University-industry collaboration on innovation in Denmark

A comparative analysis with particular emphasis on Aalborg University

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Chapter 1. Introduction

Gerwin Evers, Ina Drejer, Christian Richter Østergaard

Background

In 2015, Aalborg University (AAU) launched the strategy *Knowledge for the World*, which set the course for the university towards 2021. The strategy takes its point of departure in AAU's long tradition of building collaborative relationships with external partners. Since AAU was established in 1974, the goal has been to generate knowledge that can challenge, support and develop society (Aalborg University, 2015). AAU is in many respects perceived as a 'regional university'. Local politicians, businesses and organisations played an important role in founding the university. They wanted a university to provide opportunities for higher education in the young people in the region and thereby provide the local firms with a better educated workforce as well as make the region attractive for new firms. As noted by AAU's first Rector, Jörgen Weibull in the opening speech, the new university in Aalborg should contrary to traditional universities build a bridge between academic life and practical life and collaborate with local industries and organisations. This should be supported by introducing a project-based study form as well as having research projects focusing on relevant practical problems. However, he also noted that collaboration requires participation from two parties, therefore, he extended an invitation to the local business community, organisations, and people from the region to collaborate with the university (Weibull, 1974).

The role ascribed to AAU is a reflection of a more widespread development of the role of universities, with a move from an idealistic position focused on the creation of knowledge, towards a more instrumentalist position in society (Charles, 2003). Since the 1960s, the number of universities has doubled worldwide, existing universities have grown in size, and the number of students has grown exponentially, thereby making university education a good of the masses (Schofer & Meyer, 2005). However, the rapidly growing student numbers, particularly from the 1980s onwards, put increasing pressure on the public funding of higher education at a time when many developed economies were experiencing an economic slowdown (Zomer & Benneworth, 2011). In addition, concerns were rising with regard to the societal returns of scientific breakthroughs that were made possible by the public funding allocated to universities (Stevens, 2004). This fuelled a discussion regarding how universities could contribute to the society they were part of. Although universities were considered key institutions for the progress of the knowledge-based economy, numerous critics claimed that they were like 'ivory towers'—cut off from the developments in their direct environments (Shapin, 2012). In other words, universities were perceived as existing 'in' rather than being part 'of' their environment (Bender, 1998; Chatterton, 2000, p. 16). This increased focus on how universities contributed to society were also seen in Denmark, where it became specified in the Danish Act on Universities from 2003 that universities must collaborate with their surrounding society and that the research and teaching results must contribute to generating growth, welfare and development in society.

In response to these developments, universities were encouraged and pressurised to develop, in addition to their traditional missions of teaching and research, a third mission of external engagement with the communities in which they were located (Perkin, 2007). This third mission — which can also be referred to as 'valorisation', 'knowledge transfer', 'the third stream', or the 'entrepreneurial university' — was deemed necessary with the development of the understanding that university knowledge does not automatically flow into and becomes absorbed external actors – the transfer and absorption of

knowledge depends on interactions (Laredo, 2007). The development of the third mission reconceptualised universities from ivory towers into entrepreneurial actors driving change in society (Etzkowitz & Leydesdorff, 2000). The locus of the prime impact of the third mission was argued to be regional (Trippl, Sinozic, & Smith, 2012).

Because AAU was established with a mission that aimed wider than a purely academic impact, it can be argued that the above-described development, compared to other universities, has had a relatively limited influence on the way the AAU operates in relation to external partners. But is has certainly created a need to demonstrate the impact that AAU has on society.

Universities' influence on the surrounding society

Universities can influence their surroundings in several ways. Direct university impacts include generating regional employment by creating jobs for both academic, administrative, and support staff, while also employing a variety of people for other services, such as cleaning, catering, and maintenance (Siegfried, Sanderson, & McHenry, 2007). In addition, the investment of universities in real estate can play an important role in revitalising urban areas (Wiewel & Perry, 2015). In turn, the employment generated by the university and the inflow of both staff and students from outside the region also generates widespread demand for a wide variety of businesses (Garrido-Yserte, María, & Gallo-Rivera, 2010). This might spark investments in local public transport, while the international workforce, students, and networks of universities also create demand for international airport and train connections. Further, the presence of a well-educated workforce creates a demand for cultural activities, and universities can play an important role by providing resources and expertise in a wide range of cultural organisations, such as orchestras, museums, and libraries (Chatterton, 2000). Moreover, universities contribute directly to social and cultural life through sport teams, facilities, and a variety of other activities, thereby increasing the attractiveness of the their locality (Laredo, 2007). Universities can also play a role in informing and influencing policy processes through its knowledge base (Breznitz & Feldman, 2012) and enhancing the public understanding of science (Laredo, 2007). Although all these types of direct impacts definitely constitute clear regional societal returns on the investments in the university, these or similar effects could most likely also be realised with an alternative allocation of these resources for the public benefit. Therefore, it is important to also consider the more indirect impacts of universities. These impacts can be found in the domain of economic development, in which university knowledge can make a difference in the development of industrial activities, in particular in the region where the university is located (Charles, 2006).

Zooming in on the possible influence of universities on firms, Chesbrough (2003 p. xvi) noted, *'not all the smart people work for us, we need to work with smart people inside and outside our company',* thereby emphasizing the necessity for firms to not only rely on internal R&D sources for innovation. The increasing complexity and variability of technologies and markets can push companies to pursue a more open innovation strategy (Nooteboom, 1999) in which relying on external sources can foster firms' innovation performance (Laursen & Salter, 2006). While firms can turn to competitors or suppliers for this purpose, none of these are likely to match the knowledge position and independence of universities, thereby placing universities in a crucial position within innovation systems (Charles, 2006).

While the mobility of products and services has increased with the help of globalised logistic and IT networks enabling them to compete in global markets, the knowledge involved in their production tends to be rather sticky and bounded by geographical distance because of place-specific experiences

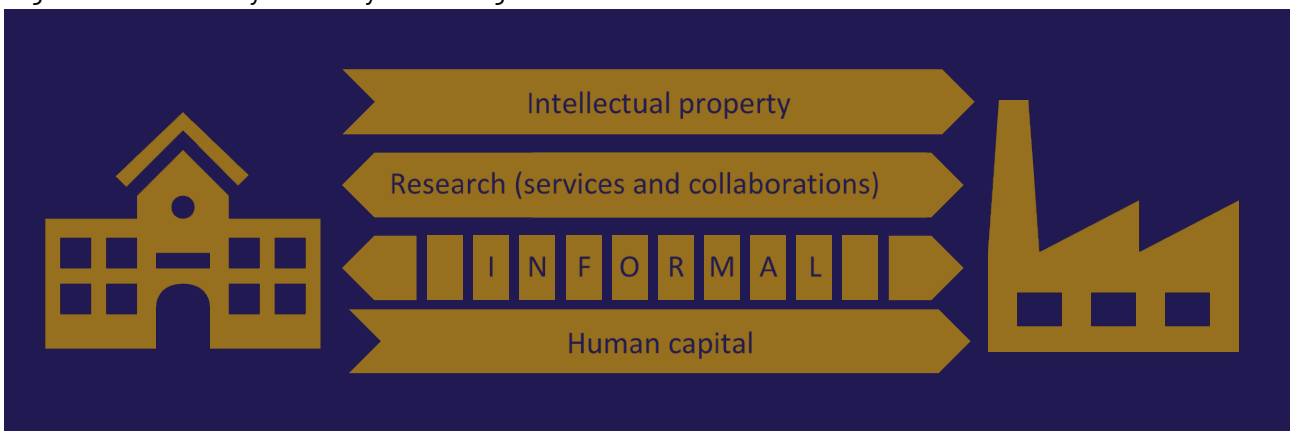
and tacit knowledge (Asheim & Isaksen, 2002). Learning capabilities, informal institutions, and the configurations of actors and their expertise that facilitate their creation are difficult to move or replicate across space (Lundvall, 1992; Markusen, 1996). Knowledge spillovers also tend to have a rather local dimension (Audretsch & Feldman, 2004), and geographical proximity is increasingly important if knowledge is transferred to different institutional settings (Boschma, 2005). In other words, *'one of the few remaining genuinely localized phenomena in this increasingly "slippery" global space economy is precisely the "stickiness" of some forms of knowledge and learning processes'* (Malmberg, 1997, p. 574). Therefore, according to Porter (1998), competitive advantages in the global economy are increasingly dependent on local resources, like knowledge, that are more difficult to access for competitors outside the region. Hence, regional industrial development, consisting of the growth and survival of firms and thereby industries, depends on firms' access to and ability to utilise the knowledge available in the region, in which universities are envisioned to play a significant role.

However, as also mentioned above, the knowledge spillovers required to unlock this potential of universities for regional industrial development are not externalities that flow through the air, but the result of deliberate actions (Breschi & Lissoni, 2001). These actions can be associated with different channels through which knowledge flows between academia and industry.

University-industry knowledge transfer channels

Figure 1.1 illustrates four main channels for university-industry knowledge flows: transfer of intellectual property, research (services and collaborations), informal interactions and human capital.

Figure 1.1. University-industry knowledge transfer channels



The development of human capital (mainly through the teaching of students), is considered to be one of the core channels through which universities enable companies to compete in the knowledge-based economy.

However, there has also been considerable attention in academic and policy circles on the potential of transfer of intellectual property — by means of spin-off companies, patents and licensing — for facilitating university-industry knowledge transfer while at the same time generating additional income for universities. Yet, only few universities have been able to generate substantial income from sales of intellectual property rights, and the current understanding is that it only plays a peripheral role for university-industry knowledge transfer, apart from some sectors that heavily rely on patents for their

competitiveness. Empirical evidence for Denmark on the minor role played by intellectual property for facilitating university-industry knowledge transfer is provided by DEA (2014).

The research channel both includes the consultancy services and contract research activities through which universities share their expertise, and research collaborations where university researchers engage more interactively with external partners. The final channel, informal interactions, while frequently mentioned as important channel, often takes place in conjunction with activities related to the other knowledge transfer channels.

In this report, we focus on university-industry collaboration on innovation.

The aim of the current report

The current report is part of AAU's work with implementing and following up on the *Knowledge for the World* strategy. It relates to the strategy's vision of being an attractive collaboration partner for private companies as well as public authorities and institutions (Aalborg University, 2015, p. 9), and focuses on documenting the extent, nature and impact of AAU's knowledge-based collaboration with external partners.

The vision and missions in *Knowledge for the World* are implemented through a set of initiatives and action plans. The action plan for knowledge collaboration presents a range of specific initiatives to strengthen AAU's knowledge collaboration, including manifesting AAU's reputation, relations and identity by documenting and communicating the value that is created through the knowledge collaboration. It is considered imperative that collaborations with AAU generate new knowledge and benefits for all involved partners. A core aim with the application of knowledge is innovation. *Knowledge for the World* in particular emphasises how AAU can support of the innovation capacity of small and medium-sized firms.

The analyses presented in this report focus on *i)* mapping which types of firms have collaborated with AAU on innovation; *ii)* providing insights into the processes through which knowledge generated at AAU is further developed and transformed into innovation or other forms of value creation in partner organisations; and *iii)* exploring the extent to which it is statistically possible to document firm-level outcomes of collaborating with AAU. Whereas the mapping and statistical outcome analyses are based on quantitative data, the insights into the collaboration processes are based on qualitative case studies. In the quantitative analyses, all Danish universities are included in order to be able to explore the extent to which AAU's collaboration patterns differ from other universities.

The aim of the analyses is to generate knowledge about who collaborates with AAU, what they gain from it, as well as which factors can support successful collaborations. Such knowledge can help AAU target their efforts to promote and further develop their knowledge collaborations.

Summary of main findings

The analyses are presented in three chapters, which supplement each other. However, the chapters are written in a form that also allows them to be read as stand-alone contributions.

Below the main findings of the analyses presented in the following chapters are summarised.

Characteristics of firms collaborating with AAU on innovation (chapter 2)

- AAU is the second most frequently used university collaboration partner on innovation by innovative firms in Denmark.

- The North Denmark region has the highest share of innovative firms that collaborate with universities – and the firms in North Denmark have a strong orientation towards AAU. Seen over a 10-year period, an average of approximately 12 percent of the innovative firms in North Denmark have collaborated with AAU.
- AAU collaborates locally as well a nationally: While having a strong embeddedness in the North Denmark region, AAU is also the Danish university with the longest average travel time between the collaborating firms and the main university campus.
    - The average travel time between AAU's main campus and the collaborating firms is approximately 150 minutes.
    - Over time, geographical proximity to AAU has become less important for collaboration.
- Firms that collaborate with AAU typically also collaborate with other Danish universities.
    - Only one third of the firms that collaborate with AAU do not simultaneously[1] collaborate with other Danish universities.
    - On average, AAU's partner firms collaborate with one to two additional Danish universities as well, which is a relatively low average number of additional university partners compared to the other Danish universities. Thus, collaboration with multiple universities at the same time is a widespread phenomenon, and not a distinctive feature of firms collaborating with AAU.
    - AAU's firm partners typically also collaborate with DTU, Copenhagen University, University of Southern Denmark and/or Aarhus University.
- AAU does not stand out compared to the other Danish universities in terms of the "type" of firms they tend to collaborate with: the firms are on average relatively large, they are R&D active, have highly educated employees, and also collaborate on innovation with other types of partners.
- Firms with employees that are graduates from AAU are more likely to collaborate with AAU on innovation than similar firms without AAU graduates among their employees.
    - Seen over time, firms characterised by being R&D active and having graduates from AAU among the employees becomes more strongly associated with collaboration with AAU.

Characteristics of the successful collaboration on innovation (chapter 3)

Private firms – as well as two public organisations – interviewed about their collaboration on innovation with AAU, emphasise that they primarily see the collaboration as a relation with individual researchers or a specific research team, rather than a relation with a particular university. Accordingly, the identified characteristics of a successful university-industry collaboration on innovation applies to a large extent to firms' collaborations with university researchers in general. However, some distinctive features of AAU as a collaboration partner are also highlighted.

A successful university-industry collaboration is characterised by:

1. A focus on generating value for all partners.
2. Commitment to and contributions from all partners to the collaboration project.
3. An acceptance of a likely long and time-consuming process towards establishing a collaboration.

[1] "Simultaneously' here refers to within the same three-year period.

4. A clear matching of expectations from the outset of the collaborations – and acknowledging that the partners come from different worlds.
5. An effort from the university researchers to see things from the perspective of the organisations they are collaborating with, and 'meeting the organisation where it is'.
6. Acknowledgement from the university researchers that the collaboration is a co-creation project and that practitioners also have something to contribute.
7. A clear relation to practice in the collaborating organisations.
8. A focus on implementation and possibilities for generating commercial value throughout the process.
9. A focus on the professional content and not the funding opportunities as drivers of the collaboration project.
10. Good personal relations – collaborations are first and foremost between people, not organisations.

The main distinctive features of AAU as a collaboration partner are that:

- AAU comes across as more used to collaborating with firms than other universities.
- AAU is more down-to-earth in their collaboration, with researchers being open to also focus on applied research through including practical challenges and challenges from the everyday business of the collaborating firms. Contrary to this, some other Danish universities are perceived as finding it more challenging to bridge the gap between research-related aims and the aims of the firms.
- Researchers as well as students from AAU seem more willing to collaborate over geographical distances than their peers from e.g. universities located in the capital region.

Firm-level performance effects of collaboration on innovation with AAU (chapter 4)

There are several challenges related to determining probable causal firm-specific performance effects of collaborating with universities on innovation. These challenges are even larger when it comes to attempting to isolate the effects of collaborating with a specific university. However, it has been possible to identify some performance-related characteristics of firms that have collaborated with AAU as well with Danish universities in general:

- Firms that have collaborated with AAU on innovation stand out from similar firms that have not collaborated with AAU by:
    - being more inclined to hire university graduates from AAU after initiating a collaboration with AAU;
    - being more inclined to having introduced products and services that are new to the firm;
    - being less inclined to having introduced products and services that are new to the market.
- Firms that have collaborated with Danish universities on innovation experience higher growth rates in turnover and employment than similar firms that have not collaborated with universities.
    - However, a similar effect cannot be found for collaboration with AAU or other specific Danish universities. This can be ascribed to the large proportion of firms collaborating with more than one university – and when controlling for these other collaborations, the university-specific effect disappears.

- The empirical and methodological difficulties in finding a performance effect of collaborating with specific universities or universities is well-known in the academic literature – despite some commissioned consultancy work claims immediate and exceptionally high positive effects on initiating a collaboration with a specific university.

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Chapter 2. Who are they? A mapping of firms with university collaboration on innovation in Denmark 2009-2018

Ina Drejer, Christian Richter Østergaard

There is a strong policy focus on the role that research-based knowledge plays in the development of new technologies and enhancement of firms' innovative capabilities (e.g., Davey et al., 2018; OECD, 2019). Even though universities are considered as one of the primary providers of research-based knowledge, firms' collaboration on innovation with universities is limited. The latest Community Innovation Survey 2016 finds that 13.8% of the product and process innovative firms in the EU have collaborated with universities or other higher education institutions, although with large variation across firm sizes. The relatively low level of university-industry collaboration (UIC) can be associated with several well-known barriers, such as differences in incentives and orientation; potential conflicts regarding approaches towards disclosure and intellectual property; cognitive distance; and lack of absorptive capacity in firms (Boschma, 2005; Bruneel et al., 2010; Cohen & Levinthal, 1990; Criscuolo et al., 2018).

In order to overcome these barriers and spur innovation, policy makers have emphasized and actively promoted UIC. From a university perspective, the policy instruments include different types of financial support and incentives mechanisms, adjustments of regulatory framework conditions and scientists' career schemes, as well as soft programs and activities for enhancing networking and collaboration (OECD, 2019). Adjustments to the university landscape in terms of mergers have also been applied as a means to enhance efficiency and improve research performance (Aula & Tienari, 2011; Liu et al., 2019). This is assumed to improve the capacity for UIC. To promote UIC from a firm-perspective, the direct policy instruments include different funding schemes for firms' collaboration with universities on innovation (such as knowledge coupons and research and innovation networks). In addition, indirect policy instruments include research and development (R&D) tax credits and subsidy schemes for small and medium size firms' hiring of university graduates (the latter has primarily been introduced as a job-generating activity to reduce unemployment among new graduates).

Restructuring the university landscape as a means to enhance UIC

For several decades, Denmark has used a combination of funding schemes, regulatory framework adjustments and targeted mobility and collaboration initiatives to enhance UIC. However, in the mid-'00s, the Danish government introduced a new and more fundamental structural policy intervention that adhered to the empirical observation that larger universities are better equipped for engaging in UIC (Davey et al., 2018). Effective from 2007, a large reform of the Danish university system reduced the number of universities from 12 to 8, and at the same time integrated 9 public research institutions into the universities. For Aalborg University, this lead to a merger with the Danish Building Research Institute (SBI) in 2007. The purpose of the reform was to strengthen the universities in order to achieve a closer collaboration with industry on innovation, while at the same time creating synergies in research and teaching, and enhancing the capabilities for attracting EU funding. The reform was supplemented by a change in the structure of the basic public funding of universities, making it more directly linked to the quality of activities (Ministry of Science, Technology and Innovation, 2009).

As a response to the policy attention and changes in the structure of funding, Danish universities' strategies are becoming increasingly focused on reaching actively out to firms and society. However, despite the increased focus on strengthening UIC on innovation, survey data do not show a clear pattern of a substantially increased proportion of innovative firms with university collaboration.

The role of regional settings in UIC

Despite being a small country, the eight universities in Denmark are located in different types of regions. The regional settings differ in terms of industry structure, population density and size, social capital, general economic conditions and access to infrastructure.

Of the eight universities in Denmark after the 2007-reform, four are located in the capital city of Copenhagen, and a fifth university, Roskilde University, is located only 30 kilometres away from Copenhagen in the neighbouring Zealand Region. The remaining three universities are located in three different administrative regions in the mid and western part of Denmark: the University of Southern Denmark belongs to the Southern Denmark Region; Aarhus University is located in the Central Denmark Region; and with its location in the North Denmark Region, Aalborg University is the most distant university from Copenhagen.

Table 2.1. Background – overview of the Danish Universities 2018

	Est.	*Scientific staff, FTE*	*Student population*	*Basic research funding mill. DKK*	*External funding mill. DKK*
Copenhagen University	1479	4,856	38,324	2,989	3,054
Aarhus University	1928	4,009	33,112	1,893	2,130
University of Southern Denmark	1966	1,936	22,257	883	759
Aalborg University	1974	1,999	20,397	813	640
CBS	1917	588	14,854	313	133
DTU/Technical University of Denmark	1829	3,359	11,538	1,602	2,171
Roskilde University	1972	448	7,907	252	86
It University of Copenhagen	1999	160	1,949	102	38

Sources: Universities Denmark and the universities' webpages.

