipyards employed 18,000 persons. By 2007, total employment dropped to 5,000. In North Denmark, the crisis led to the closure of shipyards like Aalborg Værft and Danyard Frederikshavn, leading to the establishment of spin-offs (Holm, Østergaard, & Olesen, 2017, pp. 249–250) and a growing specialisation in the provision of services such as ship maintenance and repair (Hermann, 2015). Within this context, the transformative role of the university was quickly put into practice, as will be shown in the first case.

Case 1: AAU adapts (and supports) activities related to the ICT industry

The 1980s and 1990s saw the expansion of the ICT industry. This is clearly visible when using register data to study the evolution of these businesses: between 1980 and 1990, the industry workforce increased from 2,203 to 3,786 jobs, and 9,022 persons worked in there by 2001, the highest record (figure 2). Because of the definition of the ICT industry applied in this paper, this figure shows discrepancies with the analyses by Østergaard (2005, pp. 33–47). However, the overall tendencies are the same.

Figure 2: Number of employees in ICT industry in North Denmark



These developments reflected the rapid expansion of the businesses specialised in wireless communications in North Denmark. The origins of this transformation can be found in the entry in the 1960s of SP Radio, a radio and TV manufacturer, in the market of radio communications for maritime vessels. The success of this company was followed by the emergence of spin-offs: one from SP Radio, Dancom; *producing* in turn another spinoff, Shipmate. The former would move in the early 1980s to the emerging mobile phone market, whose expansion was propelled by the introduction of the Nordic standard for Mobile Telephony (NMT) by the Nordic mobile telephony operators in 1981. The success of the NMT standard and the boom of the market favoured a new round of spin-offs from these firms: between 1980 and 1990, the number of businesses specialised in wireless communications in North Denmark grew from 5 to 16 firms (Dahl, Østergaard, & Dalum, 2010; Dalum et al., 2005).

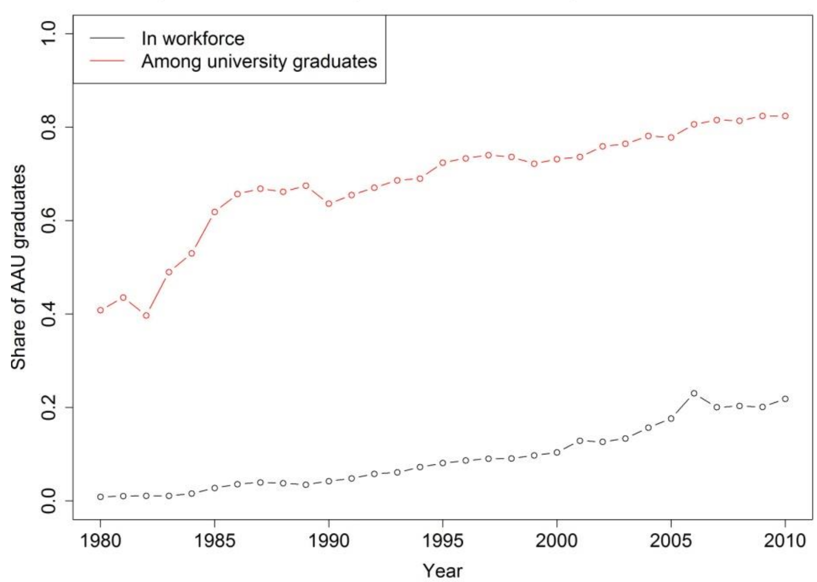
The involvement of AAU in the ICT industry started gradual, but it gained strength over time: a wide range of educational and research activities would be developed as a feedback to the developments taking place in the industry. In doing so, the university built from the educational activities that were already developing: AAU counted from its very start with two departments in electronic engineering, inherited from the engineering schools that were integrated into the higher education institution. These departments employed 200 academic staff members, providing resources for university-industry collaboration (Dalum et al., 2005; Stoerring & Dalum, 2007). However, on 1979 the Department of Electronic Systems was founded, training since then graduates with the qualifications needed by the industry. Over time, the university was able to acquire a prominent position in ICT research. This would already be visible in the first edition of Leiden University Ranking, which covers the 2006-2009 period (CWTS Leiden University, n.d.)[5]. AAU figured as the first Danish and tenth European higher education institution, when ranking universities according to the proportion of publications that reach the top 1% most cited publications. When assessing the top 10% and top 50% most cited publications the AAU claimed the third place in Denmark.

The importance of AAU for the ICT industry is best visible when using the register data to look at the share of the university graduates in the industry workforce (see figure 3). The share of university graduates increased, which indicates a growing inflow of university graduates into the industry, and the red line shows that AAU

[5] This ranking covers publications in English, in peer-reviewed journals. They can be single or co-authored publications, with researchers from other universities. In the case of Denmark, it covers the universities of Aalborg, Aarhus, Copenhagen and Southern Denmark, together with the Technical University of Denmark.

increased its importance as a supplier of graduates to the ICT industry. By 2010, more than 80% of the university graduates in the industry had received their training at AAU. Like in the previous figure, most of the increase is concentrated in the 1980-2000 period: the share of AAU graduates over ICT graduate employment grew from 40% to 63% between 1980 and 1990, and to 73% in 2000. This suggests that AAU played an important role, by enabling and keeping pace with the growth of ICT industry, which otherwise would have been limited in the development of localised capabilities (Maskell et al., 1998) due to high skilled labour shortages.

Figure 3: Share of AAU graduates in ICT industry in North Denmark



The jump from 1G to the 2G technologies (that is, from analogic mobile phones for the Nordic market to digital phones operating according to the specifications of the GSM European standard) during the second half of the 1980s represented another feedback loop between university and industry. Some of the staff in the Department of Electronic Systems contributed to the establishment, at the university campus, of the NOVI science park between 1987 and 1989, together with the city council and a local bank. The aim of the park was to promote the development of wireless communication start-ups, but it eventually provided another function: a site where two of the major companies in the cluster, Dancall and Cetelco, could work together in the development of the basic technology for a 2G terminal. Their joint venture, DC Development, succeeded in the task in 1992, although the parent firms were acquired by Amstrad and Hagenuk, due to the financial effort involved in the technological jump (Hedin, 2009; Stoerring & Dalum, 2007; Østergaard, Reinau, & Park, 2017).