The geographical characterisation of Danish universities has become more complicated in recent years as most universities have campuses in several areas of the country, either as purposely established or as a result of the above-mentioned mergers.

As the above illustrates, universities are not uniform entities: they differ in not only in size, age, academic scope, and local embeddedness, but also in e.g. access to funding, quality, and external focus. As a result, universities operate under different conditions, have different opportunities, and meet different demands for contributing to innovation through collaboration with industry. A well-known finding in the innovation literature is that collaboration on innovation both demands resources and brings in resources from the collaborating partners (Laursen & Salter, 2006). Therefore, the apparent differences in resources between the Danish universities (see Table 2.1) affect the universities' conditions for collaboration. For example, The Technical University of Denmark (DTU) received twice the amount of basic state funding for research than Aalborg University (AAU) in 2018. Despite only having 41% more

students than AAU within the technical and natural sciences, DTU had a close to four times higher number of full-time equivalent research staff within technical and natural sciences.[2]

The local industry structure and wider characteristics of firms also matters for UIC. Previous studies have shown that the likelihood of collaborating with a university depends on a set of firm specific factors, such as R&D, size and industry (Laursen & Salter, 2004). Furthermore, studies have found that geographical proximity to universities influences the likelihood of firms' collaboration with these institutions (Broström, 2010; Pinto, Fernandez-Esquinas & Uyarra, 2015; Johnston & Huggins, 2016; Drejer & Østergaard, 2017). The regional differences are quite large in Denmark and they affect the number of geographically proximate firms with the characteristics that are associated with a high propensity to collaborate with a university. In the Copenhagen region, 36% of the population aged 25–34 years had a university bachelor's or master's degree in 2018. The industry structure was specialised in services, particularly ICT, finance and insurance and was characterised by a relatively high number of large firms. In comparison, only 17% of the population aged 25–34 years had a university bachelor's or master's degree in the North Denmark region and the industry structure was specialised in manufacturing, construction and primary sector with a relatively high number of small firms.[3]

When it comes to the choice of a specific university as a collaboration partner, additional factors include the perceived quality of the university (Laursen et al., 2011) and employee-driven relations between the firm and the university (Drejer & Østergaard, 2017). Given the differences in the regional settings and the associated differences in opportunities for UIC, the policies aimed at enhancing UIC may have influenced universities in different ways.

Data

This chapter applies research and innovation survey data on firms' collaboration on innovation with the eight universities in Denmark to map the extent of collaboration with AAU, as well as to analyse the characteristics of the firms that collaborate with AAU. The survey data cover the period 2009-2018 drawing on nine partly overlapping waves of data collection each covering firms' innovation activities over a three-year period (i.e. from 2007-2009 to 2016-2018). In the tables and figures shown in the following sections, only the final years of the three-year periods surveyed are indicated.

The research and innovation survey was carried out annually until 2016, while no survey was carried out in 2017. Furthermore, after 2016, several questions in the survey were altered, rendering the findings from the 2018 survey only partially comparable with the findings from previous surveys.

The Danish research and innovation survey is mandatory, and approximately 5,000 firms are sampled for each round of the survey. The innovation part of the survey follows a common European Union Community Innovation Survey methodology. However, the Danish survey is unique in its exploration of UIC, because it since 2008 has included questions on which specific Danish university or universities, firms have collaborated with. Because the data from 2008 are subject to uncertainty, the period explored in this chapter is limited to 2009-2016/2018, with some caution also applied to the interpretations of findings for 2018.

The survey data is combined with detailed employer-employee linked register data from Statistics Denmark. This allows us to give a more detailed characterisation of the university-collaborating firms and

[2] Source: Universities Denmark's statistical resources.
[3] Source: StatBank Denmark, Statistics Denmark.

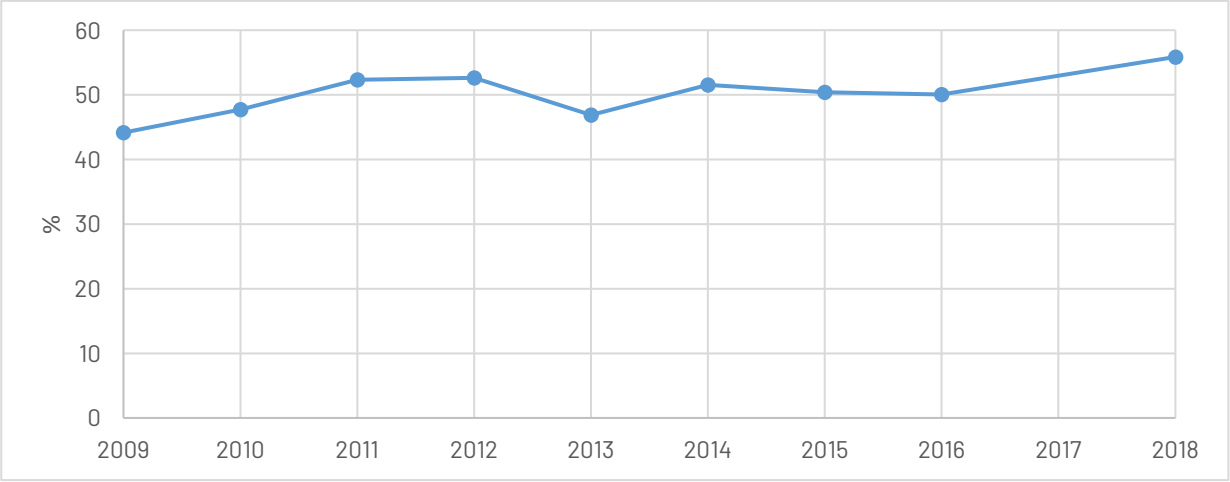
their employees. In addition to characterising the firms collaborating with Danish universities in general, as well as with each of the specific eight universities, the following sections also map the extent of the firms' collaboration with the universities. Data on collaboration is only available for firms that have reported innovation activities during the period surveyed. Innovation activity is defined as having introduced new or significantly improved products, manufacturing processes, operations, organisational structures or methods of marketing, or having had ongoing or abandoned innovation activities during the period covered by the survey. However, from 2013, the question on collaboration also includes collaboration on R&D activities in addition to innovation activities.

Please notice that for three of the eight universities, Roskilde University, CBS, and the It University, the number of collaborating firms is very low, which can cause large fluctuations across years, because a single or very few firms can affect the overall characteristics. Accordingly, in some figures, the universities with the largest fluctuations of extreme characteristics are left out in order to not distort the presentation. In these cases, figures including all eight universities can be found in Appendix 2.1.

Development in the overall pattern of university-industry collaboration on innovation

The pattern of UIC on innovation depends on the overall innovation activities of firms in Denmark. Figure 2.1 shows that the share of innovative firms in Denmark has been relatively stable between 2010 and 2016 with an indication of an increase in 2018. As mentioned above, an innovative firm is defined as a firm with innovation activities including ongoing or abandoned innovation projects.

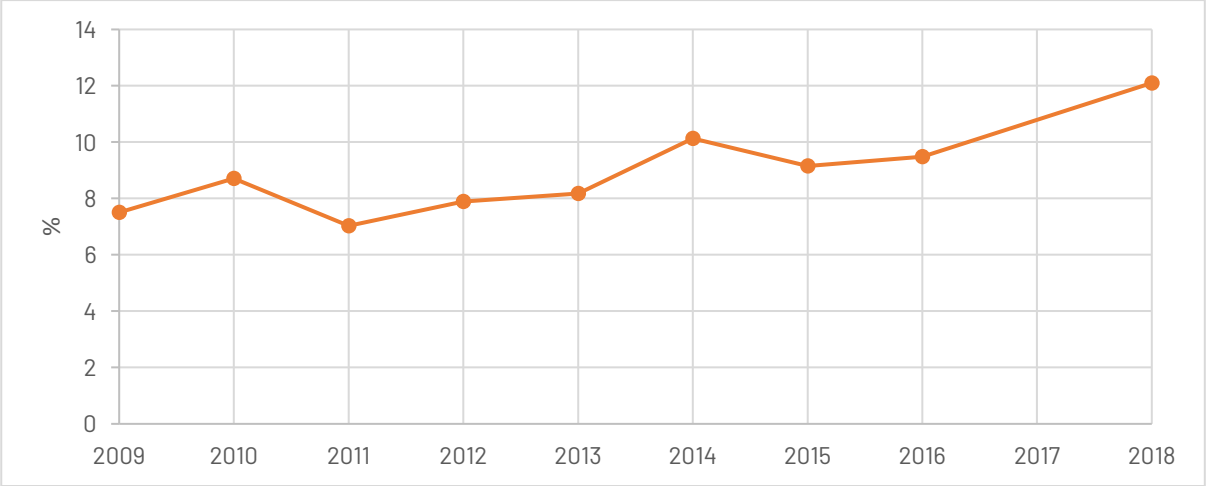
Figure 2.1. Share of innovative firms, 2009-2018



Source: Danish Research and Innovation Surveys for the period 2009-2018, Statistics Denmark. Please notice that there are no data available for 2017.

University-industry collaboration on innovation is increasing in Denmark. The share of innovative firms that collaborate with a Danish university has increased from 7% in 2011 to 12.1 % in 2018, see Figure 2.2. However, as noted in the above section, comparisons between 2018 and previous years should be made with caution.

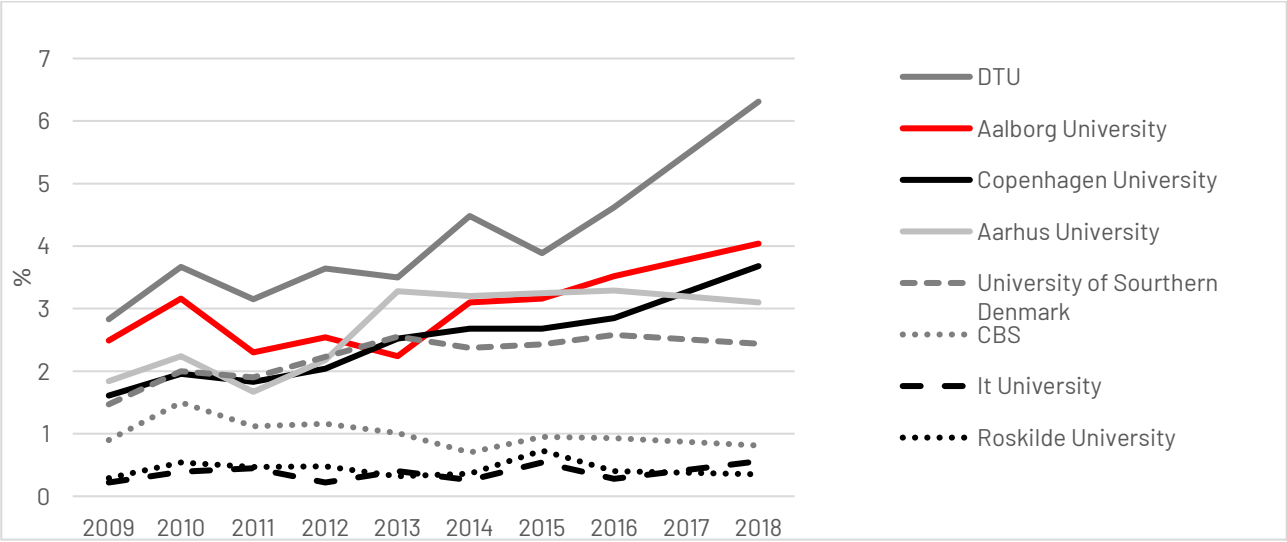
Figure 2.2. Share of innovative firms with university collaboration, 2009-2018



Source: Danish Research and Innovation Surveys for the period 2009-2018, Statistics Denmark. Please notice that there are no data available for 2017.

Despite a larger proportion of innovative companies in Denmark collaborating with Danish universities on innovation over time, there are differences acroos the eight universities. Figure 2.3 shows that the Danish universities can be divided into two groups: one group of universities who are increasingly engage in UIC, and another group of universities with whom a stagnant or declining share of innovative firms collaborate. AAU belongs to the lead group as AAU is the second most collaborative university in Denmark after DTU. The share of innovative firms in Denmark that collaborate with AAU has increased from 2.5% in 2009 to 4% in 2018.

Figure 2.3. Share of innovative firms that have collaborated with each of the Danish universities, 2009-2018

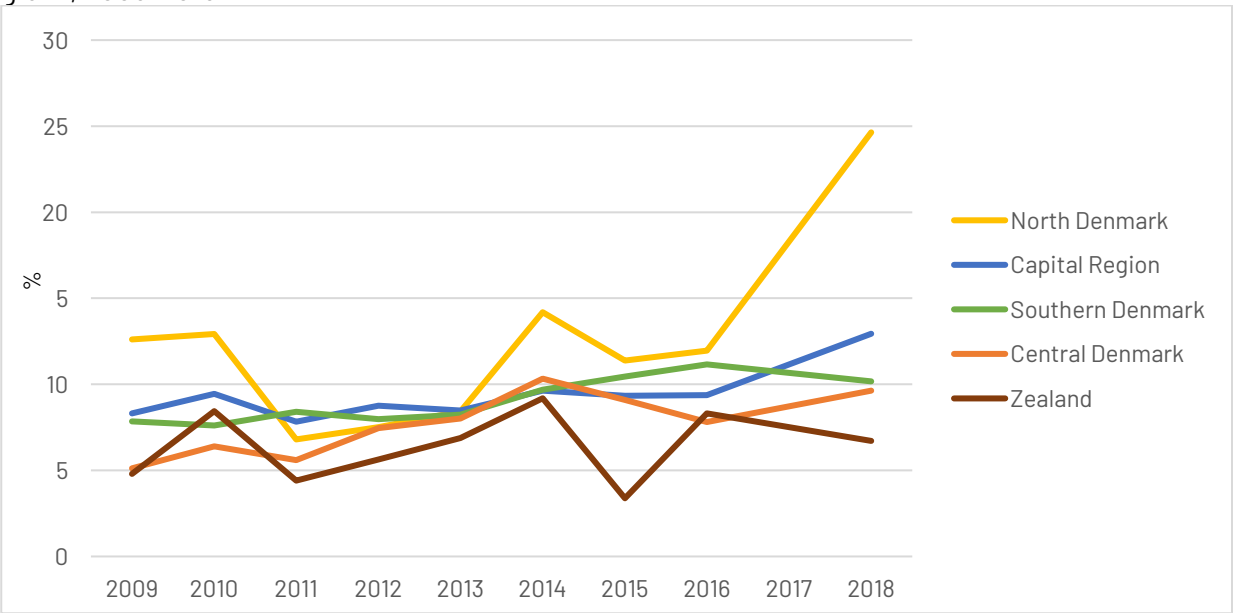


Source: Danish Research and Innovation Surveys for the period 2009-2018, Statistics Denmark. Please notice that there are no data available for 2017.

A regional perspective on university-industry collaboration on innovation

Figure 2.4 shows the differences in the share of innovative firms engaged in university collaboration on innovation among the Danish regions. The figure reveals that the share fluctuates over time in the different regions. Firms in North Denmark have the highest share of firms engaged in UIC. In 2018, the share of firms in North Denmark engaged in UIC has increased drastically, but, again, 2018 is not directly comparable with the previous years due to differences in the questionnaires. Since the North Denmark region has a lower proportion of firms with the characteristics that are associated with a high probability of UIC, the observed pattern is likely to be attributed to AAU's active approach to engagement with organizations in the region.

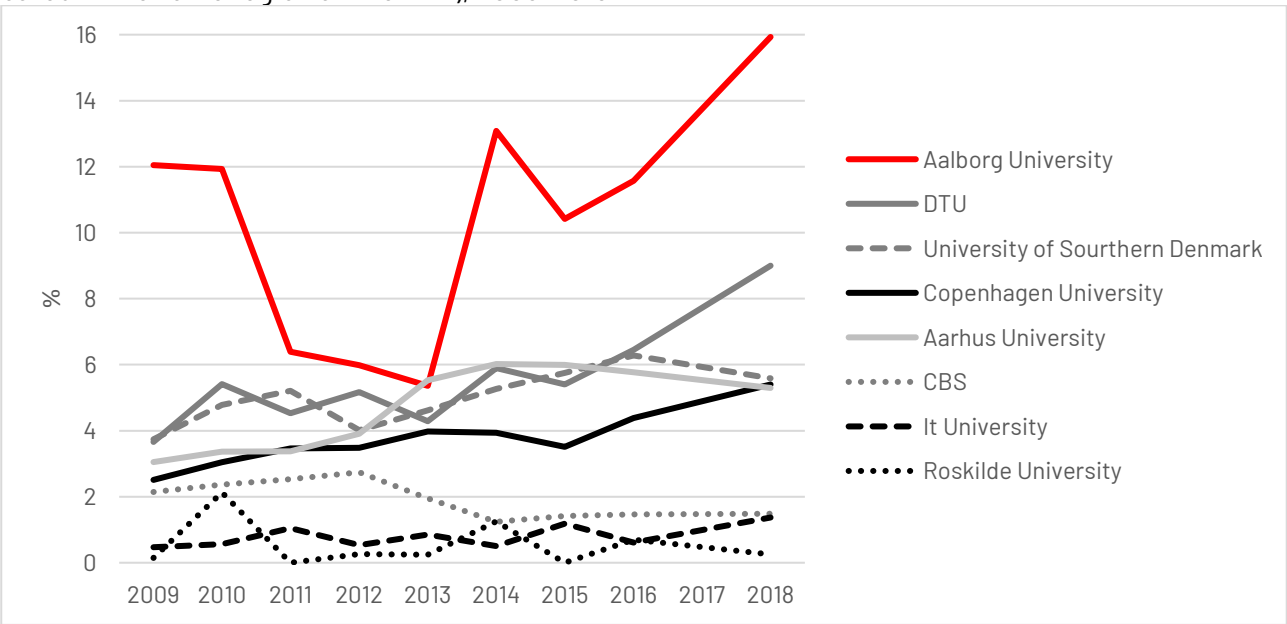
Figure 2.4. Share of innovative firms engaged in university collaboration in each of the Danish regions, 2009-2018



Source: Danish Research and Innovation Surveys for the period 2009-2018, Statistics Denmark. Please notice that there are no data available for 2017.

The literature on UIC typically finds that firms tend to collaborate with the local university. This is also true for Denmark. Figure 2.5 shows that firms in North Denmark have the highest degree of regional collaboration on innovation with a local university. That is, the firms in North Denmark are strongly oriented towards collaboration with AAU. There is some fluctuations in the level of collaboration with AAU over the period, and it is unclear why the share of innovative firms in North Denmark that collaborate with AAU drops in the period 2011 to 2013. A possible explanation could be that a slower recovery of firms in North Denmark after the financial crisis has affected the propensity to collaborate, since 2011 refers to collaboration between 2009 and 2011.

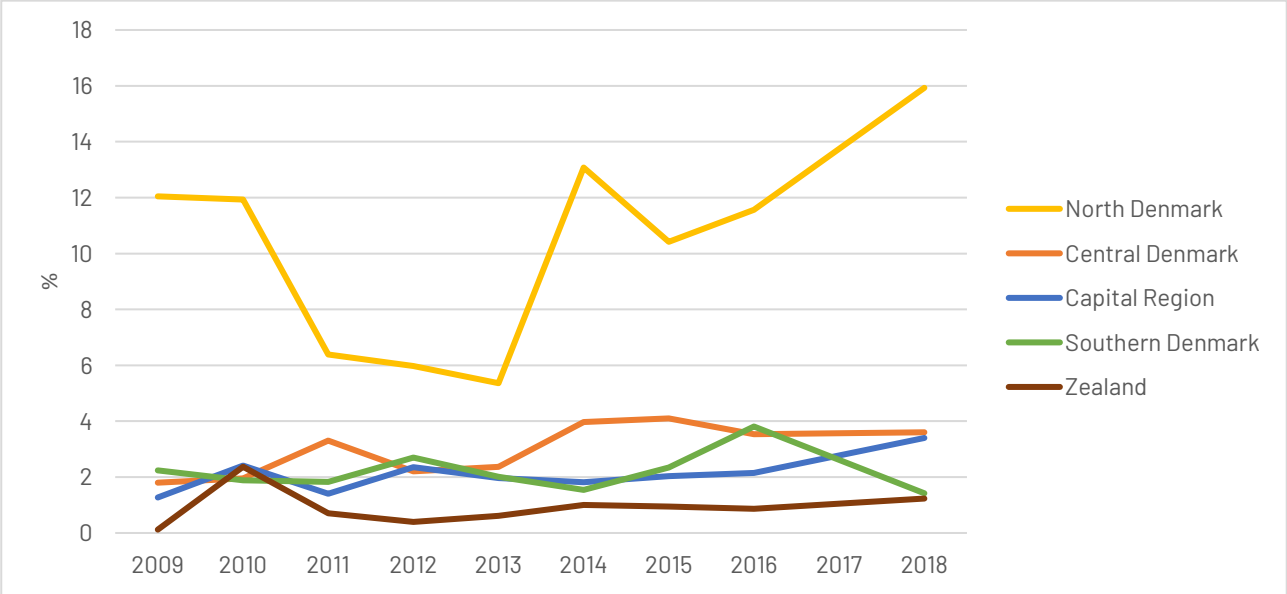
Figure 2.5. Share of innovative firms that have collaborated with a local university (i.e. university located in the same region as the firm), 2009-2018



Source: Danish Research and Innovation Surveys for the period 2009-2018, Statistics Denmark. Please notice that there are no data available for 2017.

The high level of local UIC collaboration in North Denmark does not imply that AAU is only focuses on the regional industry. Figure 2.6 reveals that AAU collaborates with firms both locally and nationally, as AAU does also collaborate with a relatively high share of innovative firms in the other Danish regions. For example, more firms in the Capital region collaborate with AAU than with CBS or the IT University, and more firms in the Zealand region collaborate with AAU than Roskilde University

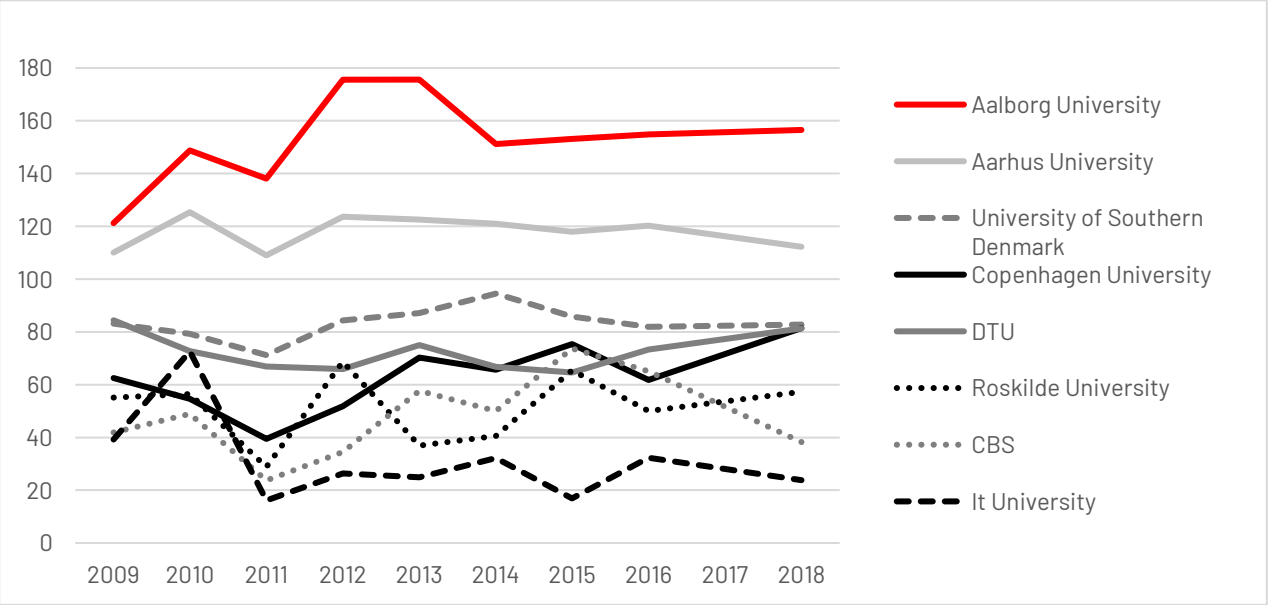
Figure 2.6. Share of innovative firms in each region that have collaborated with Aalborg University, 2009-2018



Source: Danish Research and Innovation Surveys for the period 2009-2018, Statistics Denmark. Please notice that there are no data available for 2017.

In accordance with the findings in Figure 2.6, AAU – despite being strongly rooted in the North Denmark region - is also the Danish university with the highest average travel time between the collaborating firm and the university's main campus (see Figure 2.7). Not surprisingly, it is the universities outside Copenhagen that have the highest average travel time measured in minutes to the firms that they collaborate with. That AAU has the highest average travel time during the entire period can be attributed to the peripheral location in North Denmark coupled with an openness towards collaboration with firms across the entire country. In comparison, the average travel time for DTU is between 65 and 84 minutes over the period 2009-2018, while the most 'regional' university is the It University of Copenhagen, which tends to collaborate with firms located less than half an hour away from the university campus.

Figure 2.7. Average travel time (minutes) between universities and the firms they have collaborated with, 2009-2018

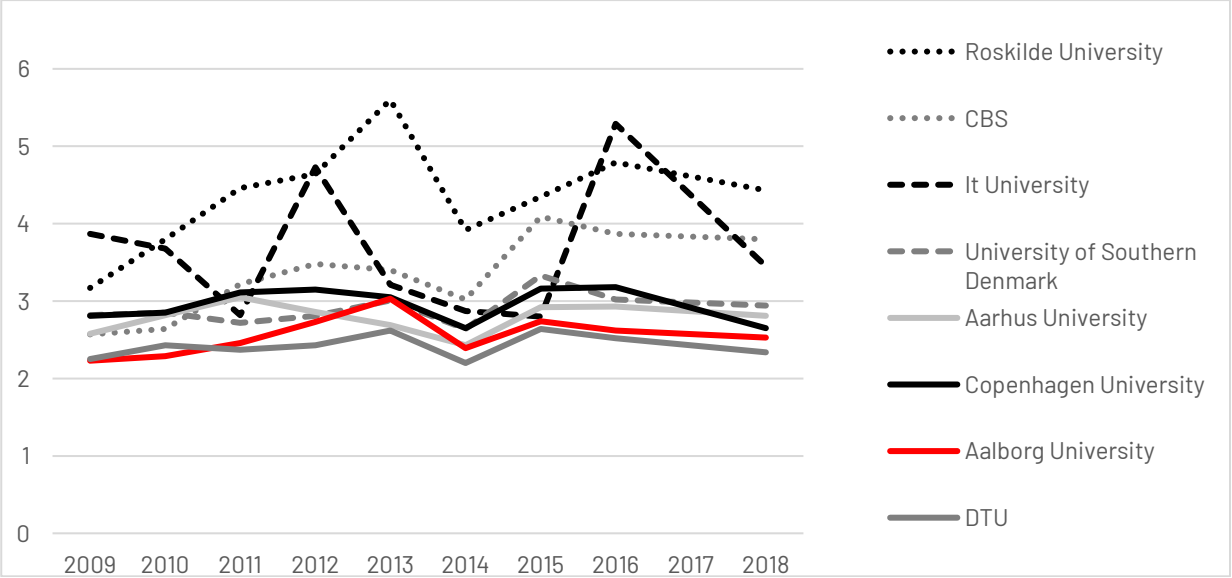


Source: Danish Research and Innovation Surveys for the period 2009-2018 and firm level register data, Statistics Denmark. Please notice that there are no data available for 2017.

Openness and university-industry collaboration on innovation

It is not uncommon that firms engaged in university collaboration collaborates with more than one university. Figure 2.8 shows that in particular the universities that relatively few firms collaborate with are engaged in collaborations with firms that collaborate with several other Danish universities. AAU and DTU, which are the two universities that most firms collaborate with, are on average involved in collaborations with firms that collaborate with a lower number of universities, the average fluctuating between two and three university partners for firms collaborating with AAU and DTU.

Figure 2.8. Average number of university partners



Source: Danish Research and Innovation Surveys for the period 2009-2018, Statistics Denmark. Please notice that there are no data available for 2017.

In accordance with the above, Table 2.2 shows that collaboration with DTU alone, followed by collaboration with AAU alone, is the most common 'combination of collaboration'. These are followed by collaborations with Aarhus University (AU) and University of Southern Denmark (SDU) alone, before collaboration with both AAU and DTU, the two major engineering-oriented universities in Denmark, appears as the fifth most frequent 'combination of collaboration'.

Table 2.2. The most frequent combinations of collaboration, 2016

Number of firms collaborating with the specific combination of universities (weighted)		
1	DTU alone	94
2	**Aalborg University alone**	**68**
3	Aarhus University alone	46
4	University of Southern Denmark alone	40
5	**Aalborg University +DTU**	**23**
6	**Aalborg University +Copenhagen University**	**22**
7	DTU+ Copenhagen University	20
8	**Aalborg University +Aarhus University**	**19**
9	Aarhus University + Copenhagen University	18
10	Aarhus University +DTU+ Copenhagen University	17

Source: Danish Research and Innovation Surveys for the period 2009-2018, Statistics Denmark.
Note: Because data from 2018 differ from previous years in several aspects, data from 2016 have been applied in the analysis of multiple university collaborations.

Focussing in AAU's collaborations, two thirds of the firms collaborating with AAU also collaborates with other Danish universities (see Table 2.3). DTU and AU are the universities, which firms collaborating with AAU most often also collaborates with. Whereas AAU and DTU share a common strength in engineering, the combination of collaborating with both AAU and AU may be a reflection of the geographical proximity between these two universities.

Table 2.3. Collaboration with AAU and other universities, 2016

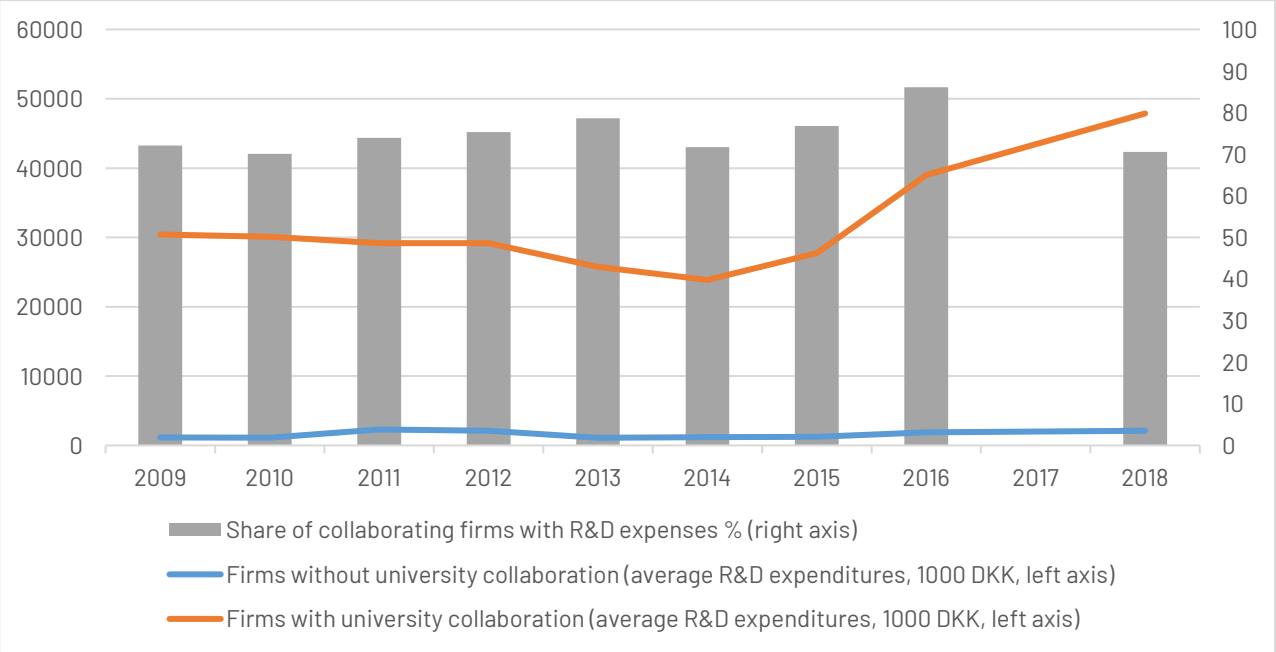
Share of all firms who collaborate with AAU, N (weighted) = 207	
AAU alone	32.96%
AAU together with other universities	67.04%
AAU+DTU	41.63%
AAU+ Aarhus University	38.96%
AAU+ University of Southern Denmark	29.38%
AAU+ Copenhagen University	27.44%
AAU+CBS	13.31%
AAU+ Roskilde University	5.72%
AAU+ It University	5.72%

Source: Danish Research and Innovation Surveys for the period 2009-2018, Statistics Denmark.
Note: The rows that show collaborations with AAU and other universities add to well above 100% because each row refers to cases where a firm collaborates with AAU and the specific other university, regardless of whether the firm also collaborates with other Danish universities at the same time.

Characteristics of firms with university collaboration on innovation

As mentioned above, previous studies have shown that firms' likelihood of collaborating with a university, among other factors, is strongly associated with its R&D activity (e.g. Laursen & Salter, 2004). Figure 2.9 reveals that this is also the case for Danish firms. Over the period 2009 and 2018, between 70 and 86 percent of the firms engaged in collaboration with a Danish university had R&D expenses, and the average R&D expenditures in firms engaged in university collaborations were considerably higher than the average R&D expenditures in firms that did not collaborate with university.

Figure 2.9. R&D activity and university-industry collaboration, 2009-2018

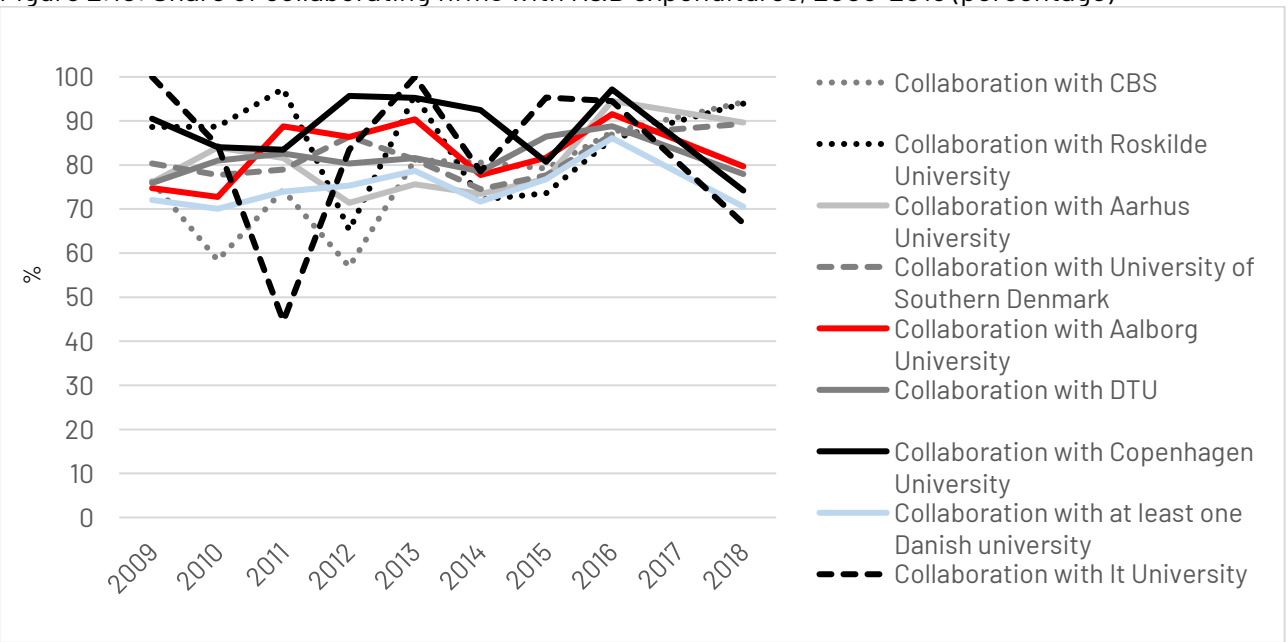


Source: Danish Research and Innovation Surveys for the period 2009-2018, Statistics Denmark. Please notice that there are no data available for 2017.

Turning to the individual universities, AAU does not differ from the other universities in terms of the share of collaborating firms with R&D activity (Figure 2.10). From 2009 to 2018, the share of firms collaborating with AAU that have R&D expenditures has increased from 76 percent to 80 percent, but there have been some fluctuations over the period.

The relatively large fluctuations for CBS, Roskilde University and the It University of Copenhagen can be ascribed the low number of collaboration firms, which allows few firms to affect the overall share.

Figure 2.10. Share of collaborating firms with R&D expenditures, 2009-2018 (percentage)

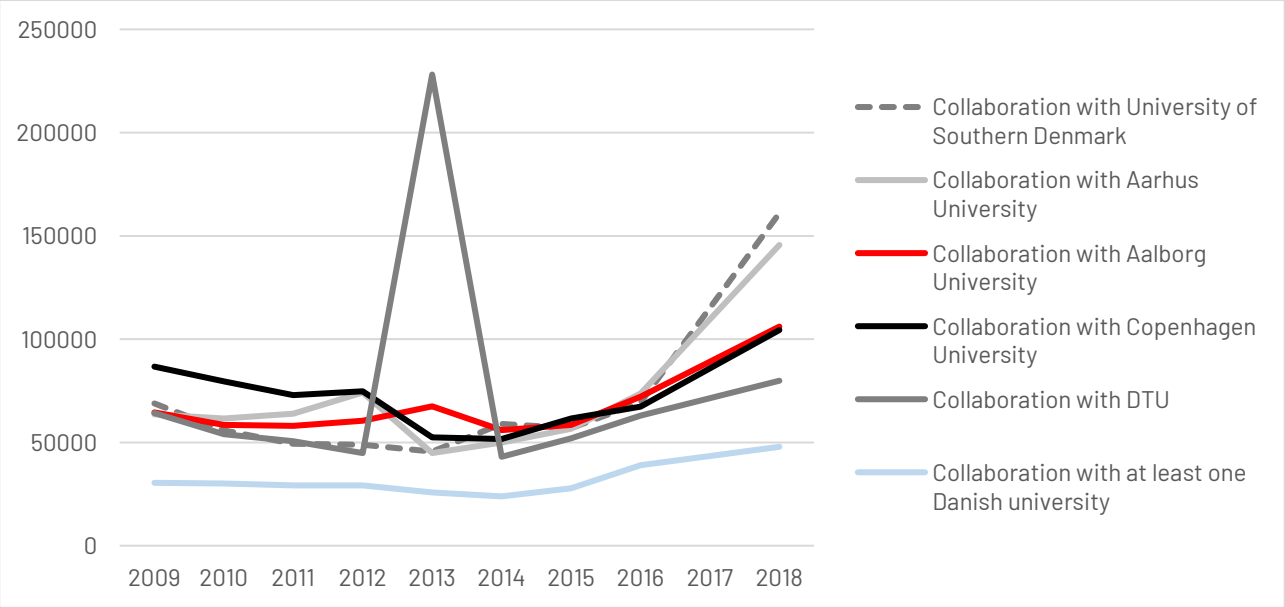


Source: Danish Research and Innovation Surveys for the period 2009-2018, Statistics Denmark. Please notice that there are no data available for 2017.

If we disregard 2018, where we see an increase in average R&D expenditures across the five universities that account for the majority of collaborations, the average R&D expenditures in firms collaborating with AAU has remained relatively stable (see Figure 2.11).

Figure 2.11 reveals an extremely high value for the average R&D expenditures in firms collaborating with DTU in 2013. This can be due to a single or few collaborations with the most R&D intensive firms in Denmark. It is well-known that the R&D expenditures in Denmark are heavily concentrated. For example, Novo Nordisk have higher R&D expenditures than the sum of the next ten firms on the list with the highest expenditures in Denmark.