Hence, the establishment of the research park supported the efforts of the businesses interested in the leap towards the GSM phones. In the coming years, in addition, the NOVI science park would gain importance as a location for the industry: the size of the science park increased from 5,000 to 40,000 m2 between the early 1990s and the early 2000s; and in the late 1990s large MNCs like Ericsson and Nokia settled there in order to develop 3G technologies (Nilsson, 2006, pp. 129–131; Stoerring & Dalum, 2007). In addition, the cluster organisation representing the firms specialised in wireless communications, NorCOM, settled there after its foundation in 1997 (the staff from AAU was also involved in the establishment of the cluster organisation). Currently the science park hosts 100 companies and 1,000 employees, although not all of businesses operate solely on the ICT industry: some are biomedical companies, and others operate both in the ICT and biomedical industries (NOVI, n.d.).

The ICT industry would follow an evolution similar to that of the science park in the 1990s. New rounds of spin-offs and the entrance of multinational corporations like Lucent or Infineon would increase the number of firms specialised on wireless communications to 51 by 2003, amounting to approximately 4,000 employees. And the opening in 1993 of the Centre for Personal Communication (CPK) by the university suggests another feedback loop: the main goal of this centre was to develop basic research on radiocommunications technology and speech recognition, with the involvement of university researchers and employees from businesses specialised in wireless communications (Dalum et al., 2005; Østergaard & Park, 2015). Its successor, the Center for Teleinfraestruktur (CTIF) is another example of this trend. The centre, established in 2004, counted with funds from the EU, but also from local firms and foundations, as well as some of the largest MNCs in the industry at the time, such as Samsung, Siemens and Nokia (Dalum et al., 2005; Hedin, 2009).

The dot.com bubble and the shift from 2G to 3G technologies in the 2000s, however, challenged the growth of the ICT industry. Many of the foreign MNCs settled in the region decided to reduce its activities or leave altogether. In addition, the entry of the smartphones into the market and the economic recession at the end of the decade led to a further wave of closures. The cluster could not absorb all the job losses from the downsizing, and by 2010 the total number of companies specialised in wireless communications was reduced to 40 businesses and 2,200 employees. The shock also seemed to influence university engagement: the CTIF reacted by focusing on the 4G standard in its research, together with businesses located in the region and abroad (Østergaard & Park, 2015). The register data shows how these shocks are reflected in the general evolution of the ICT industry (figure 2). Between 2001 and 2007, the number of jobs dropped from 9,022 to 7,233. Between 2007 and 2008, changes in the NACE classification prevent a full comparison, but the data points to the effect of the recession that hit Denmark at the end of the decade: total employment decreased from 7,780 to 6,972 jobs between 2008 and 2009. The latest record (2010) suggests a slight recovery, to 7,133 jobs.

Despite the shocks suffered by the ICT industry, the data does not suggest a substantial decrease in the engagement of the university. This is visible, for example, in the analysis of the register data (figures 2 and 3): the number of AAU graduates in the industry dropped from a peak of 1,165 in 2001 to 1,064 in 2004, but by 2007 it had already recovered to 1,452. The numbers for the 2008-2010 period witnessed a slight decrease from 1,582 to 1,559 jobs, but the proportion of AAU-trained professionals over the graduate experienced a slight increase (from 81% to 82%).

The organisations supporting the ICT industry, meanwhile, seem to have reacted to the previous crisis by broadening their focus beyond wireless communications. AAU is, with the municipality and the region, part of the BrainsBusiness partnership since 2009. NorCOM was also integrated in the partnership (Hedin, 2009). Under BrainsBusiness, there is an increasing tendency towards interdisciplinary research, involving disciplines such as "humanistic informatics, e-learning, design, mechanics and production" (Lindqvist, Olsen, Arbo, Lehto, & Hintsala, 2012).

In sum, it can be said that AAU has contributed to the development of the localised capabilities (Maskell et al., 1998) that make of North Denmark an attractive region for ICT firms. At the same time, the growth of these businesses favoured that more and more resources were dedicated to promote research connected to the ICT industry. Indeed, much of the current interactions between the university and the industry can be seen as a consequence of the feedback loops between both parts: even if the BrainsBusiness staff tries to put in contact SMEs with university researchers, many of these businesses count with AAU graduates with their own acquaintances in academia[6]. This organisation also promotes the participation of businesses in hosting students, as part of their PBL projects (interview BrainsBusiness). In addition, AAU is, according to the Leiden University Ranking for 2012-2015 (CWTS Leiden University, n.d.), the first Danish higher education institution, when comparing the universities by the proportion of their own publications that are in the top 50% of the most cited papers in the field of mathematics and computer science. The same applies for the top 10%, yet not for the top 1%, where AAU is second behind the University of Copenhagen[7]. This is an area connected to the faculties of Engineering and Science, and IT and Design. These are the ones that count, in turn, with more staff: 877 and 644 full-time employees in 2016, out of 3,351[8] (Aalborg University, n.d.-a)). The performance of the university in these areas could also be an outcome of the co-creation of localised capabilities with the industry.