Figure 2.11. Average R&D expenditures in firms with university collaborations 2009-2018, 1000 DKK (Excl. CBS, Roskilde University and IT University)

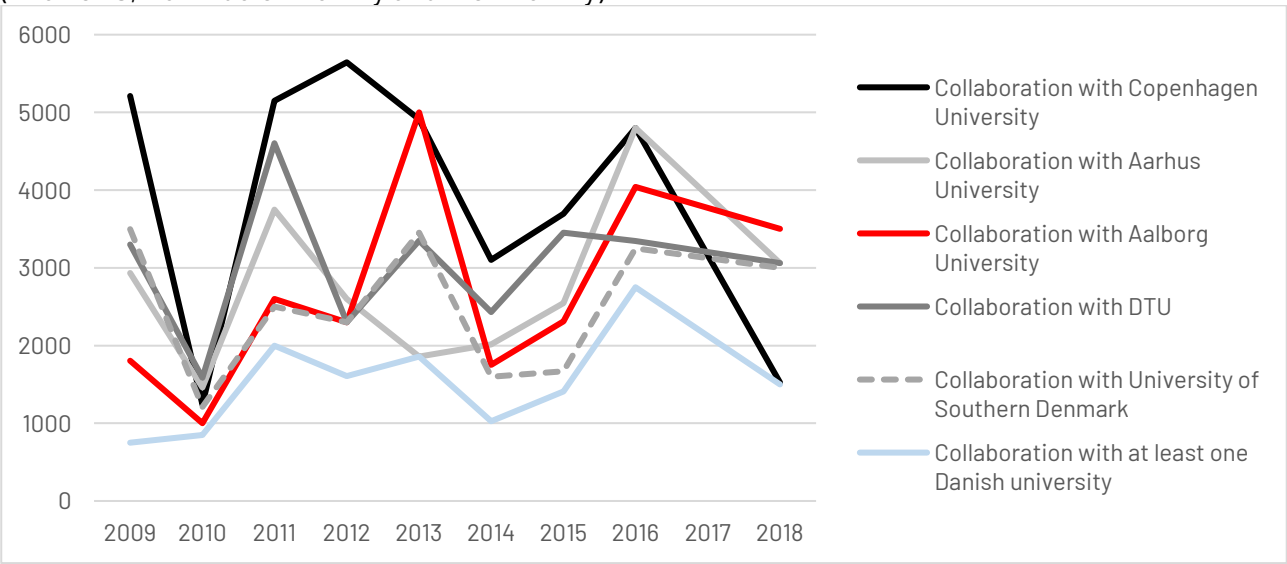


Source: Danish Research and Innovation Surveys for the period 2009-2018, Statistics Denmark. Please notice that there are no data available for 2017.
Note: CBS, Roskilde University and the IT University are excluded due to few observations which contributes to large fluctuations between years (se Appendix 2.1 for a figure including all universities).

The median values of R&D expenditures in firm with university collaborations, which are shown in Figure 2.12, are considerably lower than the average values shown in Figure 2.11. This reflects that relatively few, very large and R&D intensive firms are driving the high average values.

Although the median is not so sensitive to outliers because it expresses the level of R&D expenditures in the firm which is exactly in the middle of the distribution – i.e. there is an equal number firms with higher and lower R&D expenditures than the median – the median R&D expenditures are subject to considerable fluctuations. Disregarding these fluctuations, there does appear to be an increasing trend for the median R&D expenditures in firms collaborating with AAU. This means that the typical firm collaborating with AAU is over time devoting more resources to R&D.

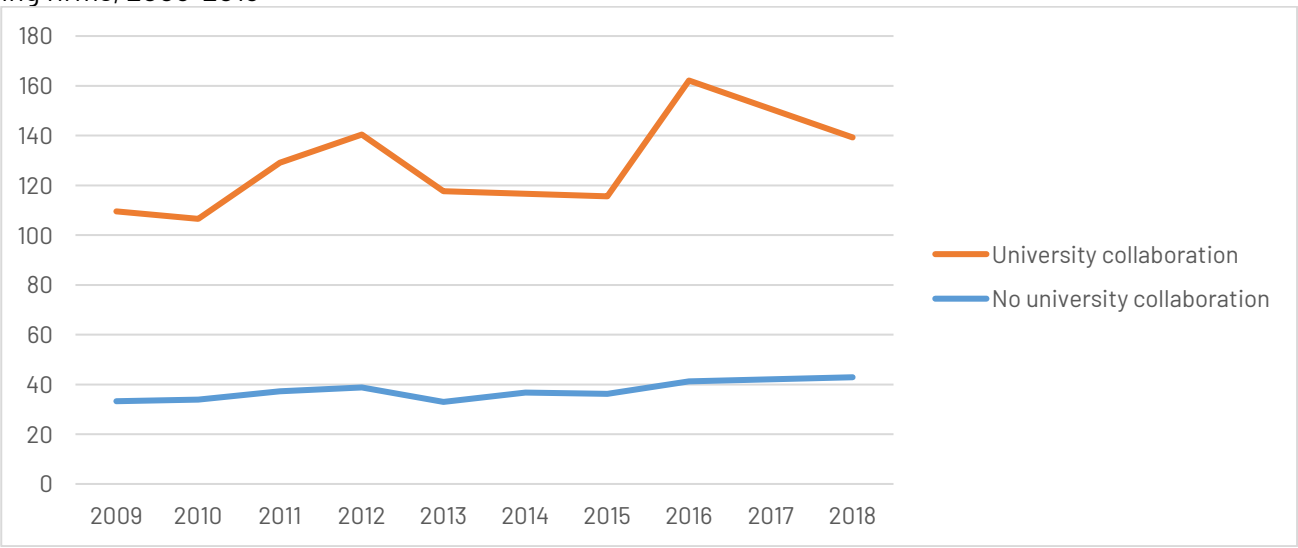
Figure 2.12. Median R&D expenditure in firms with university collaborations, 2009-2016, 1000 DKK (Excl. CBS, Roskilde University and It University)



Source: Danish Research and Innovation Surveys for the period 2009-2016, Statistics Denmark. Please notice that there are no data available for 2017.
Note: CBS, Roskilde University and the It University are excluded due to few observations which contributes to large fluctuations between years (se Appendix 2.1 for a figure including all universities).

Another characteristic of firms with collaborations with universities is that they are considerably larger than firms without university collaborations. As illustrated in Figure 2.13, the average number of Full-Time Equivalent employees in firms collaborating with universities has fluctuated between 107 and 162 between 2009 and 2018, whereas the corresponding average numbers for firms that do not collaborate with universities is 33 and 43.

Figure 2.13. Average number of Full-Time Equivalent employees in collaborating and non-collaborating firms, 2009-2018

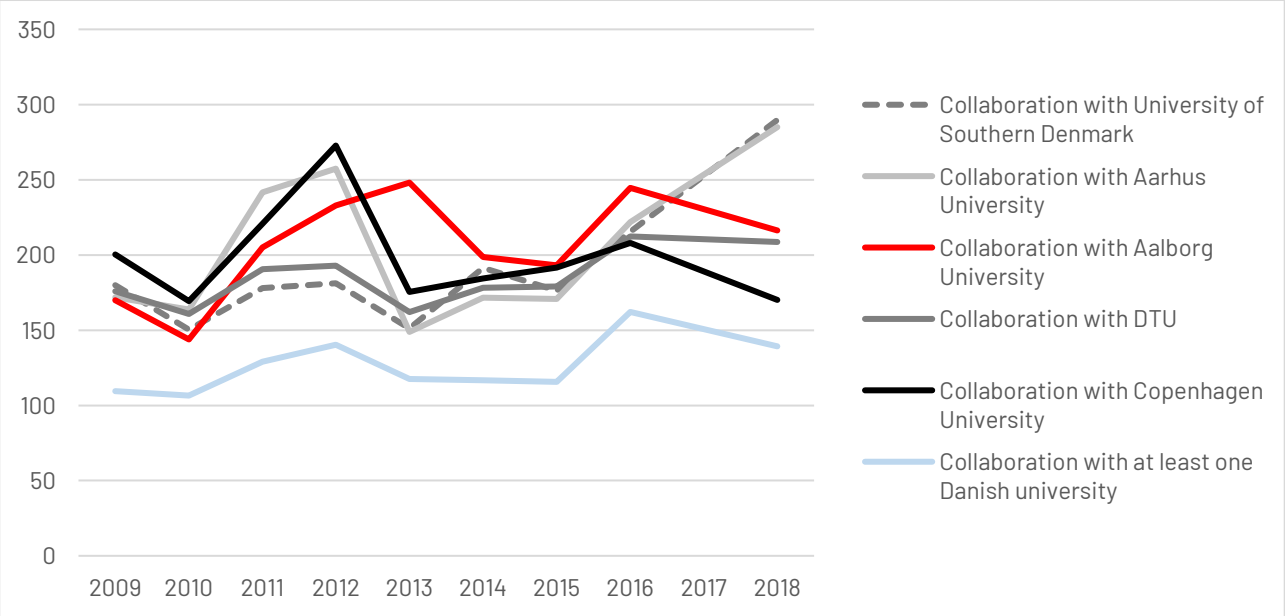


Source: Danish Research and Innovation Surveys for the period 2009-2018, and firm level register data, Statistics Denmark. Please notice that there are no data available for 2017.

Although AAU in its strategy *Knowledge for the World* emphasises how the university can support of the innovation capacity of small and medium-sized firms, neither the average (Figure 2.14) nor the median (Figure 2.15) size of firms collaborating with AAU stands out as being particular small compared to the other universities. Although fluctuating, the average size of the firms collaborating with AAU shows signs of an increasing trend. In 2009 the average number of Full-Time Equivalent employees in firms collaborating with AAU was 170, while the median was 23. In 2018 the corresponding numbers were 216 and 28.

As was the case for R&D expenditures, the fact that the median is considerably lower than the average reflects that the majority of collaborating firms are in fact small, and it is a minority of very large firms that drives up the average.

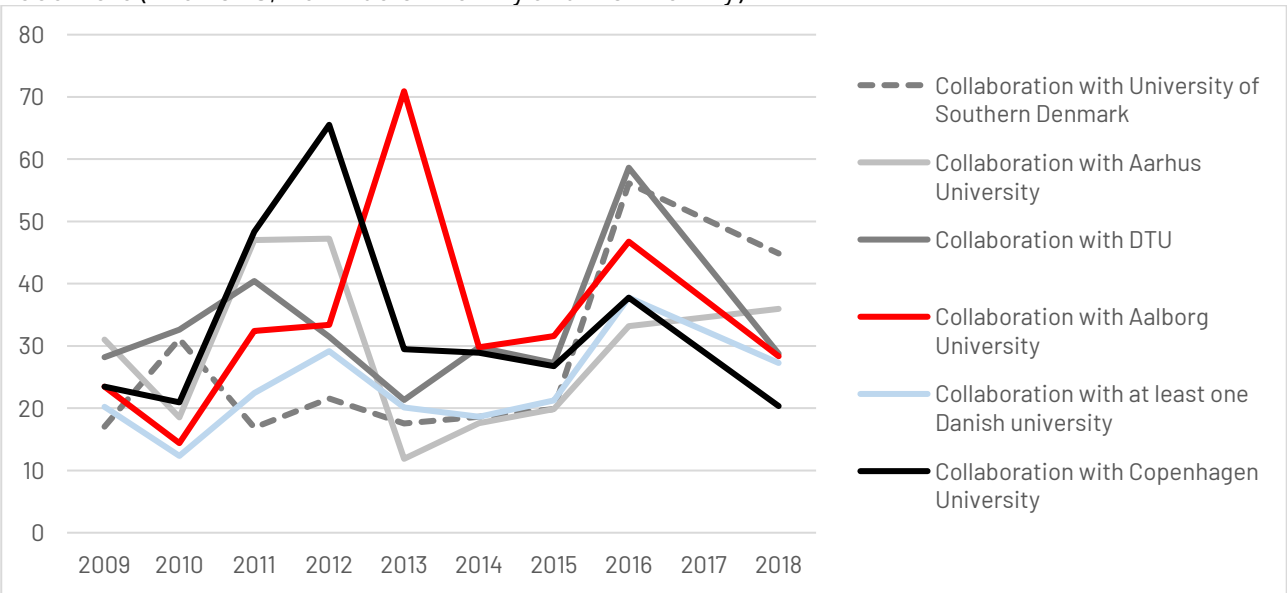
Figure 2.14. Average number of Full-Time Equivalent employees in firms with university collaboration, 2009-2018 (Excl. CBS, Roskilde University and It University)



Source: Danish Research and Innovation Surveys for the period 2009-2018, and firm level register data, Statistics Denmark. Please notice that there are no data available for 2017.
Note: CBS, Roskilde University and the It University are excluded due to few observations which contributes to large fluctuations between years (se Appendix 2.1 for a figure including all universities).

It is noticeable that the average number of Full-Time Equivalent employees in firms that collaborate with at least one Danish university is lower than the average number in firms that collaborate with any of the specific universities. This can be explained by the fact that it is the large firms that are most prone to collaborate with several universities. This means that the same larger firms are included in the calculations of the average sizes of collaborating firms for several universities – but each firm is only included once in the calculation of the average size of firms that collaborate with at least one university.

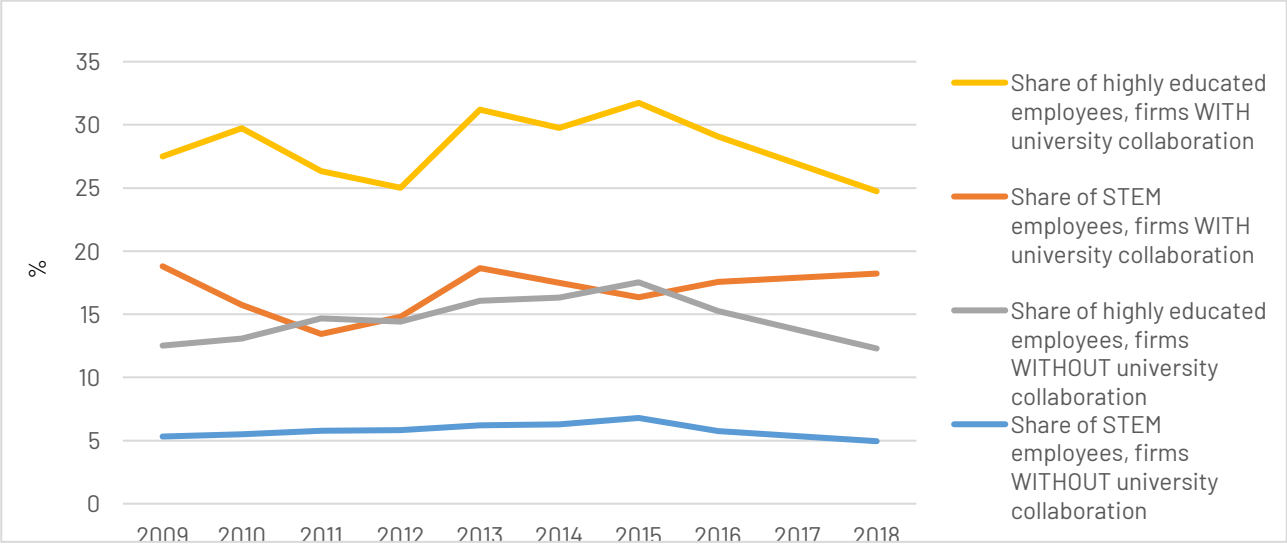
Figure 2.15. Median number of Full-Time Equivalent employees in firms with university collaboration, 2009-2018 (Excl. CBS, Roskilde University and It University)



Source: Danish Research and Innovation Surveys for the period 2009-2018, and firm level register data, Statistics Denmark. Please notice that there are no data available for 2017.
Note: CBS, Roskilde University and the It University are excluded due to few observations which contributes to large fluctuations between years (se Appendix 2.1 for a figure including all universities).

It is not just the average number of employees, but also the composition of the workforce that separates firms that collaborate with universities from those who do not engage in collaboration with universities. Figure 2.16 shows that both the share of highly educated employees, and the share of STEM-employees – i.e. employees with a degree in Science, Technology, Engineering, or Mathematics – is considerably higher in firms with university collaboration than in firms without university collaboration.

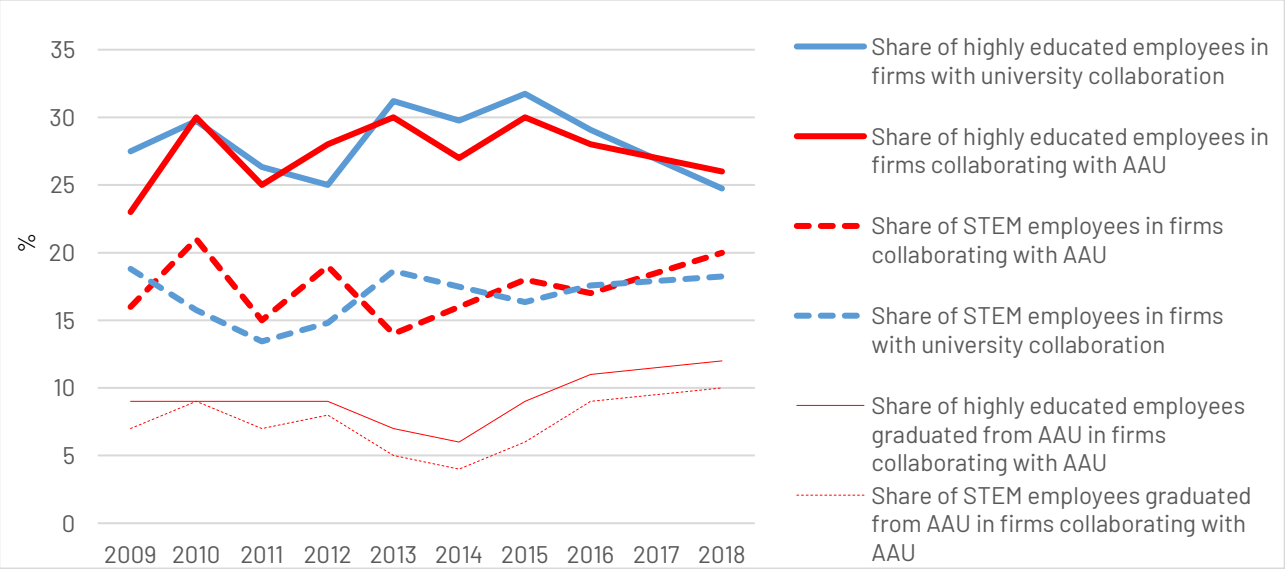
Figure 2.16. Shares of highly educated and STEM employees in collaborating and non-collaborating firms, 2009-2018



Source: Danish Research and Innovation Surveys for the period 2009-2018, as well as firm and individual level register data, Statistics Denmark. Please notice that there are no data available for 2017.

As illustrated in Figure 2.17, the composition of the workforce in firms that collaborate with AAU resembles that of firms collaborating with universities in general in Denmark. Figure 2.17 also reveals that a considerable proportion of the highly educated employees in firms collaborating with AAU are graduates from AAU – and most of these have a STEM degree,

Figure 2.17. Employee composition in firms collaborating with AAU compared to other firms with university collaboration, 2009-2018



Source: Danish Research and Innovation Surveys for the period 2009-2018, as well as firm and individual level register data, Statistics Denmark. Please notice that there are no data available for 2017.

Criscuolo et al. (2018), in an analysis based om UK firms, found that collaborating with a university as the only partner type is very rare. This is also the case for Danish firms. 95% of the firms that collaborate with AAU, also collaborates on innovation with other partner types. For all firms that collaborate with a Danish university, the share is 94%.

Suppliers, which generally are the most common collaboration partners on innovation, are also most often collaboration partners in firms that collaborate with universities. In addition to suppliers, it is in particular private customers and consultancies that are the other partner types.

When comparing AAU to the other universities, firms that collaborate with AAU are in particular more likely to also collaborate with their competitors than firms collaborating with other universities.

Table 2.4. Collaboration with other types of partners, 2016

	Collaborates with AAU	*Collaborates with a Danish university*
Suppliers	76.83	72.11
Public customers	48.52	44.97
Private customers	69.35	65.72
Competitors	43.43	30.74
GTS Institutes	47.24	44.39
Consultancies	61.68	55.73
Firms in other industries	36.77	32.51
Public research institutions	38.54	35.02
Public service providers	27.86	20.95
Other public collaboration partners	25.15	15.79

Source: Danish Research and Innovation Surveys for 2016, Statistics Denmark.

Changes in collaborating firms' characteristics over time

As a final step in the analysis we have entered the main characterizing features of firms collaborating with universities in Denmark into a logistic regression in order to explore, first, which factors remain associated with collaboration with AAU specifically when we control for the other factors, and second, whether this association changes over time.

Table 2.5 presents a summary of the findings of a regression analysis of the factors associated with collaboration with AAU in 2016. The model findings confirm that geographical proximity, the share of employees graduated from AAU, collaboration with other universities, and R&D expenditures are associated with firms' collaboration with AAU in a statistically highly significant manner. Furthermore, firms with 250 or more employees are more likely to collaborate with AAU than small firms, while firms in non-knowledge intensive service industries are less likely to collaborate with AAU than firms in other industries. However, this latter finding is only weakly statistically significant.

Table 2.5. Regression analysis: Which factors matter for firms' collaboration on innovation with AAU?

Dependent variable: Collaboration with AAU on innovation 2016	*Sign and significance*
Travel time	**- - -**
Share of employees graduated from AAU	**+ + +**
Share of employees graduated from other universities	Not significant
Collaboration with other universities	**+ + +**
R&D	**+ + +**
Size: +250 employees (benchmark: less than 10 employees)	**+ +**
Size: 100-249 employees	Not significant
Size: 50-99 employees	Not significant
Size: 10-49 employees	Not significant
Industry: Non-knowledge intensive services (benchmark: other industries)	Not significant
Industry: Knowledge intensive services	**-**
Industry: Low-tech manufacturing	Not significant
Industry: High-tech manufacturing	Not significant
Concordance	91.3
N (weighted)	5861.75

Source: Danish Research and Innovation Surveys for 2016, as well as firm and individual level register data, Statistics Denmark.
Note: +++ indicates a positive coefficient that is significant at the 0.01 level; ++ indicates a positive coefficient that is significant at the 0.05 level; --- indicates a negative coefficient that is significant at the 0.01 level; - indicates a negative coefficient that is significant at the 0.1 level. The concordance shows that the model is better to predict the outcome than the 50/50 percent baseline.

Table 2.6 summarises the findings of the analyses exploring the extent to which there have been any changes between 2009 and 2016 in which firm-level factors are associated with collaboration with AAU.

Over time, having R&D expenditures has become more strongly associated with firms' collaboration with AAU. Having employees who are graduates from AAU has also become more strongly associated with collaboration with AAU. Geographical proximity between a firm and AAU has, on the other hand, become less strongly associated with collaboration with AAU.

Table 2.6. Regression analysis: Change in factors' importance between 2009 and 2016?

Dependent variable: Collaboration with AAU 2009 and/or 2016. Interactions with time dummies are used for assessing changes in the importance of factors over time	*Change in importance*
Travel time	Decreased importance in 2016 compared to 2009
Share of employees graduated from AAU	Increased importance in 2016 compared to 2009
Share of employees graduated from other universities	No significant importance
Collaboration with other universities	No change in importance over time
R&D	Increased importance in 2016 compared to 2009
Size	No change in importance over time
Industry: Non-knowledge intensive services (benchmark: other industries)	No change in importance over time
Industry: Knowledge intensive services	No significant importance
Industry: Low-tech manufacturing	No significant importance
Industry: High-tech manufacturing	Decreased importance in 2016 compared to 2009

Source: Danish Research and Innovation Surveys for the periods 2009 and 2016, as well as firm and individual level register data, Statistics Denmark.

Who collaborates with Danish universities – and Aalborg University in particular?

The mappings and analyses presented in this chapter shows that the findings from the international academic literature on what characterizes firms involved in UIC on innovation also applies for Denmark – and these characteristics are relatively stable over time.

Thus, R&D activity is a distinctive characteristic of firms' collaboration with universities in Denmark: the vast majority of firms engaged in UIC have R&D activities, and there appears to be a tendency of R&D expenditures becoming more important over time. Firm size also matters for university-collaboration. Although the typical firm collaborating with a university – in accordance with the business structure in Denmark - is quite small, the average size of the collaborating firm is by Danish standards quite large.

The employee composition in firms also matters for their likelihood of engaging in UIC, the share of highly educated employees as well as the share of STEM employees being considerably higher in firms that collaborate with universities than in non-collaborating firms.

Furthermore, geographical proximity between a firm and university also plays a role for the likelihood of collaboration.

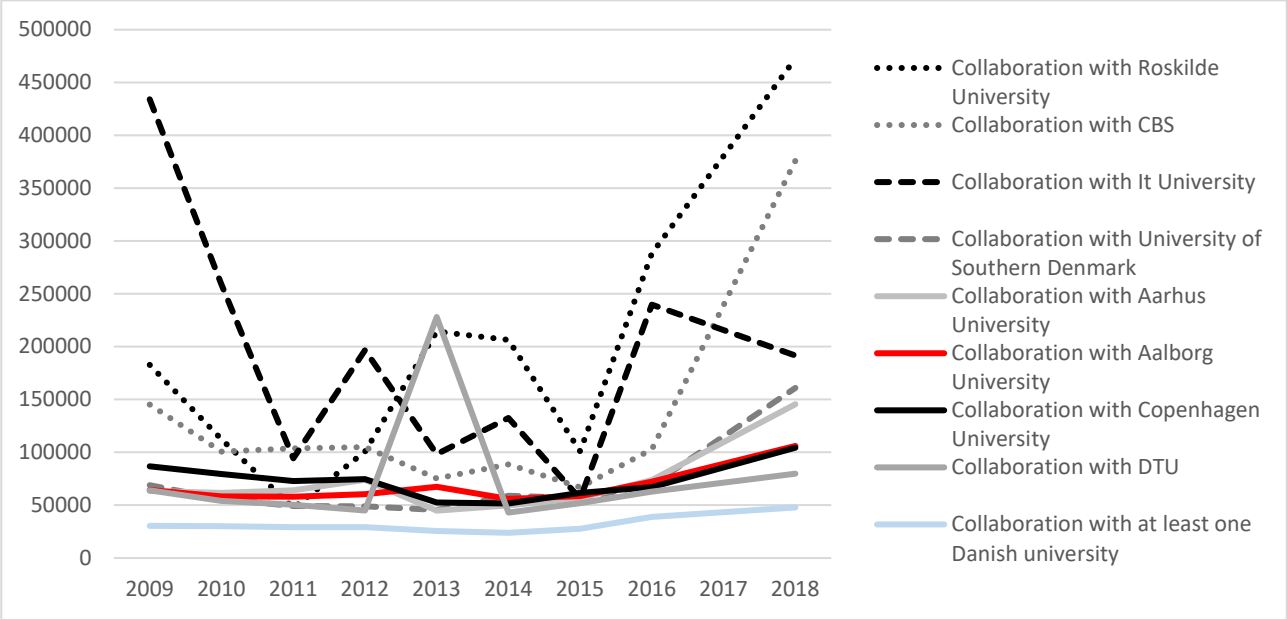
Based on the above, there are no signs of fundamental changes in UIC patterns in Denmark in the wake of the structural reform of the university sector in 2007. Although there is a weak tendency for an increase in the share of firms involved in UIC, it is still the same types of firms that collaborate.

Looking and the individual Danish universities, the two main technically oriented universities in Denmark, DTU and AAU, tend to dominate in UIC. However, there has also been an increase in the proportion of innovative firms that collaborate with Copenhagen University, Aarhus University and the University of Southern Denmark.

Zooming in on AAU, the firms that collaborate with this university basically share the same characteristics as firms collaborating with other universities in Denmark. AAU does stand out by being by far the most locally rooted university in the sense that firms in the North Denmark Region engaged in university collaboration tend to collaborate with AAU. Even though there is also a tendency for local collaborations in the other regions, it cannot match strength of this tendency in North Denmark. It is, however, remarkable that AAU combines this strong regional embeddedness with an ability for also collaborating over geographical distances, as illustrated by the shares of innovative firms in other regions collaborating with AAU, and AAU being the university in Denmark with the highest average travel time between the collaboration firms and AAU's main campus. Finally, collaboration with AAU is also strongly associated with the collaborating firms having employees who are graduates from AAU.

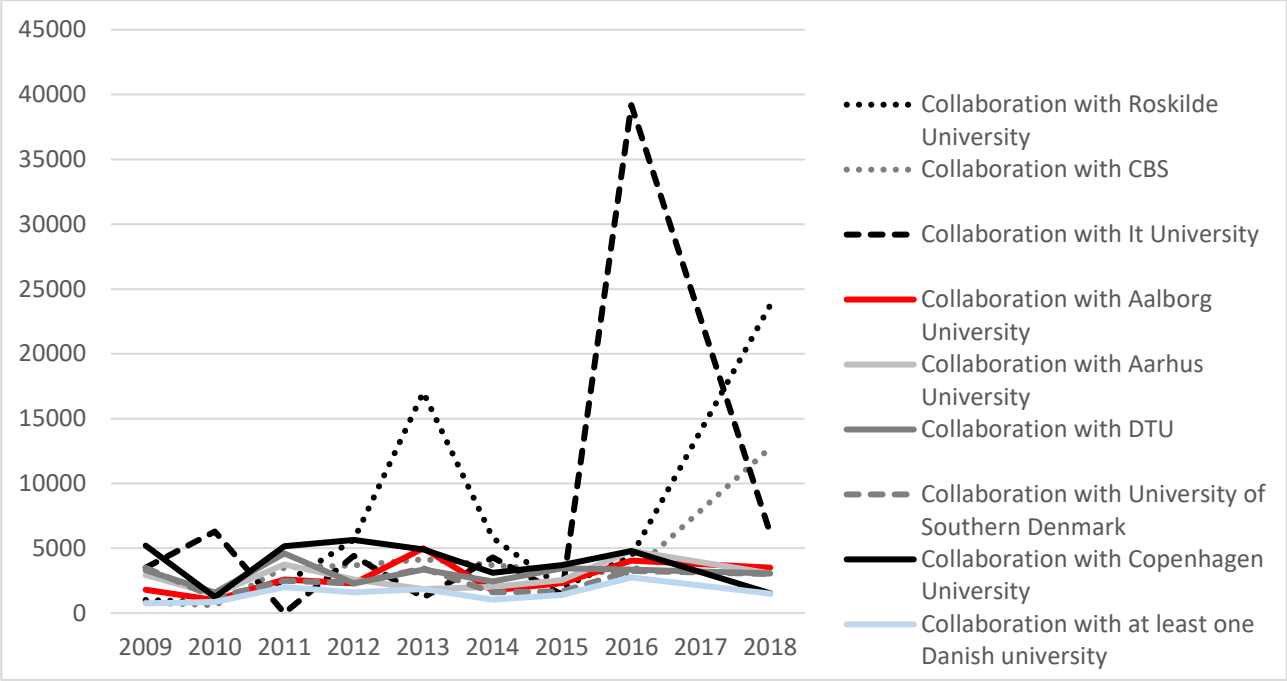
Appendix 2.1

Figure A2.1. Average R&D expenditures in firms with university collaborations, 2009-2018, 1000 DKK



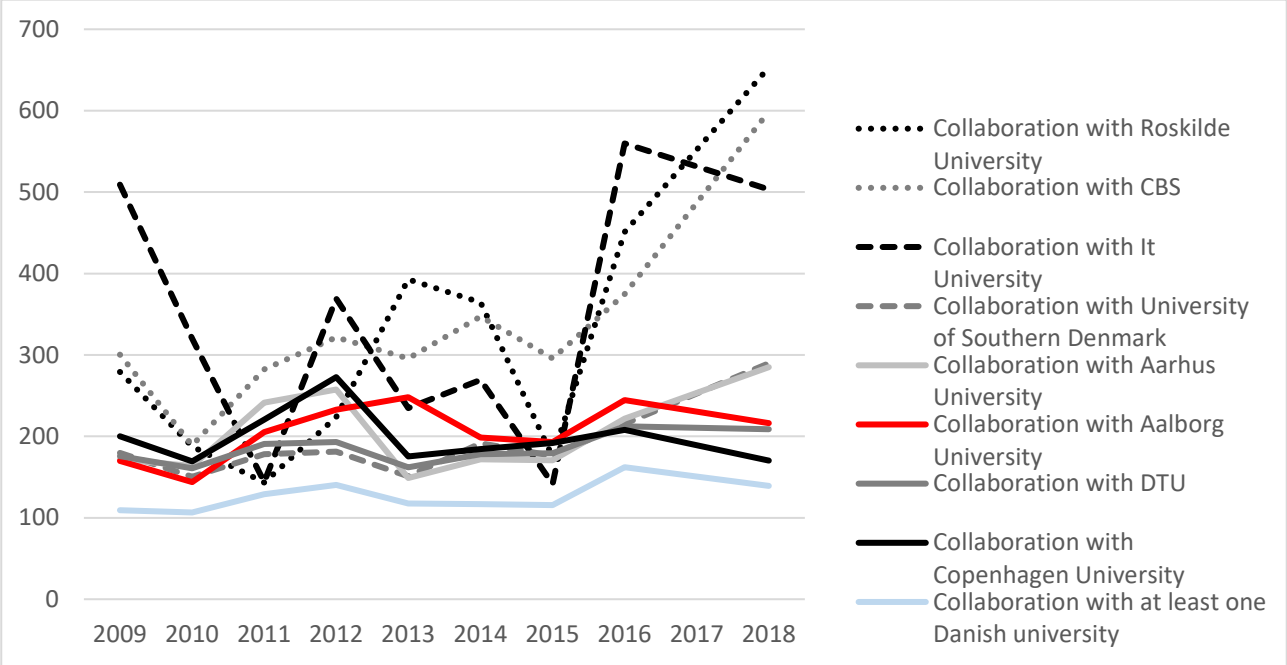
Source: Danish Research and Innovation Surveys for the period 2009-2018, Statistics Denmark. Please notice that there are no data available for 2017.

Figure A2.2. Median R&D expenditure in firms with university collaborations, 2009-2018, 1000 DKK



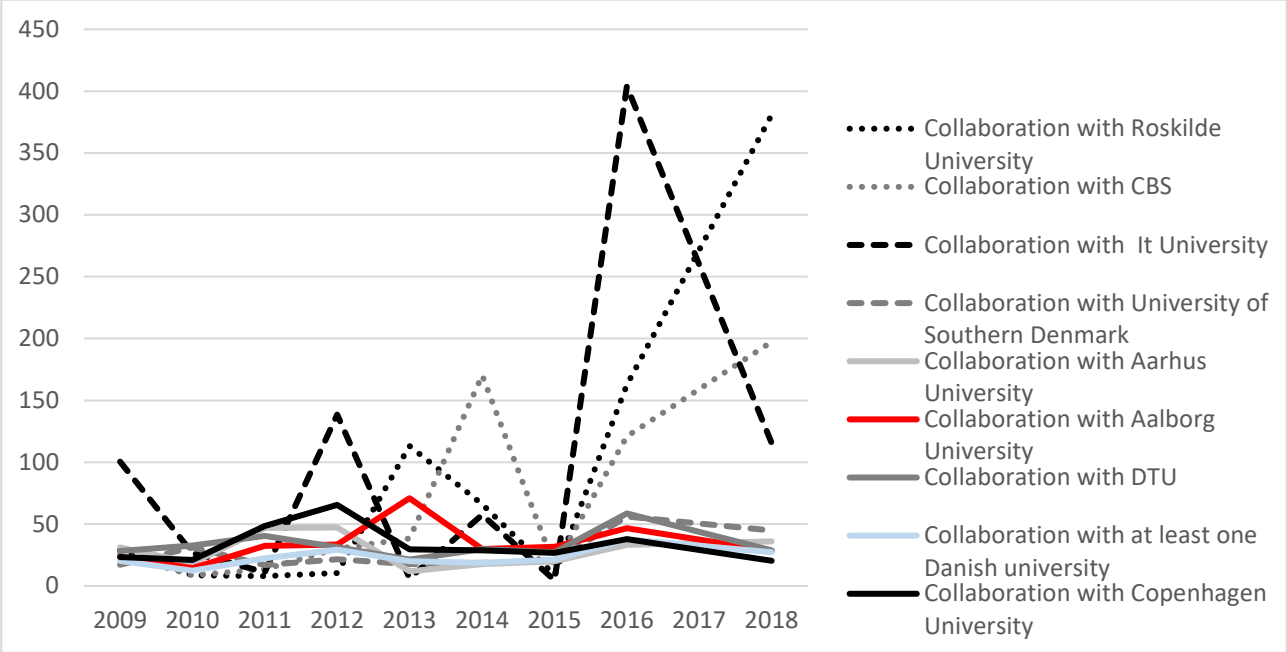
Source: Danish Research and Innovation Surveys for the period 2009-2018, Statistics Denmark. Please notice that there are no data available for 2017.

Figure A2.3. Average number of full-time equivalent employees in firms with university collaborations, 2009-2018



Source: Danish Research and Innovation Surveys for the period 2009-2018, as well as firm level register data, Statistics Denmark. Please notice that there are no data available for 2017.

Figure A2.4. Median number of full-time equivalent employees in firms with university collaborations, 2009-2018



Source: Danish Research and Innovation Surveys for the period 2009-2018, as well as firm level register data, Statistics Denmark. Please notice that there are no data available for 2017.

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Chapter 3. Successful university collaboration: insights from nine case studies of collaboration with Aalborg University

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Introduction

This chapter provides qualitative insights that supplement the quantitative mapping and analysis of effects of private companies' collaborations on innovation with Aalborg University (AAU). Whereas the quantitative analyses can measure the extent of the collaborations, identify characteristics of collaborating firms, and seek to isolate company-level effects of such collaborations, the qualitative inquiries can provide information about the processes through which knowledge generated at AAU is further developed and transformed into innovation or other forms of value creation in the collaborating organisations.

The qualitative analysis presented in this chapter reports findings from seven case studies of private companies' and two cases of public sector organisations' collaborations with AAU – seen through the lenses of these organisations.

In addition to providing insights into how collaborations are established and organised, what collaborations focus on and which outcomes they generate, as well as possible challenges associated with the collaborations, the analysis highlights the characteristics of what the collaborating organisations perceive as successful collaborations with a university in general and AAU specifically.

Overview of interviewed organisations

Chapter 2's mapping of private-sector companies that have collaborated with AAU on innovation provides an elaborate description of the types of companies that the university collaborate with. The main distinctive characteristics of companies collaborating with AAU are that:

- The companies can be found across Denmark. Despite a large proportion of innovative companies in North Denmark collaborating with AAU, AAU is also the Danish university with the longest average travel time between the collaborating companies and the main university campus.
- The companies are likely to carry out R&D activities.
- The companies are more likely to have highly educated employees (bachelor's degree or above) than non-collaborating companies – and often employees who are graduates from AAU.
- The companies are larger than non-collaborating firms.

The knowledge about public-sector organisations collaborating with AAU is more limited. Based on formal collaboration contracts registered by AAU Innovation, the most frequent public collaboration partners are ministries and agencies, regional authorities, municipalities, and educational institutions. Among regions, North Denmark Region accounts for more than two thirds of the collaborative agreements with AAU, whereas Aalborg Municipality accounts for more than one third of AAU's collaborative agreements with municipalities.

Table 3.1 below presents an overview of the nine public and private sector organisations that have been interviewed.

Table 3.1. Overview of case companies

	Industry	*# employees*	*Location*	*Main type(s) of collaboration*	*Collaborating department at AAU*
PRIVATE_A	ICT	500+	Nationwide representation, interview at workplace in North Denmark	Formal and informal research projects, including PhD projects. Student projects	Electronic Systems
PRIVATE_B	Construction materials and other manufacturing	500+	Zealand	Joint research projects – externally funded PhD and post doc. Projects (fully and partially funded) Student projects, interns	Chemistry and Bioscience
PRIVATE_C	Experimental development	Less than 100	Southern Denmark	Industrial PhD Joint research projects – externally funded	Energy Technology
PRIVATE_D	Consulting engineering activities	100-500	Capital Region	Industrial PhD Student assistants	Built Environment
PRIVATE_E	Construction materials and other manufacturing	100-500	Central Denmark	Industrial PhD and industrial post.docs. Students – project work	Chemistry and Bioscience Planning
PRIVATE_F	Distribution of electricity	500+	Zealand	PhD (industrial) Joint research projects – externally funded Student projects	Built Environment
PRIVATE_G	Water collection, purification and supply	100-500	Central Denmark	Joint research projects – externally funded (previously also EU projects) Purchase of research services Student projects, internships	Built Environment Communication and Psychology
PUBLIC_A	Special schools for disabled persons	100-500	North Denmark	Joint research projects – funded by company	Culture and Learning
PUBLIC_B	Cultural education	100-500	Central Denmark	Joint research projects externally funded	Culture and Learning

Seven of the nine interviewed organisations are private sector companies. One of these is a utility company, PRIVATE_G, which became privatised approximately ten years ago. The seven private companies have between 60 and 1000+ employees, with only two having less than 200 employees.[4] Accordingly, the interviewed companies are relatively large, also compared to the average size of companies collaborating with AAU. Possible explanations for this bias are discussed in more detail in the following section on Method. In accordance with the characteristics of companies collaborating with AAU, the interviewed companies are dispersed across Denmark, with only one company/workplace being located in North Denmark.[5] Most companies have an R&D department, and they all have university graduates among their employees. Their industry coverage is broad, including both service and manufacturing.

The two interviewed public sector organisations are related to education, although in different ways. One is organisationally associated to regional authorities, whereas the other is a municipal organisation. As such, they represent the most frequent types of AAU's public sector collaboration partners.

Method

The interviewed organisations were identified through a mini-survey carried out by Statistics Denmark ultimo 2019. This survey covered *i)* private companies, which in Statistics Denmark's latest surveys on research and innovation activities in the business sector[6] had reported collaboration on innovation with AAU; and *ii)* public sector workplaces, which in COI's[7] survey from 2016 on innovation in the public sector had reported collaboration on innovation with an institution of higher education or research.[8]

Based on the mini-survey, Statistics Denmark provided a list of 20 organisations that in the survey confirmed to have collaborated with AAU within the last five years leading up to the time of the survey, and consented to be contacted by researchers from AAU for a follow-up interview. Of these, 12 were contacted with an inquiry for an interview. Two organisations did not respond to this inquiry, and one public sector organisation in the healthcare sector, which had initially sent a positive response to the interview request, became unavailable for an interview due to the COVID-19 outbreak.