Case 2: Attempts to support activities related to the biomedical industry

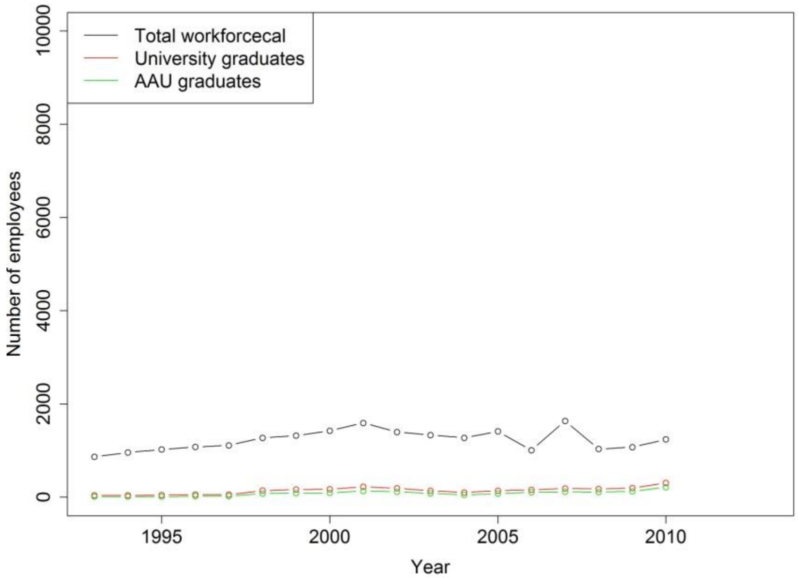
The activities of AAU in relation to the biomedical industry have been focused around a cluster initiative, which was formalised in 2003 under the name of Biomed Community. The Industrial Liaisons Office at Aalborg University supported the development of this cluster initiative since its beginning in 2000, together with the Aalborg municipality and the regional administration. The university had already developed research in the biomedical field, with the establishment of the Centre for Sensory Motor Interaction in 1978, but in 2003 started collaborating actively with Aalborg Hospital and Aarhus University, under the umbrella of the HEALTHnTECH Research Centre, supporting the development of new products by

[6] Because of this, they devote efforts to put businesses in contact with other departments than those that they know already, stimulating new collaboration opportunities (interview BrainsBusiness).

[7] The ranking data does not allow to test for statistical associations between the publications' number of citations, and the involvement of industry partners. However, research conducted in the case of Spain suggests an statistical association between academics' research excellence, and the likelihood that they engage into the formation of spin-offs. The former does not seem to be positively related to the development of research partnerships, nevertheless (D'Este, Rentocchini, & Yegros, 2015).

[8] The third faculty in number of employees is Social Sciences (486), followed by Humanities (434) and Medicine (306). 604 employees are not ascribed to a specific Faculty.

Figure 4: Number of employees in biomedical industry in North Denmark (excl. hospital)



the industry. The actors involved in the development of the cluster initiative also facilitated the establishment of the Research House facility, next to the Aalborg Hospital. The Research House provides educational and research services, as well as spaces for testing new products. It also works as a business incubator (Stoerring & Dalum, 2007; Universitetshospital, 2015). The university also invested resources in the training of graduates, by providing two specialisations within Electrical Engineering (Master of Biomedical Engineering and Mater of Medical Informatics), and starting a degree in Health Technology in 2000 (Stoerring & Dalum, 2007). Hence, it can be said that the actions developed by the university could have impacted on the industry via the generation of new knowledge, the transfer of existing know-how, the development of technological innovations through spin-offs, and the creation of human capital (Drucker & Goldstein, 2007).

The data suggests, however, that the biomedical industry counted in the early 2000s with a small company base, and that its capacity to absorb university graduates was rather limited, providing little ground for the start of a series of feedback loops between university actions and industry demand. The Biomed Community initiative included 35 firms at its start, but many of them worked in the distribution of health care equipment or were primarily small university spin-offs. The trajectory of the cluster businesses, in addition, tended to be rather unstable: the disappearance and the establishment of new firms was not an uncommon phenomenon. As a result, many graduates from medical degrees opted for moving to other regions in Denmark or to the ICT industry (Stoerring & Dalum, 2007).

These trends are visible in the register data: between 1993 (previous years had to be excluded from the analysis, due to the small number of observations available[9]) and 2000, the total workforce increased from 866 to 1,426 jobs (figure 4). However, the industry experienced some losses in the first half of the 2000s, and the cluster initiative does not seem to have stimulated the expansion of the industry. Rather, the total number oscillated between 1,000 and 1,600 jobs in the 2001-2007 period (with a peak of 1,636 in 2007), and between 1,000 and 1,200 jobs in the 2008-2010 period, with a peak in 2010 (1,240 jobs).

This has been the case even if figure 5 suggests an increasing involvement of AAU graduates in the biomedical industries among the university graduates in the sector, approaching the levels of the ICT firms. Already before the start of the Biomed Community cluster initiative, the proportion of former AAU students over the graduate workforce had grown (from 34% in 1993 to 54% in 2000). The years after the start of Biomed Community were followed by increases in the weight of AAU graduates (reaching 65% by 2006). A similar trend is visible for the 2008-2010 period, despite the change to the NACE 2 industrial classification: the proportion of AAU-trained professionals over the graduate workforce increased from 62% to 70%. The absolute number of AAU graduates, however, did not experience substantial increases since the start of the Biomed Community cluster initiative. In fact, the numbers dropped from 134 to 50 between 2001 and 2004, recovering to 115 by 2007. The main exception is between 2009 and 2010, when the number of AAU graduates working in the industry grew from 126 to 215.