The above-described approach to identifying potential case organisation was chosen to avoid 'the usual suspect' identification of cases, as well as to allow for including cases that might not be registered in AAU Innovation's contract database due to the nature of the collaboration being mainly informal. Because large companies with R&D activities are overrepresented in the surveys on research and innovation activities in the business sector, this implies a bias towards this type of companies in the case company selection. However, as documented by Østergaard & Drejer (2020), relatively large R&D active companies are more likely to be recurring or persistent collaborators with universities, AAU included. As such, these companies account for the majority of collaborations with AAU. An additional

[4] In order to ensure the anonymity of the case companies, firm sizes are only shown in broad categories in Table 3.1.
[5] Other interviewed companies have offices/facilities in North Denmark, but in these cases, the interviews were carried out with people located in the main offices outside North Denmark, as it was employees from these premises that were engaged in the collaborations.
[6] This is an annual survey carried out by Statistics Denmark. For further information, see https://www.dst.dk/da/Statistik/emner/uddannelse-og-viden/forskning-udvikling-og-innovation/innovation (available in Danish only).
[7] COI is the Danish centre for public innovation, see https://www.coi.dk/en/.
[8] Unlike the private sector survey on innovation, the public sector survey does not include information about collaboration with specific universities.

potential bias in the selection of case companies is the self-selection among the potential interviewees in the mini-survey, where company-representatives who consider collaboration with AAU to play a significant role for the companies' innovation activities, are likely to be more inclined to make themselves available for an interview, compared to representatives from companies, where the collaboration is found to be less important/having provided little value to the companies. The interviewees may thus be more positively inclined towards AAU than the average collaborator.

There were only five public sector organisations in the list provided by Statistics Denmark, of which two were interviewed.[9] In COI's survey-questionnaire to the public sector organisations, universities were classified together with university colleges and other knowledge institutions into one category of collaboration partner types. Therefore, little is known about whether the low number of potential case organisations on the list provided by Statistics Denmark was caused by a low frequency of collaborations with universities in the public sector. However, it is likely that e.g. university colleges are a more preferred collaboration partner by public sector organisations relative to universities. A supplementary, and much more straightforward explanation for the low number of public sector organisations on Statistics Denmark's list, is that the number of respondents in COI's survey was substantially lower than was the case for Statistics Denmark's survey aimed at the business sector.

During the period March – May 2020, interviews were carried out with representatives from nine organisations that have collaborated with AAU during the last five years. The majority of the collaborations were still ongoing. Due to the COVID-19 lockdown, the interviews were carried out via video meetings, or, in a single case, as a telephone interview. With the exception of the telephone interview, both researchers involved in the analysis participated in the interviews. The interviewees were typically directors of either technology, R&D, development or equivalent.

The eight video interviews were recorded and subsequently documented in detailed case summaries. The case summaries were prepared in two steps: first, based on the recording, a chronological in-depth summary was prepared. Second, the summary was structured according to main topics. Due to technical issues, the telephone interview was not recorded, but based on detailed notes, a summary was produced immediately after the interview was completed. In the analysis, a colour coding was applied to the summaries based on relevance to the following seven themes:

1. Types of collaboration
2. Initiating the collaboration/finding the right partner
3. Content of collaboration
4. Output and how/the extent to which it is utilised (outcomes)
5. Challenges in different stages of the collaboration
6. AAU as a collaboration partner
7. Characteristics of a good collaboration

These seven themes are reflected in the structure of the reporting of the insights from case studies in the following sections.

[9] Four of these five organisations received a request for an interview. One was not approached because it was the exact same type of organisation as one of the organisations that was interviewed, thus not adding any additional variety to the group of interviewed organisations.

Insights from the case studies

AAU as a collaboration partner

The general perception among the interviewees is that they collaborate with individual researchers or research groups, and not with a university. This the is in accordance with Johnston & Huggins (2018, p. 16), who find that companies assess the credibility of potential university collaboration partners based on whether these possess comprehensive knowledge and expertise of a given field, and have the ability to apply this knowledge and expertise to the companies' needs – and this credibility is assessed at the individual rather than at the institutional level. However, whereas some have not paid much attention to whether collaborations with researchers from AAU are different from collaborations with researchers from other universities, others do identify some features where AAU distinguishes itself from other Danish universities.

PRIVATE_A only collaborates with AAU on research projects,[10] and is therefore not able to compare collaboration with AAU to other university collaborations. However, seen over time, PRIVATE_A finds that AAU has become more focused on use-value, and has moved away from an elitist research attitude where 'we do research because we can – and if it turns out to be useful that is great, but of secondary importance'. This is backed by PRIVATE_C, who perceives AAU as being more 'down to earth' in the collaboration, and focused on applied research, compared to others, who tend to be more high-flying and 'nice-to-know'-oriented.

PRIVATE_G finds that AAU is more accustomed to collaborating with companies compared to other Danish universities, who are described as not knowing how to go about it, and are lacking the commercial understanding.

The literature on university-industry collaboration finds that companies tend to collaborate with a local university, which indicates that geographical proximity might help overcome barriers to collaboration (Broström, 2010; Laursen et al., 2011; D'Este et al., 2013). However, researchers – as well as students – from AAU are by PRIVATE_B described as being less geographically bound than what is the case for Copenhagen-based universities, and one interviewee describes how it seems as if everything outside the Greater Copenhagen Area appears to be closer to Aalborg than to Copenhagen.

PRIVATE_B also praises AAU's researchers for being aware – and honest – about the limitations to their areas of expertise, and not afraid to refer to others instead of just saying 'of course we can do that', and then not being able to deliver when push comes to shove. This makes AAU an attractive collaboration partner for PRIVATE_B, because the company trusts that when the university engages in a collaboration, then the topic is actually within the researchers' areas of expertise. Furthermore, although AAU's administration, in several cases is perceived as being a somewhat rigid, PRIVATE_B finds that AAU is relatively easy to deal with in relation to acquiring pre-emptive rights to technological outputs.

Types of collaboration

Perkmann & Salter (2012) emphasise that companies are more likely to have a productive partnership with a university if they thoroughly consider how to structure the collaboration. In particular, the firms should consider the desired – or necessary – time horizon of a collaboration, as well as how the inherent conflicting interest between researchers, who have an interest in making findings public through academic publications, and companies, who typically aspire a proprietary and confidential access to find-

[10] The company does have some collaboration with other Danish universities, but this is collaboration is related to recruitment and career development.

ings, can be managed. Different ways of organising are suitable for short- versus long-time collaborations, and the same goes for open access versus proprietary collaboration projects. The collaborations studied in the present chapter are mainly of a relatively long-term nature, and, at least from the collaborating private companies' perspective, there is in most cases an aim to ensure some degree of proprietary access or pre-emptive rights to the knowledge produced in the collaboration.

The types of collaboration found in the various cases differ across the following six categories. In most cases, a mix of collaborative approaches are found, either originating from a central research project or evolving in parallel without explicit overlaps.

i. Students – project work, internships (student assistants)
ii. PhD and postdoc projects (including industrial PhD and postdoc projects funded by Innovation Fund Denmark)
iii. Joint research projects – externally funded
iv. Joint research projects – funded by the company (not necessarily transfer of funds between company and AAU)
v. Different advisory functions – both ways
vi. Purchase of research services – not explicitly covered in the interviews.

The involvement of students in both project work and internships is often connected to other collaborative activities with AAU. In the case of PRIVATE_E, an industrial PhD student organises the collaboration with students on semester projects.

Student projects are often involved in exploring or solving practical challenges in the organisations with a more limited framing than research projects. In the case of PRIVATE_B, the extent of student involvement varies from providing a case for the students to solve, to having them engage more actively with the organisation.

It is generally acknowledged that the companies 'give more than they get' when it comes to student projects. Several of the interviewed companies regard the involvement in student activities as a part of the social responsibility of the organisation. As emphasized by PRIVATE_B, their involvement in these activities are founded in an organisational philosophy of wanting to be a part of educating young people. In general, this is viewed as an important aspect of engagements with students.

Nonetheless, PRIVATE_B highlights that student projects can provide value for both parties, and PRIVATE_G finds that the presence of the students provides the organisation with a very dynamic environment. In addition, several regard student projects or the hiring of student assistants as ideal ways of initiating a recruitment process, as this provides the companies with an insight into the competencies – professional as well as social - of the students (PRIVATE_D, PRIVATE_A and PRIVATE_G). Both PRIVATE_B and PRIVATE_D emphasize the value added from providing the university with lecturers, supervisors and external examiners. This entry point is highlighted as a good approach to getting an insight into the students' priorities and provide the company with a head start in their recruitment processes. Furthermore, the connection with the students adds to the general awareness of the company in the student community, as well as to a deeper insight in the surrounding society into what the company actually works with.

AAU students are by the companies perceived as independent and easy to integrate in the organisation. Several respondents emphasize that these competencies are developed through the AAU PBL model,

which provides the students with competencies and a flexibility not found to the same extent in students from other universities.

In contrast to the student activities, the involvement in research projects is regarded as a more equal relation for all parties involved. For the majority of joint research projects, external funding is needed, especially for the small- and medium sized companies. While the organisations would perhaps be going for the same results without external funding, this would not leave room for deeper explorations and sharing knowledge through scientific publications. Without the external funding, there would not have been the time to follow the same formal requirements from the university. This is e.g. the case of PRIVATE_C, where the majority of activities are concerned with developing new technology for which externally funded collaborative projects are pivotal. Externally funded projects concern both industrial PhDs, post docs and joint research projects.

As with student projects, industrial PhD projects are often regarded as a central aspect of the recruitment process of the organisation in e.g. PRIVATE_D, PRIVATE_B and PRIVATE_E. In the case of PRIVATE_B, PhD students manage their own project but are often also connected to other projects in the organisation. From the point of view of the firm, this ensures that the PhD students' resources are focused on their project rather than being used to 'put out fires' around the organisation.

The public sector organisation PUBLIC_A represents a case of a joint research project funded by internal development funds within the organisation, because they did not find that they had enough time to apply and wait for external funding. In PRIVATE_B, the majority of projects are funded internally, especially PhDs, as the challenges of constructing collaborative contracts and discussing IP rights are then reduced. However, in most cases where external funding is not essential for the research projects, it is still considered relevant as it provides a framing for the collaboration.

Collaborations in the form of purchases of research services are not explicitly covered in the interviews. However, PRIVATE_G emphasizes that when there is a need for university-based knowhow, they purchase the expertise from universities. This represents cases in which the company knows which services or activities are required, and where product testing and development is not necessary ('We need what you already have; we do not need you to develop something new for us' - PRIVATE_G).

The participation in committees and advisory boards also represents a type of engagement emphasized in the interviews as a point of entry for collaborative projects. This includes both activities where practitioners serve in committees and advisory boards of research projects and where researchers participate in boards in organisations and networks.

Initiating a university collaboration

While this section provides an overview of different entry channels into a university collaboration, the challenges that some of the interviewed organisations have experienced in relation to initiating a collaboration are discussed in further detail in the section on 'Challenges in collaborating with universities' below.

The process of initiating a collaboration with a university and finding the right university partner is rarely linear. It is influenced both by the external and internal relations of the company as well as the primary content of the collaboration and the competencies needed. Fitjar and Gjelsvik (2018, p. 1527) argue that because search is time-consuming and costly, companies may have a limited search scope when they look for appropriate collaboration partners among universities. This search scope may be

limited to universities that the company already knows (or knows of), and therefore consider trustworthy.

PRIVATE_E describes how, especially for a company that has no prior experience with university-industry collaboration, approaching a university represents crossing a threshold; it can be difficult to ask the right questions and make the project specific enough to discuss in a university context. Contrary to this, PRIVATE_F, which is a company with extensive experience of collaborating with AAU and other universities, represents a very proactive case. PRIVATE_F synthesises three approaches, which the company applies when looking for new collaborative partners from universities: 'i) You already know the person; ii) You use your network; iii) You scout the new literature to see who is a recurring figure/trend setting within specific themes'.

All in all, the interviews represent various approaches to initiating a university collaboration; these include personal networking, competence scouting, educational activities and using AAU Match. Finally, the interviews also revealed some new and unconventional approaches to initiating collaborations with the aim of changing the roles of the participating companies.

Network relations

When initiating a university collaboration, there is a marked difference between entering through a personal network, through general network relations or through cold calling.

Collaborations covered in the interviews are often with a specific, and recurring, researcher or research group (e.g. PRIVATE_A; PRIVATE_B; PRIVATE_G). Some research groups are active in inviting the practitioners to discuss potentials and ideas. In several cases, previous industrial PhDs become the facilitators of contacts between the organisation and the university (PRIVATE_B; PRIVATE_E).

Collaboration partners are often found in personal networks that already exist. This is in accordance with earlier findings in the academic literature, e.g. Thune (2007), who, in a study of Norwegian cases of university-industry collaborations find that collaborations often emerge out of prior established ties. As described by PRIVATE_G, this approach feels 'safe' and is often successful. Knowing the university representatives ensures that the researchers are on par with the level of complexity in the organisation (PUBLIC_A). Initiating a project with a researcher, which the company has not previously worked with, is time consuming as it takes time to get close to each other and create a joint mind-set. But such a process is necessary to create alignment and find a joint direction for the project. On occasion, this process can also lead to the termination of a project application based on a lack of either personal or professional fit (PRIVATE_F). However, continuing to enter into projects with known partners can also entail that new perspectives are not added to the collaborations (PRIVATE_G).

Network relations can comprise of relations established through e.g. specialized committees (PRIVATE_D), advisory boards (PRIVATE_F), networks for knowledge sharing (PUBLIC_A) or alumni relations (PRIVATE_A). In a quantitative study of university-industry collaborations, Drejer & Østergaard (2017) find that having employees who are graduates from AAU increases the likelihood of collaborating with AAU on innovation. This is confirmed in the descriptive analyses in Chapter 2, which are based on the same type of data as Drejer & Østergaard (2017). However, common educational backgrounds/alumni relations as a point of departure for setting up university collaborations was not typical throughout the analysed cases. An exception is PRIVATE_A, which is located physically near the university, and has a high degree of employees from AAU. PRIVATE_A finds that the personal education-based networks into the university strengthen their possibility to collaborate both in terms of informal knowledge sharing and in more formalized research projects.

In the case of PUBLIC_A, the collaboration was established through a network for knowledge sharing that is comprised of both researchers and practitioners. The point of contact to this network was established as an employee of the organisation participated in a master programme. However, it is generally noted that becoming a part of these networks can prove a struggle for practitioners as the entry barriers are high and requires many practitioners to step outside of their comfort zone.

Competencies

Naturally, there is a blurring of lines between collaborations established through personal networks and collaborations driven by the search for specific competencies.

In numerous occasions, the cases represent longstanding interactions with one specific research group or individual researcher, and it is the expertise and competencies of this research group/individual researcher that drives the collaboration (PRIVATE_B). However, when needed, new research groups are sought out to fit the evolution of ambitions and goals of the organisations. These new research groups typically complement, rather than substitute the longstanding collaboration partners.

Some cases illustrate how collaborations have been initiated through companies getting in contact with researchers based on their research profiles and inviting them into a dialogue about new developments within the company. This represents cases in which the organisations have other contacts at universities but are expanding into new areas of interest and therefore also need to expand their university network. The best way to identify new potential collaboration partners at AAU as well as at other Danish universities is by the interviewees typically described as asking around/word-of-mouth about which research groups have expertise in a particular area

AAU Match

One case represents a collaboration facilitated by AAU Match. PRIVATE_E had previously had on-and-off contacts with AAU, but wanted to establish a closer and more structured collaboration, which was initiated through approaching AAU Match with the ambition to establish a collaboration on a PhD project. This contact lead to the establishment of an industrial PhD project and subsequently an industrial post doc project. In addition, the PhD student has facilitated semester projects for students from a specific department at AAU, and has functioned as a bridge between the department and the company.

Alternative approaches to initiating a collaboration

In some cases, it is emphasized that the organisations, based on their existing experience with university-practice collaborations, are interested in changing the role that the organisation takes on during the collaboration. This change is generally described as moving from being end-users that are invited to participate in already defined research projects to becoming more involved in defining the project as a whole. PRIVATE_F made this change in role division, and is now initiating projects and inviting partners to join. By doing so, they have become more focused on their direct outcomes of the projects. Although this process is more time consuming for the organisation, it means that there is a greater focus on the activities of the project, which also enables to steer clear of partners that focus more on applying for external funds than on addressing challenges.

One approach to being proactive, which is practiced by PRIVATE_F, is to invite universities into the organisation to do Google Sprints where researchers present their research. Based on this, participants in an internal graduate program can work on how to integrate this kind of research into the organisation.

The content of collaboration

The content of the collaborations differs across the various cases. In general, they are divided across:

- Product development
- Process and organisational development
- Testing and documentation

Product development

Product development is a driver for both PRIVATE_G and PRIVATE_A in their collaboration with AAU.

While the university collaboration rarely relates to the direct commercialization of products, both because the companies do not find that there are anyone at AAU who can help in that process and because there is low professional interest from researchers in this part of the process, there is a lot to be gained from exploring and developing products in collaboration with universities.

Collaborating with universities provides an edge and an insight into the new trends that are driving the market, as e.g. described by PRIVATE_A. In addition, the exploration of new possibilities in collaboration with the university creates a legitimacy and credibility in the market.

Furthermore, on the technology side, the collaborative setting also enables a closer link to other actors in the supply chain. In addition, the collaboration provides access to end users for the university; by doing so, the university gains access to knowledge about the needs in the market in exchange for their technical knowledge.

One example of a product development-related collaboration is represented in the case of PRIVATE_G, which has focused on developing cost efficient measurement and Internet-Of-Things solutions for PRIVATE_G systems. The university collaboration provides value, as universities are generally perceived as 'being closer to the frontier of what is technically possible. And this is of great use to us when we work towards launching the product for the market'.

Process and organisational development

Several collaborations revolve around process and organisational development both intra- and inter-organisationally. PRIVATE_E has initiated university collaborations with bachelor and master students as well as PhD students to explore sub-processes in their production processes. This includes both explorative processes and process optimizations. In the case of PRIVATE_G, a collaboration with researchers concerned the development of new strategic approaches and creative innovation processes in collaborative settings with stakeholders. This also included continuing education of employees through courses at AAU.

In regards to exploring processes, the university collaboration represents more than specific internal processes in the company. It also concerns process development across the supply chain, as described by PRIVATE_A, which potentially requires a broader collaboration across university departments.

A special case of process and organisational development is found in the two public sector collaborations that revolve around softer organisational aspects including co-creation with practitioners. This approach to university-industry collaboration can occur along a continuum of engagement and co-creation with relevant stakeholders depending on the level of inclusion and the change objectives in the project.

In PUBLIC_B the collaboration was characterized as 'participatory research' [11], as researchers followed the existing organisational practices to describe rather than change processes. In contrast, the collaboration that PUBLIC_A was involved in was based on co-development of organisational processes through action research. This collaboration included co-exploration of organisational challenges and multiple cycles of researcher-facilitated interdisciplinary learning groups in the organisation to create organisational learning and change.

As evident in both public sector cases, soft co-creation processes require that the researchers become a part of the organisation in which the project takes place to ensure applicability in the organisation rather than the researcher becoming the 'guest of the week' and/or mainly being in the way. For instance, in the case of PUBLIC_B, the practitioners were found to be more change-oriented when the research concerned their everyday practices. This helped reduce the complexity of transferring knowledge from the project to the participants.

Testing and documentation

Several projects within explorative technologies are defined by a focus on technology testing and documentation. In the case of PRIVATE_C, the business area in itself is not yet profitable on market terms, for which reason externally funded, collaborative projects are necessary to explore and develop the field. Universities provide access to highly specialized equipment that the organisations do not possess internally. Thus, university collaborations provide the opportunity of completing tests the companies cannot do by themselves; especially in areas where fundamental research is still needed.

In several cases, the companies express that university projects are organised around a content that is primarily experimental rather than a content that is ready to be commercialized. The processes of testing and experimenting are important but 'are not the activities that will bring home the bacon in the short run' (PRIVATE_B). Although explorative, the projects often take an existing problem as a point of departure, and evolve from there.

However, in the case of PRIVATE_F, where the market is mature and quite competitive, there is a limited interest in fundamental research and greater interest in a more applicable and ready-to-the market output.

The experimenting processes are often emphasized when the companies address perspectives that are less critical for the current day-to-day business. This is e.g. the case in PRIVATE_E, who are currently in the process of initiating a collaborative project with AAU to explore potentials for sustainability-related developments.

In addition to the emerging collaboration on sustainability, PRIVATE_E primarily engages in university collaboration to explore raw materials and their connection to product features. Based on previous experiences of collaboration with external consultants, PRIVATE_E found it necessary to create a structure around their knowledge absorption, for which reason they wanted to initiate a more systematic and well-structured university collaboration. Throughout the collaborative process of testing and exploring, the company finds that it gets something else from engaging with a university compared to trading with GTS institutes, which have previously been used. The GTS institutes are described as more

[11] "Følgeforskning" in Danish.

expensive to use than universities, but they can be used for specific tasks for which a well-defined contract can be drawn up, and then the relation terminates when the task is completed.