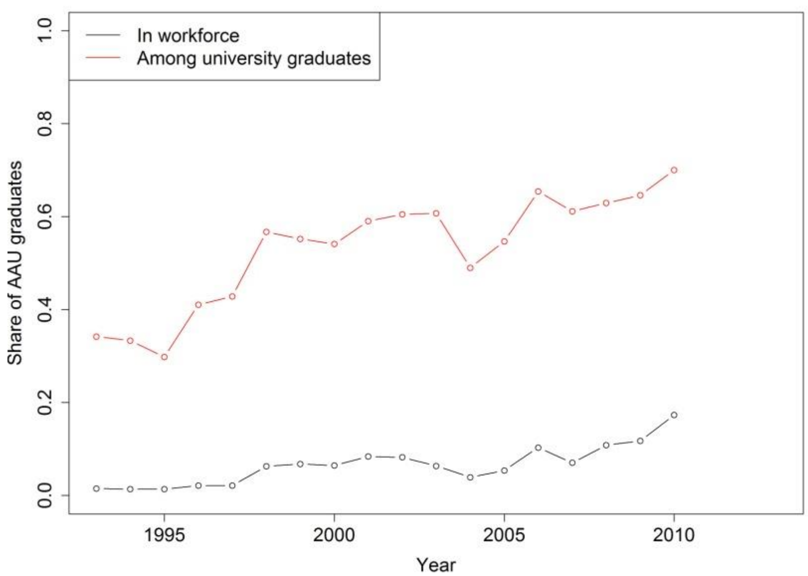
The university, in addition, does not seem to have acquired a strong position in this field: according to the Leiden University Ranking for 2006-2009, AAU was the last Danish university, concerning the proportion of its own publications that were in the top 50% of the most cited publications for the field of Biomedical and health sciences. The same result applied for the top 10% and top 1%. By the 2012-2015, AAU's position in the ranking had not changed (CWTS Leiden University, n.d.). This

---

[9] Statistics Denmark regulations prevent including cells with less than three cases, in order to protect the anonymity of the respondents. The total workforce in the biomedical industries clearly overcame this threshold, yet that was not the case for the graduates working in there.

suggests that the quality and relevance of AAU papers in the biomedical field was (and still is) below average.

Figure 5: Share of AAU graduates in biomedical industry in North Denmark (excl. hospital)



Indeed, one could argue that the young age of Biomed Community prevents further enquiries on the feedback loops with the educational, research, knowledge transfer and technological innovation activities (Drucker & Goldstein, 2007) generated by the university. The acquisition of the AAU spin-off Neurodan by the Otto Bock Group (Germany), and the allocation of its R&D premises close to the university, suggested that other large firms could follow the same pattern, increasing the size of the cluster's company base. In addition, the first graduates with a Health Technology degree completed their education in 2005. However, the analysis of the register data until 2010 suggests that the feedback loops between Aalborg University and the biomedical industry do not seem to have stimulated an expansion of the latter. In fact, most of the graduates came already from AAU by the start of the cluster initiative. If anything, the proportion of former AAU students over the graduate workforce has continued increasing until 2010, yet this trend did not seem to accelerate after 2000.

Moreover, the most recent information available suggests that the company base of the Biomed Community cluster remains limited, with 38 businesses (Biomed Community, n.d.), and hence insufficient to stimulate feedback loops with the university. In addition, some of the most recent entrants in the cluster, like MEDEI and NociTech, are spin-offs from the university, suggesting that the entrepreneurial spin-offs dynamics that could support the growth of the cluster (as in the wireless cluster) are still lacking (Dahl et al., 2010; Aalborg University Department of Health Science and Technology, n.d.).

Despite the lack of feedback from the biomedical industry, AAU has taken part in further efforts to stimulate the growth of these businesses. This is the case of the Empowering Industry & Research Initiative (EIR). Since 2011 it promotes the development and patenting of innovations, as well as the creation of university spin-offs in areas such as biotechnology, medicine, biomedical technology, sports technology or welfare technology, stimulating interaction between the biomedical and ICT industries (Empowering Industry and Research, n.d.). The AAU Faculty of Medicine, founded in 2010, is participating in the initiative. According to one of the experts from the North Denmark Region (interview regional expert), EIR has helped promoting further interest in university-industry collaboration among AAU researchers, who feared these activities would take too much time. In addition, the yearly number of patents filed shows a certain tendency to grow since the early 2000s, with a peak of eight in 2010. Afterwards the numbers decrease to five in 2015 (no patents were filed in 2013 (Aalborg University Department of Health Science and Technology, n.d.)).

Contrary to the expectations of the conceptual model, the data available suggests that the university keeps dedicating resources to the biomedical industry, despite the lack of a company base capable of stimulating the demand for graduates and research activity. These actions can be partly explained by the involvement of public actors such as the university, the Aalborg municipality, the regional administration and the Aalborg hospital in the initiative: these actors might be interested in investing more resources in the formation of the industry, with various goals in mind[10] (Stoerring & Dalum, 2007; interview regional expert).

[10] University professionals, for example, are interested in being able to train medical doctors in order to stimulate health professionals' involvement in the development of research (Stoerring & Dalum, 2007). These interests are similar to the goals of the AAU Faculty of Medicine's strategy for the 2011-2015 period (Aalborg Universitet, 2011), which aimed at strengthening the educational and research profile of the university in the area of medicine. Finally, another reason for the continuity of the Biomed Community is to ensure that the region retains a university hospital: *"When you go (...) to directors of hospitals and the university, they all agree that is important for North Denmark to have an efficient cluster collaboration, because otherwise we are a little player in the national competition. If we do not excel in providing good healthcare, research, and we do not have an industry base, we can have a negative spiral going down. And then we loose some research, some*

Discussion and Conclusion

This paper has given insight on the feedback loops between a university and two industries of its region; and how these processes affect the creation of localised capabilities, reinforcing the competitiveness of these industries and their growth. In order to conduct this task, a conceptual model has been devised, and applied to two cases in the region of North Denmark. These are:

Case 1: the interaction between AAU and the ICT industry, since the foundation of the university in 1974 (Dalum et al, 2005).

Case 2: the interaction between AAU and the biomedical industry, since the start of university involvement in a cluster initiative related to the industry, since 2000 (Stoerring & Dalum, 2007).

The data suggests that the industries included in these cases have evolved differently: the ICT industry grew considerably (the firms specialised in wireless communications expanded from 5 in 1980 to 51 in its peak in the early 2000s, counting with more than 4,000 employees. By 2010, 40 businesses remained, with 2,200 employees). The number of companies involved in the Biomed Community (an initiative aimed at promoting the development of the biomedical industry in the region), on the other hand, has remained more or less stable, close to 40 (Dalum et al., 2005; Stoerring & Dalum, 2007; Østergaard & Park, 2015). In addition, many of the cluster businesses are small university-spin offs. In this respect, the conceptual model sheds some light on the role played by university-industry feedback loops in shaping the localised capabilities of the ICT and biomedical industries, providing an answer to the research question guiding this paper:

RQ: What are the mechanisms leading to the co-creation of localised capabilities between universities and nascent industries at the regional level?

One fundamental aspect here seems to be the employment size of the regional industry during university-industry interaction. The workforce of the ICT industry was larger than that of the biomedical industry at the start of university engagement, and the gap in the size of these industries grew over time. As

doctors, and it might end up that we don't have a university hospital anymore. So it's very much a politically driven initiative" (interview with regional expert).

expected in the conceptual model, this difference seems to have influenced the extent to which feedback loops could take place between the industry and the university. While the employment size of the ICT industry facilitated the start of a series of feedback loops and the creation of localised capabilities strengthening the position of the businesses and their expansion; the smaller size of the biomedical industry seems to have prevented the co-creation of localised capabilities through university-industry interaction.

The university incremented over time its range of activities in relation to the ICT industry, supporting its expansion between the late 1970s and the 1980s: AAU counted with 200 academic staff members in the Technical Faculty, and the opening of the Department of Electronic Systems entailed devoting resources to the training of graduates specialised on electronics (Dalum et al., 2005; Stoerring & Dalum, 2007). Indeed, the analysis of the register data indicates an increase over time in the number of AAU electronics graduates employed in the industry, in particular in the second half of the 1980s. These graduates would constitute a fundamental part of the industry, to the point that currently many of its businesses count with AAU graduates (interview BrainsBusiness). The collaboration of AAU in the construction of the NOVI science park, between 1987 and 1989, seems to be part of this first feedback loop.

The shift from the 1G to the 2G technologies, in addition, seems to have elicited a further increase in the engagement of the university. The NOVI science park became the setting for the joint effort of Dancall and Cetelco in developing the basic technology for a 2G terminal, and the size of the science park increased over time, to the point that by the early 2000s its size had increased to 40,000 m2. This facility also became the site for the cluster organisation, NorCOM, in 1997. Staff members from AAU were involved in the creation of the cluster (Nilsson, 2006; Stoerring & Dalum, 2007). Further involvement on the part of the university can also be seen in the creation of research centres: the CPK in 1993, and the CTIF in 2004. The latter, in addition, was partly financed by the industry (Dalum et al., 2005; Hedin, 2009), suggesting an interest of ICT businesses in promoting the transfer on university knowledge, as expected in the conceptual model. Moreover, the register data shows that the number of AAU graduates, and their weight over the graduate workforce, increased until the early 2000s. Therefore, the interaction between the ICT industry and AAU seems to follow the pattern expected in the conceptual model: the demand from the nascent industry has been followed by an increase in university activities. Not just in education, but also in knowledge creation (and the transfer of existing know-how, via channels such as the university research centres, the NOVI science park, or the cluster organisation[11]). Contrary to the model, however, the downturns experienced by the wireless businesses (Østergaard & Park, 2015) in the latter years do not seem to have reduced considerably the engagement of the university.

The evolution of the biomedical industry, on the other hand, suggests a lack of feedback loops between university and industry, relative to its ICT counterpart. The university has been involved in initiatives aimed at supporting activities related to the industry, starting with the participation of the Biomed Community cluster initiative in 2000. These include the establishment of the Research House Facility, whose functions also include providing space for the development of spin-offs; and the provision of graduates, including two specialisations within Electrical Engineering and a degree in Health Technology. (Stoerring & Dalum, 2007; Universitetshospital, 2015). These initiatives, therefore, have had a potential for benefiting the industry via the generation of human capital, the creation of knowledge and the transfer of know-how, and the generation of technological innovation (Drucker & Goldstein, 2007), via the creation of spin-offs (Drejer et al., 2014a, p.8). These actions, nevertheless, do not seem to have met a response on the part of the industry, and the developments in the industry at the start of the cluster initiative suggest that the ability of biomedical businesses to react to university activities with an increased demand for university support was rather limited: the Biomed Community cluster counted with 35 businesses at its start. At that time, many of the firms were small university spin-offs, and hence firms whose capacity to employ university graduates was limited (Stoerring & Dalum, 2007). The analysis of the register data confirms this impression: the industry workforce has not grown since the start of the Biomed Community in 2000, despite the involvement of the university in activities related to the industry. In any case, the

[11] The NOVI science park can also be seen as a seedbed for university spin-offs (that is, technological innovation impacts stemming from the university (Drucker & Goldstein, 2007, pp. 127–132), yet at the practice it has focused to a greater extent on the attraction of external businesses (Nilsson, 2006).

proportion of AAU graduates over the graduate workforce has grown to levels similar to those of the ICT industry.

Based on the conceptual model developed for this paper, this suggests that the dynamics in the biomedical industry have lacked the impetus necessary to grow and absorb graduates from the university. The efforts from the university, in turn, have not sufficed to guarantee the success of the industry: if the businesses lack the critical mass required to grow, university actions are unlikely to generate the localised capabilities that will guarantee the competitiveness of the industry, and its growth. The creation of localised capabilities depends on the extent to which a university and an industry can influence each other via feedback loops. It depends, in a way, on both parts' involvement. Nevertheless, the involvement of the university does not seem to have decreased. In fact, actions such as the opening of the AAU Faculty of Medicine and the EIR research collaboration initiative (Empowering Industry and Research, n.d.) suggest otherwise.