Output and outcomes of the collaboration

The outputs of the research collaborations, and the extent to which these are utilised and transferred into a value-generating outcome vary across the cases. PhD and postdoc projects often have a recruitment perspective in addition to aiming for a specific research output. Whereas some companies see PhD and postdoc projects as a way to get access to the best employees – and also test out specific candidates – one rurally located company saw the involvement in research projects with associated PhDs and/or postdocs as necessary for attracting enough highly qualified staff to keep the research and development department running at the current level of activity.

In addition to research collaborations, hosting student projects and hiring student assistants is, as mentioned in the section on types of collaboration above, also considered to be part of a recruitment activity for the majority of companies involved in these kinds of activities. This being said, PRIVATE_E mentions how a student project testing one of the company's products resulted in insights that are now applied directly in the marketing of this product. This illustrates that although the interviewed companies generally see student projects as an activity where the company is mainly providing a service to the university by contributing to the training of the students – which can have a derived recruitment effect – the student projects can also prove to be directly valuable to the companies.

As mentioned above, the scope of collaboration ranges from early-stage explorations and testing to activities closer to the market. There appears to be some relation with the companies' industry affiliation and type of technology/knowledge involved, but – to no surprise – the size of the company also matters, since large companies may have the financial means to operate with a longer time horizon before a potential return materialises. PRIVATE_D is an example of a company, which has been able to transfer the outputs of an industrial PhD project to a marketable service while the project was still running. And in the case of PRIVATE_F, which, although being a private company, operates in a highly regulated market, the collaboration with AAU has resulted in the start-up of a new company.

Several case companies mention how they can detect a change in universities in general as well as for AAU in particular, where their awareness that projects must generate value has increased over the last decade. However, as is discussed in the section on 'Challenges in collaborating with universities' below, this perception of a high awareness of the need for value-creation does not stand completely uncontested.

As also discussed above, collaboration projects do not only contribute to the development of new products or services, they can also contribute to optimising production processes, as well as provide the companies with insights on customer motives and behaviour. In relation to production processes, the traditional manufacturing companies in particular emphasise how the university can contribute with a more fundamental scientific knowledge about the company's product and production processes, e.g. about underlying chemical processes. PRIVATE_E describes how this has enabled the company to work in a more cumulative way in its development activities compared to earlier, when the company worked in a much more empirical way without having a complete understanding of 'what was actually going on'.

Finally, collaborating – and more specifically co-developing something - with a university is by several seen as something that increases the legitimacy or trustworthiness of the collaborating company and its offerings.

The above discussion of outputs and outcomes of collaborations with AAU applies to a large extent to the experiences of the private companies only. The two public sector organisations collaborate in a distinctively different way compared to the private companies, which also leads to different outputs. Both public sector organisations emphasise the importance of a close relation to everyday practices. In the case of PUBLIC_A, the collaboration was on an action research project which is described as having transformed the organisation through introducing new ways of working with organisational learning at all levels of the organisation. The project has also led to joint research publications between PUBLIC_A and AAU.

In contrast to PUBLIC_A, the output of the collaboration between PUBLIC_B and AAU, which was a 'participatory research' project, was utilised to a much lesser degree. The primary output is a report, and although the process is described as having been a good experience, the project simply faded out when the funding ended without having made a considerable mark on the organisation.

Challenges in collaborating with universities

The academic literature on university-industry collaborations identifies a range of barriers or challenges for such collaborations, which e.g. are related to differences among the collaborating partners in incentives, differences in orientation towards openness, as well as potential conflicts regarding intellectual property (Bruneel et al., 2010). For the non-university partner, the lack of absorptive capacity – defined as the ability to recognise the value of, assimilate and apply new knowledge (Cohen & Levinthal, 1990) – can also be an important barrier (Bruneel et al., 2010; Laursen et al., 2011). These challenges may relate to different stages in the collaboration process. Therefore, we distinguish between challenges related to the initiation of collaborations with AAU, challenges in the collaboration process, and challenges related to utilising the output. It should also be noted that some of the barriers to university-industry collaboration identified in the literature are of such a nature that they make a collaboration unlikely. This e.g. applies to the absorptive capacity barrier, which is not very prominent in the nine case organisations, since they all have an above average absorptive capacity by having university graduates among their employees, and, in the case of the private sector companies, by also often having employees dedicated to R&D and technology development.

Challenges in initiating a collaboration

Initiating a university–industry collaboration is based on a process of search for a relevant partner, which can accommodate the needs instigating the search. As illustrated in the interviews, both companies and universities can actively search for partners. As discussed in the section on 'Initiating a university collaboration', network relations can play a role in the search process. The social dimension of a relation not only involves knowing who knows what – which is an important first step in finding a relevant collaboration partner – but also a closer personal connection, which allows for the mutual exchange of knowledge and ideas. However, AAU has a mission of reaching out to a broader set of collaboration partners, also including small and medium sized companies, which do not necessarily have prior connections, employee-related or otherwise, to the university. AAU Match has been established to help overcome the barriers that companies may experience in approaching the university and finding the right partner.

As illustrated above, only one of the interviewed companies, PRIVATE_E, has used AAU Match as the entry-point to the university. In PRIVATE_E's case, AAU Match established a successful relation to one of the natural science departments, but the company does see a challenge for companies in approaching the university. There is a threshold that may be difficult for many companies to overcome, because

it can be difficult to see what they can actually use the university researchers (or students) for. Therefore, the companies need to make some internal considerations before they approach the university (in this specific case AAU Match): ask the right questions, and concretise how a collaboration with the university can generate value for the company. Other companies, including the public sector organisation PUBLIC_A, calls for an increased focus from the university on improving visibility and telling the good stories about what a university collaboration can contribute to an organisation.

Although there is room for improvement from the university's side, PRIVATE_E also emphasises that the companies need to be aware of and accept that the university is a different type of organisation than a company, with different sets of priorities. Otherwise, disappointments may occur, e.g. in relation to things taking a much longer time than the companies would have preferred, also in the relation-building phase.

Other companies also stress the access to – or lack of – funding as a challenge for establishing collaborations with universities. PRIVATE_D would e.g. like for the entire technical consultancy sector to become more involved with the university sector, but they find access to funding to be a constraining factor, not least in the current situation, where the COVID-19-crisis has put the consultancy sector under severe pressure and limited the funds available in the companies for engaging in knowledge exchanges with universities. Therefore, they call for alternative ways of funding university-industry collaborations that are less costly for the companies than e.g. PhD projects.

There are, however, mixed views on the issue of funding. PRIVATE_A e.g. describes the funding system as 'a jungle, too cumbersome and making everything very formalistic [...]. The perception here - if we lump it all together - is that it is so cumbersome with these public funds [...]. I must admit, that when I am reading about rates and trust deeds and by-laws etc., then I just think: It is easier to not do it, it is just too complicated!'. Instead, PRIVATE_A either finds the funding internally when AAU needs to be compensated for a specific service, or they join in on projects where the university researchers have secured the funding.

Some companies find that the funding in itself sometimes appears to be more important to the university than the actual project content. PRIVATE_F states bluntly that their experience with e.g. EU projects is that researchers are more interested in applying for the funding that in figuring out what the content should be. Over the last decade, this has made the company weary, and as a result of having been part of too many university projects, where they afterwards have asked themselves 'what did that actually contribute?', they have changed direction towards a much stronger focus on what is in it for them when it comes to university collaborations. Accordingly, PRIVATE_F calls for the university, as well as the companies, to invest more time in the initial phase on matching the expectations and developing projects that focus on generating value for all participating partners.

Some of the companies, which are experienced in collaborating with AAU, are relatively critical about the role of the university administration in the contract negotiation phase. Both PRIVATE_B and PRIVATE_G have e.g. experienced challenges in terms of a perceived rigidity from AAU's lawyers in relation to intellectual property rights and commercialisation. It is acknowledged that this might be governed by statutory instruments, but it is nonetheless perceived as a nuisance. As one of the interviewees puts it: 'If you could just make sure that the administration does not work against us when we draw up contracts [...]. We do not question that we should remunerate you appropriately, but if we could just be allowed to protect our technology, then we look forward to any future collaborations'.

Challenges in the collaboration process

The challenges that are emphasised in relation to the actual collaboration process concern differences in time-perspectives and needs for documentation before application/exploitation of results, differences in product versus process focus, and, in terms of externally funded projects, excessive controlling demands.

PRIVATE_D is an example of a company that has experienced a clash between cultures in terms of when the fruits of a collaboration are ready to be harvested. Although acknowledging that universities cannot be associated with something that is not scientifically well-documented, they do see a need for developing a model that is better equipped to meet the needs of both parties, because not all companies can wait e.g. four years before they start generating a return on an investment. However, the acceptable time to return on investments varies across industries.

Some companies also find the university is more interested in the process than in the product/outcome of the collaboration. Although nothing can be generalised from the interviews in terms of differences between public and private sector organisations, the two public sector interviewees do stand out in terms of valuing the process in its own right to a much higher degree than the interviewees from the private companies. But PUBLIC_B did experience challenges in terms of keeping focus on the process because day-to-day practical issues related to the running of the organisation interfered with the project activities.

Finally, PRIVATE_F is in accordance with PRIVATE_A when it comes to finding the public funding system cumbersome to work with. PRIVATE_F finds that foundation grants, and in particular EU funds, have a setup which is not oriented towards receiving applications from private companies: 'It requires an entire controlling department to account for expenses and receipts, and the company is simply not geared to that'. This is not a critique that is directly aimed at AAU, but it can affect the attractiveness of engaging in externally funded collaboration projects with the university, if the companies cannot enter in a way that places the majority of the administrative burden on the university, which is perceived as being more geared to handle such burdens. The perception of rules and regulations imposed by funding agencies as transaction related barriers to university-industry collaboration is by no means unique to the cases studied here. The same finding is e.g. documented by Bruneel et al. (2010) in an analysis based of British firms.

Challenges in utilising the output

A recurring concern in relation to university collaborations is that the only output will be a report that ends up on a shelf. Several interviewees from both the public and private organisations have been part of collaboration projects – also with AAU – where the output has been just this.

PUBLIC_B describes how the project faded out when the funding ended. The reason for this is mainly ascribed to internal reasons, where focus remained on moving on with everyday business, while there was a lack of attention to how the research could be applied as a tool for changing work practices. At best, only a few project extracts were used in practice.

Turning the output of a university collaboration project into practice has also on occasions been a challenge for PRIVATE_A. But here the main challenge was a too large focus on the technological aspects, reflecting that the motivation for entering into the project was technological curiosity, whereas considerations about whether there would actually be a sufficiently large market for a niche technological solution were wanting. Accordingly, PRIVATE_A's assessment is that they need to become better at

introducing a proof-of-concept-thinking and customer cases into their collaboration with AAU. PRIVATE_A also finds that they may be collaborating too narrowly with AAU, and should become better at including more disciplines in their collaborations in order to cover a wider range of the value chain.

PRIVATE_F has developed an internal approach with sponsors in the organisation as a means to avoid the 'report on a shelf'-problem, where it becomes difficult to see which value a collaboration project with the university has generated for the company. The role of the sponsor is to ensure the embeddedness of the collaboration project in the company, which is also seen as necessary in order to counterbalance the tendency at the university to focus on the theoretical aspects and the relevance for the university ('research for the sake of research'), while paying little attention to the company's perspective. PRIVATE_F in general criticises the Danish universities for being too convinced of the relevance of their research to companies, without realising the needs to make the research more operational and tangible. In that sense, PRIVATE_F still perceives a gap between research and commercial application (known as the' valley of death' in the academic literature, see e.g. Weyant, 2011).

However, PRIVATE_G detects a change over the last years in AAU's attention towards the importance of collaborations generating value. Going back a few years, PRIVATE_G felt that AAU was very project driven, paying more attention to having a new project defined by the time an ongoing project was approaching its end, than to the actual outcomes of the project.

Characteristics of a good collaboration

Above, different aspects of organisations' collaborations with AAU are discussed. In this final section, the lessons learned from the interviewees in relation to what – seen from the organisations' perspective - characterises a good collaboration, are synthesised.

The importance of the individual characteristics may vary across different types of collaborations and partners. However, according to the interviewees, in a good collaboration project there is:

1. Focus on generating value for all partners.
2. Commitment to and contributions from all partners to the collaboration project.
3. Acceptance of a likely long and time-consuming process towards establishing a collaboration.[12]
4. A clear matching of expectations from the outset of the collaboration – and acknowledging that the partners come from different worlds.
5. An effort from the university researchers to see things from the perspective of the organisations they are collaborating with, and 'meeting the organisation where it is'.
6. Acknowledgement from the university researchers that the collaboration project is a co-creation and that practitioners also have something to contribute.
7. A clear relation to practice in the collaborating organisation.
8. Focus on implementation and possibilities for generating commercial value throughout the process.
9. A focus on the professional content and not the funding opportunities as drivers of the collaboration project.
10. Good personal relations - collaborations are first and foremost between people, not organisations.

[12] Some companies spend up to a year getting to know a new university collaboration partner before entering into a formal collaboration.

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Chapter 4. Exploring the impact of university-industry collaborations[13]

Gerwin Evers, Ina Drejer, Christian Richter Østergaard

Introduction

Although the innovation literature generally assumes positive outcomes of university-industry collaborations on innovation, there are relatively few empirical analyses of this, in particular when it comes to relating collaborations with specific universities to firm-level performance.

University-industry collaborations can vary in scope from multimillion projects with double digit numbers of participants, to more informal structured one-on-one collaborations. Some collaborations rely heavily on public national or European funding, while other projects are primarily private funded. Yet, the commonality between these varying collaborations is that both industry and academic actors collaborate on innovation activities. In this way, these collaborative research endeavours offer university and industry actors a setting that can enable the co-production and sharing of knowledge (Canhoto, Quinton, Jackson, & Dibb, 2016). Co-production entails that both university and industry actors recombine their expertise and together create new knowledge or applications (Van De Ven & Johnson, 2006).

Although both academia and industry are characterised by globalisation, the academic literature — in accordance with the findings presented in Chapter 2 in this report — has found that a strong bias towards geographically and institutionally proximate collaboration still remains (D'Este, Guy, & Iammarino, 2013; Hoekman, Koen, & Frank Van Oort, 2009). It is suggested that companies prefer to collaborate with a geographically proximate university partner of sufficient quality rather than to work across larger distances with a university partner with a stronger scientific track record (Fitjar & Gjelsvik, 2018). Geographical proximity is found to be particularly important in short-term applied projects, in which trust and transaction costs might play a decisive role (Broström, 2010). While geographical proximity clearly drives down interaction costs, geographical proximity is neither a necessary nor sufficient condition for collaboration per se, and its prime benefit stems from its correlation with other proximities — such as cultural and social (Boschma, 2005). Participation in university–industry collaborations can decrease the social distance and enable subsequent informal exchange of knowledge at the university–industry interface (Østergaard, 2009). Research collaborations are also considered to be more suited to the exchange of tacit knowledge than other university-industry channels (Schartinger, Rammer, Fischer, & Fröhlich, 2002), owing to their interactive character. Hence, university–industry collaborations are considered a vital channel for realising university–industry knowledge spillovers.

Studying the impact of university-industry collaborations – a brief overview of trends in the academic literature

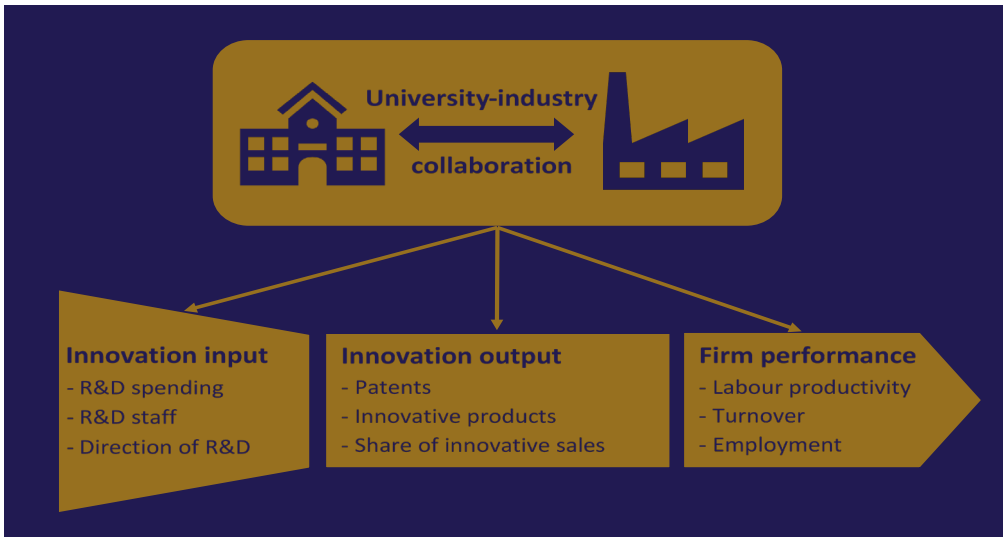
Although studies on the impacts of university-industry collaborations have been carried out around the world, there is a strong bias towards the developed countries context.[14] The impacts discussed in these studies can be categorized into three dimensions:

- Impact on innovation input
- Impact on innovation output
- Impact on firm performance

[13] Part of this chapter draws on Evers (2020).

[14] See the technical report (Evers, 2021) for an overview of the studies deemed most relevant.

Figure 4.1. University-industry collaboration impact dimensions



For each of these dimensions, several indicators have been applied, some of which have turned out to be better suited for measuring impact of collaborations than others. The following section will briefly discuss the three impact dimensions and summarise the available academic empirical evidence.

Impact on innovation input

R&D spending and the direction of R&D

Several studies assess the potential of university-industry collaborations for pushing firms to increase their investments in R&D. These investments could play a role in helping firms overcome knowledge transfer barriers such as lacking absorptive capacity i.e. the firm's capacity to recognize the value of new, external information, assimilate it, and apply it (Cohen & Levinthal, 1990). Furthermore, these investments might lay the foundation for further R&D projects. Some studies have also argued that university-industry collaboration might affect the type of R&D conducted, were firms change the focus of their R&D activities towards more fundamental research when collaborating with a university.

Scandura (2016) finds that firms in the aftermath of a university-industry collaboration tend to increase their investments in R&D. Yet studying these effects can be complicated by the necessity to distinguish the effect of the collaboration from the collaboration itself. Is an observed increase in R&D the results of investments related to the collaboration project itself, which will fade away when the collaboration ends, or is it a continued impact on the R&D?

R&D staff

Due to the challenges associated with using the development in R&D investments as a measure of the impact of university-industry collaborations, Mazzucato (2011) and others suggest to assess the impact on the recruitment of R&D staff instead. If a project indeed leads to the hiring of R&D staff, who subsequently stays on after the collaboration is finished, this can be considered a long-term impact of the collaboration. The hiring of university graduates in general might be a useful indicator, as their hiring may be able to increase the level of absorptive capacity and narrow the gap between institutional cultures, and thereby facilitate the potential of knowledge transfer and co-creation.

Impact on innovation output

Firm-level impacts from university collaboration on innovation outputs are argued to stem from the knowledge gained during the collaborations. Three distinct indicators have received considerable attention in the literature: patents, introduction of innovations, and share of sales from innovative products.

Patents

Some studies consider the impact of university-industry collaborations on patenting (e.g. Lööf & Broström, 2008). Patents are seen as a step for firms to claim their intellectual property and subsequently allow it to capture value for the firm. Yet, studies show that a substantial share of patents remain unused for strategic reasons (e.g. Torrisi et al., 2016). In addition, the use of patents varies considerably between sectors. While the pharmaceutical sector is an avid user of patents, firms in other sectors prefer to apply other strategies to appropriate value from their intellectual property. These two considerations make patents unable to provide a comprehensive insight into the impact of university-industry collaboration on innovation output.

Innovative products and share of innovative sales

Some studies apply innovation survey data to explore whether firms collaborating with universities is associated with introducing innovative products or services on the market or with the share of innovative sales. A recent example is Hewitt-Dundas et al. (2019), who, based on UK innovation survey data, find that university-industry collaboration increases the probability that a firm will introduce new-to-the-market innovation rather than innovation that is new to the firm only. The focus on newness of innovation rather than on innovation itself can be ascribed to the particular feature of most innovation surveys, where firms are only asked about university collaborations if they are actively engaged in innovation activities – and therefore it is not possible to estimate the association between university-innovation collaboration and innovation activity in general with the use of most innovation surveys.