Even if the nature of this papar as a case study prevents generalisation, the insights delivered here suggest implications for regional innovation policies, which might stimulate further research. The lack of strong bottom-up dynamics at the industry side (that is, the absence of a strong industry base) might pose a challenge to policies relying on universities as main drivers of regional development. Both parts, university and industry, seem to be necessary for the development of localised capabilities. In a way, these suggestions are similar to the smart specialisation strategies' call (Asheim, 2014, pp. 7-11) for basing innovation policies on the existing strengths of the regions: policymakers might be interested in developing new industries, but if these developments do not depart from already existing developments, they are less likely to thrive. The same might go for the role of the university as a trigger for regional development.

Acknowledgements

The authors wish to thank Ina Drejer and Christian Østergaard (Aalborg University) and David Charles (University of Lincoln) for their comments on this paper. Thanks are also due to Bram Timmermans (Norwegian School of Economics and Aalborg University) and the members of the IKE Research Group. The authors take all responsibility for any remaining flaws.

Bibliography

Asheim, B. T. (2014). North Denmark Region RIS3 Expert Assessment. An expert assessment of behalf of DG Regional and Urban Policy. DG Regional and Urban Policy (Vol. 123).

Abreu, M., & Grinevich, V. (2013). The nature of academic entrepeneurship in the UK: Widening the focus on entrepeneurial activities. *Research Policy*, *42*, 408–422.

Biomed Community. (n.d.). Biomed Community. Retrieved May 1, 2017, from http://www.hst.aau.dk/innovation-co-operation/empowering-industry-research/

Charles, D. (2006). Universities as key knowledge infrastructures in regional innovation systems. *Innovation: The European Journal of Social Science Research*, *19*(1), 117–130. https://doi.org/10.1080/13511610600608013

CWTS Leiden University. (n.d.). CWTS Leiden Ranking 2017. Retrieved August 22, 2017, from http://www.leidenranking.com/ranking/2017/list

D'Este, P., & Patel, P. (2007). University-industry linkages in the UK: What are the factors underlying the variety of interactions with industry? *Research Policy*, *36*(9), 1295–1313. https://doi.org/10.1016/j.respol.2007.05.002

D'Este, P., Rentocchini, F., & Yegros, A. (2015). Star scientists versus interdisciplinary scientists : exploring the distinct patterns of engagement in university-industry interactions. Paper to be presented at DRUID15, Rome, June 15-17, 2015.

Dahl, M. S., Østergaard, C. R., & Dalum, B. (2010). Emergence of regional clusters: the role of spinoffs in the early growth process. In *The Handbook of Evolutionary Economic Geography*. Cheltenham, UK: Edward Elgar Publishing, Incorporated.

Dalum, B., Østergaard, C. R., & Villumsen, G. (2005). Technological life cycles: lessons from a cluster facing disruption. *European Urban and Regional Studies*, *12*(3), 229–246. https://doi.org/10.1177/0969776405056594

Danmarks Statistik. (1990). *Danmark i 30 år*. Kobenhavn. https://doi.org/87- 501 -0769 -0

Drejer, I., Holm, J. R., & Nielsen, K. (2014a). *To what extent is a "regional university"* *regional? The case of Aalborg University. Unpublished dcoument*. IMPAKT, Department of Business and Management. Aalborg University.

Drejer, I., Holm, J. R., & Nielsen, K. (2014b). *Aalborg Universitets bidrag til udvikling i Region Nordjylland*. IMPAKT, Institut for Økonomi og Ledelse. Aalborg Universitet.

Drejer, I., & Østergaard, C. R. (2017). Exploring determinants of firms' collaboration with specific universities: employee-driven relations and geographical proximity. *Regional Studies*, 1–14. https://doi.org/10.1080/00343404.2017.1281389

Drucker, J., & Goldstein, H. (2007). Assessing the regional economic development impacts of universities: a review of current approaches. *International Regional Science Review*, *30*(1), 20–46. https://doi.org/10.1177/0160017606296731

Empowering Industry and Research. (n.d.). Empowering Industry & Research. Retrieved May 1, 2017, from http://www.eirbusinesspark.com/

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations. *Research Policy*, *29*(2), 109–123. https://doi.org/10.1016/S0048-7333(99)00055-4

Eurostat. (1996). *NACE Rev. 1 Statistical classification of economic activities in the European Community*. Luxembourg.

Florida, R. (2002). *The rise of the creative class, and how it is transforming work, leisure, community and everyday life*. (Basic Books, Ed.). New York.

Florida, R. (2003). Cities and the Creative Class. *City & Community*, (March), 3–19.

Folketings-redaktion, A. stiftstidendes. (1969, December 13). Universitetsdebatten i folketinget viste, at det skal være alvor i Aalborg i 1975. *Søndags Stiftstidende Aalborg Nordjysk Amtstidende*, p. 4.

Galland, D. (2012). Is regional planning dead or just coping? The transformation of a state sociospatial project into growth-oriented strategies. *Environment and Planning C: Government and Policy*, *30*(3), 536–552. https://doi.org/10.1068/c11150

Gregersen, B., Linde, L. T., & Rasmussen, J. G. (2009). Linking between Danish universities and society. *Science and Public Policy*, *36*(2), 151–156. https://doi.org/10.3152/030234209X406818

Hall, P. A., & Soskice, D. (2001). An introduction to Varieties of Capitalism. In P. A. Hall & D. Soskice (Eds.), *Varieties of Capitalism. The Institutional Foundations of Comparative Advantage* (pp. 1–68). Oxford University Press.

Hedin, S. (2009). *Higher education institutions as drivers of regional development*

Nordregio Working Paper 2009:3. Stockholm.

Hermann, R. R. (2015). *Greening of the maritime industry: Delivering product and service eco-innovations*. Aalborg Universitetsforlag. (Ph.d.-serien for Det Teknisk-Naturvidenskabelige Fakultet, Aalborg Universitet). https://doi.org/10.5278/vbn.phd.engsci.00015

Holm, J. R., Østergaard, C. R., & Olesen, T. R. (2017). Destruction and Reallocation of Skills Following Large Company Closures. *Journal of Regional Science*, *57*(2), 245–265. https://doi.org/10.1111/jors.12302

Isaksen, A., & Trippl, M. (2014). *New Path Development in the Periphery. No 2014/31, Papers in Innovation Studies, Lund University, CIRCLE - Center for Innovation, Research and Competences in the Learning Economy*.

Isaksen, A., & Trippl, M. (2014). *Regional industrial path development in different regional innovation systems : A conceptual analysis. No 2014/17, Papers in Innovation Studies, Lund University, CIRCLE - Center for Innovation, Research and Competences in the Learning Economy*.

Kendrup, Sø. (2006). *OECD / IMHE project Supporting the Contribution of Higher Education Institutions to Regional Development. Subreport: Aalborg University Jutland-Funen, Denmark. OECD / IMHE*.

Koldbæk, J. (1974, September 2). Det begyndte i sol - og endte i regn (not available online). *Søndags Stiftstidende Aalborg Nordjysk Amtstidende*, pp. 2–3.

Laursen, K., Reichstein, T., & Salter, A. (2011). Exploring the Effect of Geographical Proximity and University Quality on University–Industry Collaboration in the United Kingdom. *Regional Studies*, *45*(4), 507–523. https://doi.org/10.1080/00343400903401618

Lindqvist, M., Olsen, L. S., Arbo, P., Lehto, V., & Hintsala, H. (2012). *Strategies for Interaction and the Role of Higher Education Institutions in Regional Development in the Nordic Countries – Case Studies. Nordregio Working Paper 2012:3*. Stockholm.

Linkedin. (2017). Alumni tool Aalborg University.

Marques, P. (2017). Human capital and university – business interactions : an example from the wine industry Human capital and university – business interactions : an example from the wine industry. *Regional Studies, Regional Science*, *4*(1), 154–160. https://doi.org/10.1080/21681376.2017.1341818

Maskell, P., Eskelinen, H., Hannibalsson, I., Malmberg, A., & Vatne, E. (1998). Localised capabilities and the competitiveness of regions and countries. In *Competitiveness, Localised Learning and Regional Development. Specialization and Prosperity in Small Open Economies* (p. 273). Taylor & Francis. Retrieved from https://ebookcentral.proquest.com/lib/aalborguniv-ebooks/detail.action?docID=169634

Nilsson, J. (2006). Regions with comprehensive technical universities. In J. Nilsson (Ed.), *The Role of Universities in Regional Innovation Systems: A Nordic Perspective* (pp. 114–143). Frederiksberg: Copenhagen Business School Press.

NOVI. (n.d.). About Novi. Retrieved May 1, 2017, from http://novi.dk/en/about-novi

Pavitt, K. (1984). Sectoral patterns of innovation; Towards a taxonomy and a theory. *Research Policy*, *13*(1984), 343–374.

Perkmann, M., & Walsh, K. (2007). University – industry relationships and open innovation : Towards a research agenda. *Internal Journal of Management Reviews*, *9*(4), 259–280. https://doi.org/10.1111/j.1468-2370.2007.00225.x

Piekkari, R., Welch, C., & Paavilainen, E. (2009). The Case Study as Disciplinary Convention. *Organizational Research Methods*, *12*(3), 567–589.

Plenge, P. (2014). *Ledelse af AAU: syv fortællinger fra AAU's ledelseshistorie* (Aalborg Un). Aalborg Universitet, AAU Kommunikation.

Pyndt, J. (1969, December 13). Protestrejsen til København blev en værdig bevighend. *Søndags Stiftstidende Aalborg Nordjysk Amtstidende*, p. 2.

Ragin, C. C. (2009). Reflections on casing and case-oriented research. In C. C. Ragin & D. Bryne (Eds.), *The Sage handbook of case-based methods* (pp. 522–534). Sage publications.

Region Nordjylland. (2016). Initiativer 2015-2018. Retrieved October 4, 2017, from http://www.rn.dk/regional-udvikling/vaekstforum/initiativer/initiativer-2015-2018

Richards, A., & Polavieja, J. G. de. (1997). *Trade unions, unemployment and working class fragmentation in Spain* (No. 112). Centro de Estudios Avanzados en Ciencias Sociales, Madrid.

Rodríguez-Pose, A. (2013). Do institutions matter for regional development? *Regional Studies*, *47*(7), 1034–1047. https://doi.org/10.1080/00343404.2012.748978

Rodríguez-Pose, A., & Fitjar, R. D. (2013). Buzz, Archipelago Economies and the Future of Intermediate and Peripheral Areas in a Spiky World. *European Planning Studies*, *21*(3), 355–372. https://doi.org/10.1080/09654313.2012.716246

Skaarup, J. P. (1974, September 1). AUC vil gøre landsdelen mere attraktiv. *Søndags Stiftstidende Aalborg Nordjysk Amtstidende*, p. 9.

Statistics Denmark. (n.d.). Statbank Denmark.

Statsministeret. (n.d.). Statsministre siden 1848. Retrieved June 7, 2017, from http://www.stm.dk/Index/mainstart.asp/_a_1596.html

Stoerring, D., & Dalum, B. (2007). Cluster emergence: a comparative study of two cases in North Jutland, Denmark. In P. Cooke & D. Schwartz (Eds.), *Creative Regions: Technology, Culture and Knowledge Entrepreneurship* (pp. 127–147). Routledge.

Timmermans, B. (2010). *The Danish integrated database for labor market research: towards demystification for the English speaking audience. DRUID Working Paper No. 10-16*.

Universitetshospital, A. (2015). Forskningens Hus. Retrieved September 19, 2017, from http://www.aalborguh.rn.dk/forskning/forskningens-hus

Welch, C., Piekkari, R., Plakoyiannaki, E., & Paavilainen-Mäntymäki, E. (2011). Theorising from case studies : Towards a pluralist future for international business research. *Journal of International Business Studies*, *42*, 740–762. https://doi.org/10.1057/jibs.2010.55

Wood, D. F. (2003). Problem based learning. *BMJ*, *326*(7384).

Yin, R. K. (2014). *Case study research: Design and methods - fifth edition*. Sage publications.

Østergaard, C. R. (2005). *The Development Perspectives for the ICT Sector in North Jutland. Phd Thesis*. Aalborg University.

Østergaard, C. R., & Park, E. K. (2015). What Makes Clusters Decline? A Study on Disruption and Evolution of a High-Tech Cluster in Denmark. *Regional Studies*, *0*(March), 1–16. https://doi.org/10.1080/00343404.2015.1015975

Østergaard, C. R., Reinau, K. H., & Park, E. K. (2017). The Dual Role of Multinational Corporations in Cluster Evolution: When You Dance with the Devil, You Wait for the Song to Stop. In F. Belussi & J.-L. Hervás-Oliver (Eds.), *Unfolding Cluster Evolution* (pp. 39–55). Routledge.

Aalborg Universitet. (2011). Strategi for Det Sundhedsvidenskabelige Fakultet 2011-2015. Aalborg. Retrieved from http://www.medicine.aau.dk/digitalAssets/86/86006_strategi_det_sundhedsvidenskabelige_fakultet_aau.pdf

Aalborg Universitets Historie. (n.d.). Retrieved May 1, 2017, from http://www.aau.dk/om-aau/historie-priser/historie/

Aalborg University. (n.d.-a). Ansatte på Aalborg Universitet. Retrieved August 22, 2017, from http://www.aau.dk/om-aau/aau-i-tal/ansatte/

Aalborg University. (n.d.-b). PBL Academy. Retrieved June 1, 2017, from http://www.pbl.aau.dk/

Aalborg University. (n.d.-c). Studerende på Aalborg Universitet. Retrieved June 1, 2017, from http://www.aau.dk/om-aau/aau-i-tal/studerende/

Aalborg University Department of Health Science and Technology. (n.d.). Technology transfer statistics. Retrieved September 19, 2017, from http://www.smi.hst.aau.dk/innovation/access-to-labs-and-equipment/

Appendix 1: Variables used in quantitative analyses

Variable	Variable Name	Specification
Institution of highest completed education	HFINSTNR	Aalborg University: 280776, 851416, 851446 Universities (including PhD schools): 101441, 101455, 101530, 101535, 101560, 101582, 147406, 151413, 173405, 265407, 265415, 280776, 280777, 280778, 280779, 280780, 280781, 280782, 280783, 280784, 280785, 280786, 280787, 280788, 280789, 280790, 280791, 280833, 280834, 280835, 280836, 280837, 280838, 280839, 280840, 280841, 280843, 280844, 280845, 280846, 280847, 280848, 280849, 280850, 280857, 280858, 280859, 280860, 280861, 280904, 280907, 313402, 330401, 461416, 461437, 461450, 537406, 561408, 561411, 621406, 657410, 751418, 751431, 751453, 751465, 851416, 851446
Industry	PDB932 (1980-2003)	**NACE1(.1) 1980-2007** *ICT industry:* Manufacture of office machinery and computers (30), Manufacture of radio, television and communication equipment and apparatus (32), Computer and related activities (72), Telecommunications (642), Research and experimental development on natural sciences and Engineering (731), Reproduction of computer media (2233), Manufacture of insulated wire and cable (3130), Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment (3320), Wholesale of electrical household appliances and radio and television Goods (5143), Wholesale of office machinery and equipment (5164), Wholesale of other machinery for use in industry, trade and navigation (5165), Wholesale of computers, computer peripheral equipment and software (5184), Wholesale of other office machinery and equipment (5185), Renting of office machinery and equipment, including computers (7133) *Medical industry (without hospital and related activities):* Manufacture of pharmaceuticals, medicinal chemicals and botanical products (244), Manufacture of medical and surgical equipment and orthopaedic appliances (331), Research and experimental development on natural sciences and Engineering (731), Wholesale of pharmaceutical goods (5146)
	PDB03 (2004-2010)	**NACE2 2008-2010** *ICT industry:* Telecommunications (61), Computer programming, consultancy and related activities (62), Manufacture of electronic components and boards (261), Manufacture of computers and peripheral equipment (262), Manufacture of communication equipment (263), Manufacture of irradiation, electromedical and electrotherapeutic equipment (266), Manufacture of optical instruments and photographic equipment (267), Manufacture of wiring and wiring devices (273), Software publishing (582), Data processing, hosting and related activities; web

		portals (631), Repair of computers and communication equipment (951), Manufacture of instruments and appliances for measuring, testing and navigation (2651), Manufacture of office machinery and equipment (except computers and peripheral equipment) (2823), Repair of electronic and optical equipment (3313), Construction of utility projects for electricity and telecommunications (4222), Wholesale of computers, computer peripheral equipment and software (4651), Wholesale of electronic and telecommunications equipment and parts (4652), Other research and experimental development on natural sciences and engineering (7219), Renting and leasing of office machinery and equipment (including computers) (7733) *Medical industry (without hospital and related activities):* Manufacture of basic pharmaceutical products and pharmaceutical preparations (21), Manufacture of medical and dental instruments and supplies (325), Wholesale of pharmaceutical goods (4646), Research and experimental development on biotechnology (7211), Other research and experimental development on natural sciences and engineering (7219)
Location of employment	ARBKOM	Municipality codes are used to determine the region, in which the individual`s workplace is located (according to the most recent geographical map of Denmark)
Type of employment	PJOB	Full-time employment if PJOB=1