Impact on firm performance

Although there is an increased focus on how innovations can help address major societal challenges, a vital aim — from business as well as societal perspective — is that the university-industry collaborations improve firms' competitive position, thereby enabling a stronger growth trajectory. However, the academic literature on the economic impact dimension is relatively scarce, and in general, academic and policy evaluation studies are struggling to find strong effects of university-industry collaborations on firm performance (sometimes also referred to as outcome, which is a third-order effect after the effects on input and output). Despite the absence of strong evidence in the literature, the three most commonly applied economic impact indicators in the university-industry literature are briefly discussed below.

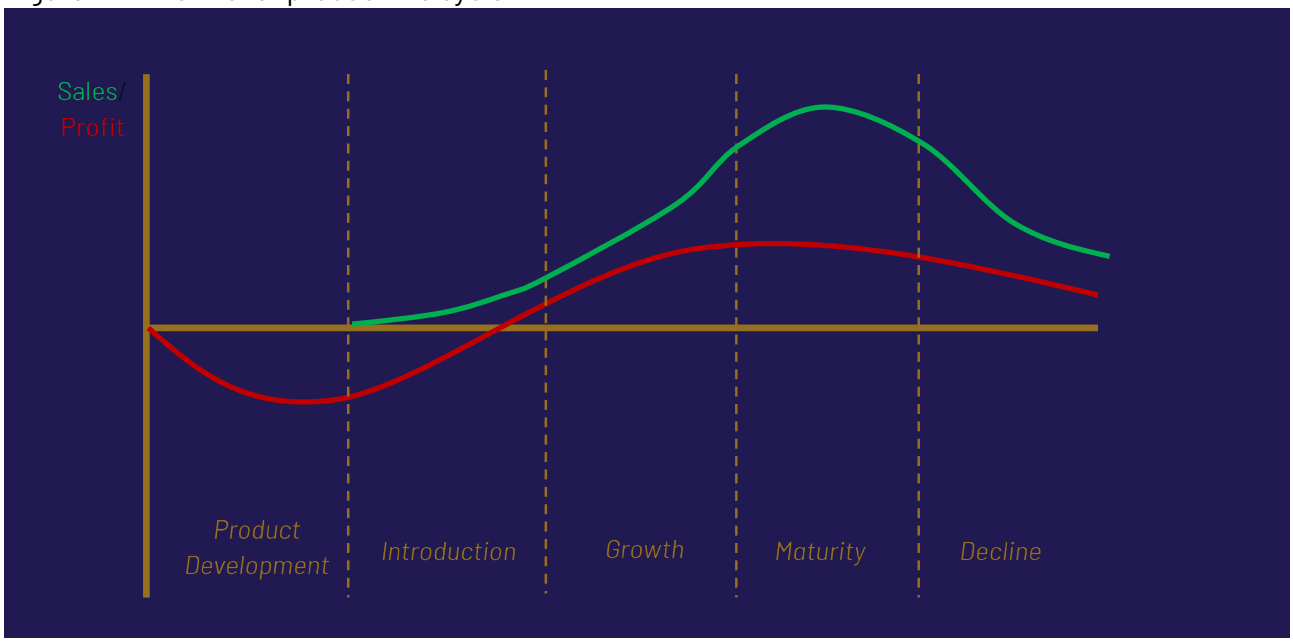
Labour productivity

The academic literature includes analyses of the impact of university-industry collaboration on firms' labour productivity for e.g. the Netherlands (Belderbos, Carree, & Lokshin, 2004), Italy (Medda, Piga, & Siegel, 2004), Japan (Motohashi, 2005) and South-Korea (Eom & Lee, 2010) — but none of these studies are able to show any association between university-industry collaboration and labour productivity at the firm level.

One likely explanation for the lack of empirically based evidence of the association between university-industry collaboration and labour productivity is that studying these types of associations can be a long-term game, where it is difficult to determine when the impact of the collaboration is likely to ma-

terialize and how long it may take before other firms catch up. Inter-sector and inter-firm heterogeneity can complicate matters further. For part of this explanation, it is relevant to refer to the theorized impact of R&D on labour productivity. University-industry collaborations are most likely to primarily take place in the early stages of the product life cycle. As is shown in Figure 4.2, these early stages are characterized by declining profits, as substantial investments need to be made in the early product development phase. These investments could include the additional recruitment of R&D staff, which will not add to the *net added value* in the short run, thereby negatively affecting the labour productivity. A further complication is that firms might also receive public funding for their collaboration with a university (to reduce the depth of the 'red valley' illustrated in Figure 4.2), which would have a positive impact on the measured labour productivity because the public funding is included in the firms turnover, but in reality does not contribute to the productivity of the firm.

Figure 4.2. Profit over product life cycle



Furthermore, university-industry collaborations might help some firms to sustain their edge over the competition, preventing competitors to catch-up, but not allowing the firms to increase their edge. Yet, when a firm might gain an edge over their competition, employees might be aware and appropriate some of this added labour productivity into their own wages.

In addition to the above-discussed issues, measuring changes in labour productivity itself is challenging. There are e.g. large fluctuations in productivity measures where 25%+ annual changes are by no means uncommon. Although there are some methods to address this, the resulting standard deviation in this variable remains large.[15]

[15] Although we, based on the experiences from earlier studies, do not consider labour productivity a promising indicator for measuring the impact of university-industry collaborations in the present analysis, analyses have for the sake of completeness been run on the association between university-industry collaboration on changes in labour productivity. But, as expected, the analyses failed to produce robust significant results.

Turnover

Eom & Lee (2010) is an example of an analysis, based on Korean data, that includes the growth of sales as a potential impact of university-industry collaboration. Adopting this measure can resolve some of the challenges discussed above for labour productivity. Turnover captures all additional revenue, also the revenue that is consumed by higher wages. It also takes away the high annual fluctuations that are observed for labour productivity. Despite this, Eom & Lee (2010) are not able to find any impact of university-industry collaboration on the volume of sales (nor on labour productivity, which is also explored in the analysis).

Employment

While employment growth is not a straightforward firm performance indicator, since an increase in labour productivity can reduce the need for employees, the growth in employment can be an indicator of desirable local labour market conditions. Furthermore, Klomp & Van Leeuwen (2001) applies employment growth (as well as growth in turnover) as a performance measure of process innovation, based on the assumption that implementing process innovations enhances the competitiveness of all sales. Accordingly, employment growth could be an indirect measures of process innovation impacts of university-industry collaborations.

The grey literature on Denmark

In addition to the academic literature, there are several studies on the impact of university-industry collaborations carried out by consultancy agencies in the Danish context (e.g. Damvad, 2012a, 2012b, 2016; IRIS Group, 2017). Contrary to the academic literature, these studies generally find effects — in some cases very considerable effects — of university-industry collaboration on labour productivity. Possible explanations of the differences in findings between the academic and grey literature could include the timeframes considered, the applied matching procedures, the treatment of outliers as well as the model specifications.

In the present analysis we find it to be a considerable strength that the same data and model specifications are applied in the analyses of impacts of university-industry collaboration for several Danish universities, and that collaboration with other universities is included as a control variable in the university-specific analysis. Because, as documented in Chapter 2, a considerable proportion of the firms in Denmark that are engaged in university collaboration, collaborates with more than one university at a given point of time, the impact of collaboration with one university would be exaggerated if these additional collaborations were not taken into account.

Data and methods

The data applied in the analyses presented in the current chapter are the same type of research and innovation survey data provided by Statistics Denmark as those applied in Chapter 2. For the analyses carried out in the following, there is only data available on all variables of interest in the of research and innovation survey data covering the periods 2007-2009 till 2010-2012.

The survey data provides insight into innovation input indicators, such as R&D spending and R&D collaboration, and innovation output indicators, such as share of sales from innovative products. As described in Chapter 2, firms also are asked whether they collaborated with a university for their innovation and R&D activities, and in case this is a Danish university, firms are asked to name this university (or these universities in case the company collaborates with more than one Danish university). The survey data are for the purpose of the present analyses merged with register data from Statistics Denmark, which provides data on firm characteristics and performance indicators.

Empirical challenges

While the applied data provides us data for all three impact levels – i.e. input, output and performance – there are several empirical challenges to consider. Three of the main issues are discussed in this section.

The *first* challenge concerns a potential *selection bias*. As is the case of most social sciences research, this study relies on observational survey data. While this data is the best we have, and can provide interesting insights, it also introduces selection bias as a major concern in these studies. From the literature, and as also shown in Chapter 2, we know that firms collaborating with universities have on average different characteristics than firms that do not engage in such collaborations. Firms collaborating with universities e.g. tend to:

- Invest more in R&D
- Employ a larger share of university graduates
- Be larger

Cohen, Nelson, & Walsh (2002) have also shown that firms involved in university-industry collaborations tend to cluster in particular sectors.

To estimate the causal effect of university-industry collaborations, this selection bias needs to be addressed. Several methods can be considered for this purpose, although the most common methods in the literature are two-step regression and matching analyses.

The *second* challenge relates to the expected time span (*time lag*) for a university-industry collaboration to generate a measurable impact on innovation input, innovation output or firm performance. It is likely that different time frames need to be considered.

Innovation input

If we consider the impact on innovation inputs, we can think about the short-term boosting of R&D expenditures in the context of the collaboration, but the impact can, as Scandura (2016) showed, also take place on a longer time horizon. As we in the present analyses focus on hiring as indicator of innovation input, a longer time horizon needs to be taken as this hiring is likely to take time to occur and therefore we adopted a time frame from the start of the collaboration in year t-2 till t+2 to capture all hiring that takes place in the context of university-industry collaborations (see Figure 4.3).

Innovation output

Innovation outputs, for which a university-industry collaboration can claim credit, need to occur in the timeframe of the collaboration. Opting for a longer timeframe, and it might capture the effect of the increase in innovation input that is also likely in the long term to boost innovation output (for studies on this topic see e.g. Eom & Lee, 2010; Lööf & Broström, 2008; Torugsa & Arundel, 2013).

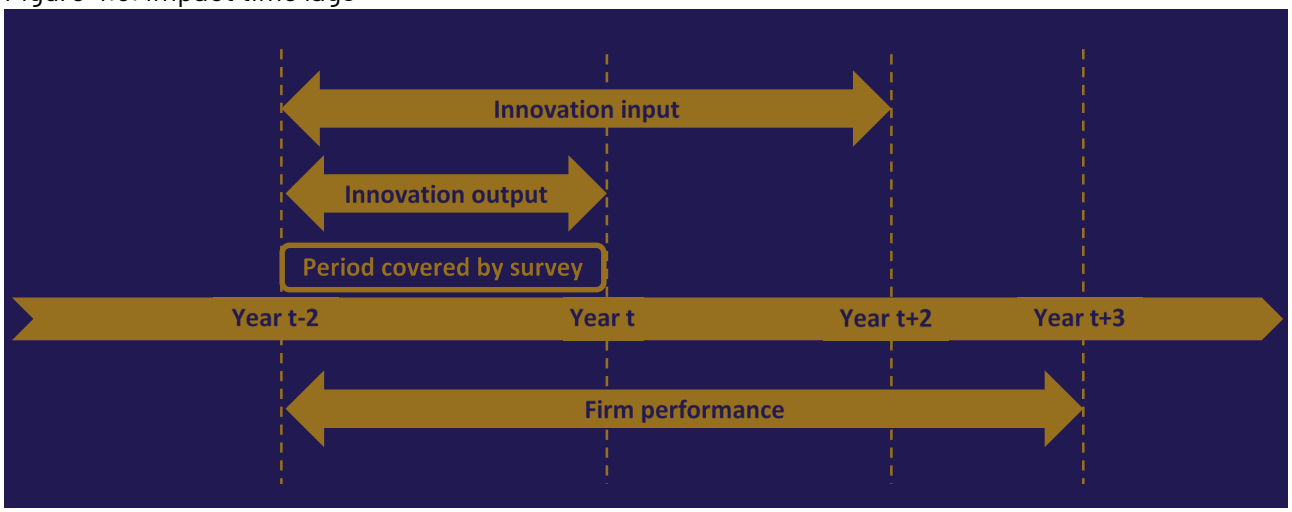
Firm performance

Firm performance requires a longer timeframe, as it takes time for these impacts to materialize. The academic literature tends to apply a time lag of 2-3 years, while some of the consultancy studies adopt an even longer time lag. Stretching the time lag too far might introduce a survivor bias into the sample, and catch-up effects might reduce the impact of the collaboration in the long run.

This study opts to track the change in firm performance from the start of the surveyed period (which is two years prior to the year the survey is conducted, meaning e.g. that for firms participating in the 2012 survey, performance changes are measured from 2010). In this way, all potential effects of the collaboration are captured from the possible start of the collaboration, which might not be the case if the

measurement would start from 2012. The changes in firm performance are tracked until three years after the reference year of the survey (e.g. 2012 + 3 years) in order to also capture the firm performance effects in the direct aftermath of the collaboration.

Figure 4.3. Impact time lags



The *third* challenge relates to the *sample size*. When studying the impact of university-industry collaboration, it is important to note that only a small share of the R&D and innovation active companies is collaborating with a university. Even when only the firms with any innovation related activities are considered (about 50% of the sample), still only about 10% are engaged in an R&D- or innovation-related collaboration with a university. While this leaves still a considerable sample to work with, it poses a real limitation in the in empirical design used in this study if the impact of university-industry collaborations in general is studied without any controls of prior years:

- The analyses of the effects on innovation output require the inclusion of some controls at time t-2. This leads to dropping the observations that are not sampled in both years.
- The share of firms that are collaborating with a specific university are by definition lower than the share of firms that are collaborating with any university. In practice, these shares are much lower, leaving for some universities even less than 50 firms indicating to be collaborating with this specific university.

To reduce these concerns, the analyses reported in this study are based on a pooled data set of the four available years.[16] Pooling the years has an added advantage to exclude year-specific effects such as the results from economic cycles from driving the results, which can be observed in some of the year specific models. In the Technical Report (Evers, 2021), results from additional analyses run for the specific years are shown.

Empirical approach

This section describes the empirical strategy followed, which takes into consideration the empirical challenges discussed above.

[16] If firms are included in more than two "paired" survey waves (i.e. year t and t-2), only one random pair of observations is picked.

Firms operating in the primary sector, utilities and construction sector have been excluded from the sample, as they only have very few university-industry collaborations. Additionally, it has been decided to only report the university specific effects for Aalborg University (AAU), Aarhus University (AU), the Technical University of Denmark (DTU), University of Copenhagen (KU) and University of Southern Denmark (SDU). Roskilde University and IT University of Copenhagen have been excluded because of their size, and hence low number of firms collaborating with these institutions, and CBS has been excluded due to it having a solely social sciences profile, which makes its collaborations differ from the types of collaborations observed for the other universities.

Addressing the selection bias

As the interest of this study is to look into the likely causal impact of university-industry collaborations, the possible selection biases need to be addressed in the empirical strategy. In the academic literature, two methods for doing so are widely used:

- Two-steps models, such as Heckmann regressions, which aims to correct for the selection effect.
- Matching, which is a method where counterfactuals are selected for firms that have collaborated with a university. These counterfactuals are firms with similar characteristics as the firms that have collaborated with a university, and, in what we can measure, they only differ in that they are not collaborating. The observed difference between this treatment and control group is then considered to be the causal impact of the collaboration.

This study, in line with the recent literature and most consultancy studies on this topic opts for the use of matching. The literature has covered several ways to conduct matching analyses. Propensity Score Matching (Rosenbaum & Rubin, 1983) has been widely applied in the literature. This matching procedure applies a model to estimate the likelihood (i.e. the propensity) of a firm in the sample to collaborate with a university, and subsequently matches firms with a similar likelihood of collaborating with a university. While Propensity Score Matching can take away most of the selection bias, the present analyses apply Genetic Matching where, in addition to the propensity-score, additional co-variates are added to assure the optimal balance in relevant covariates between the firms collaborating with a university and the non-collaborating firms (the latter being the control group). The co-variates include for the innovation output and firm performance analyses[17] R&D intensity (measured as R&D expenditures relative to turnover), share of university graduates in the workforce, firm size (measured as log(number of Full-Time Equivalent employees)), sectoral dummies and year dummies. In addition to these co-variates, the analyses for the different impact dimensions include other co-variates that are of relevance to the specific impact dimension. These additional co-variates are described in the next section.

The standard mean deviation is used to evaluate whether a proper balance is achieved between the collaborating and non-collaborating control group of firms. The Technical Report (Evers, 2021) provides an overview of the balances achieved for each impact dimension.

[17] The innovation input analysis is the result of previous work (Evers, 2020), in which some minor different methodological choices have been made. The previous work is available online: https://vbn.aau.dk/en/publications/the-role-of-university-industry-interaction-in-regional-industria (chapter D)

Estimating the impact

This section elaborates on how each impact dimension is operationalized and how the analysis is conducted.

Innovation input

The innovation input analyses assess the impact of university-industry collaborations on the hiring of graduates at the firm level.

The analyses focus on all the new employees recruited by a firm over the time window t-2 till t+2 (see also Figure 4.3). The first analysis assesses the knowledge intensity of the recruited workforce, by assessing the share of university graduates among newly recruited staff:

$$\text{share of university graduates} = \frac{\text{number of university graduates among new hirees}}{\text{number of new hirees}}$$

Subsequent analyses assess the share of graduates from a particular university, *X*, among the university graduates hired:

$$\text{share university } X \text{ of university graduates hired } = \frac{\text{number of university } X \text{ graduates hired}}{\text{number of university graduates hired}}$$

For these latter analyses, additional co-variates applied in the matching procedure include the share of graduates from the specific university prior to the collaboration, and the travel time to the specific university, as both these co-variates play an important role in predicting the future recruitment behaviour of firms. In the next step, difference-in-difference analysis is used to assess the difference between the group of firms that is collaborating with a university and the group of non-collaborating firms.

Innovation output

The innovation output analyses assess the impact of university-industry collaborations on the innovative sales at the firm level. In the research and innovation survey, firms are asked several questions about their innovation output. The one of interest for this study assesses the share of sales generated by innovative products and services. The survey distinguishes between three categories of shares of sales of new products and services, which are based on newness:

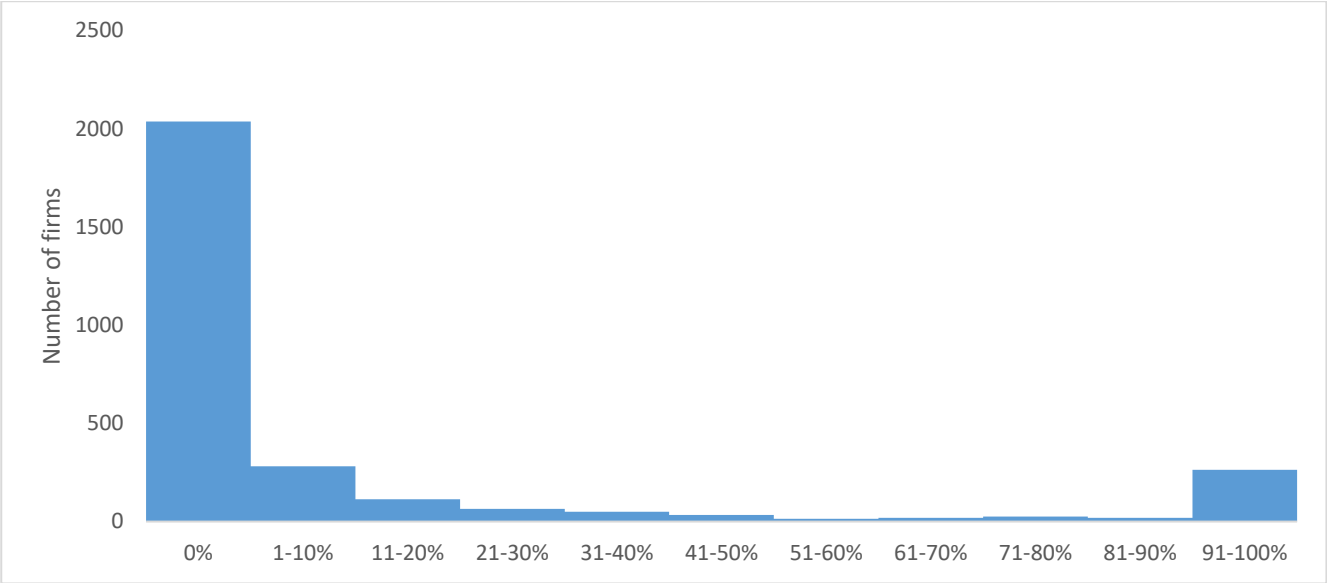
- Share of sales from products/services new to the world
- Share of sales from products/services new to the market (but known to the world)
- Share of sales from products/services new to the firm (but known to the market and world)

A fourth category is established by summing the values for the above three categories into a variable indicating the total of innovative sales. For each model, the matching assures that, in addition to the general co-variates applied, the total share of innovative sales are equal in the group of firms collaborating with a university and in the control group. Collaboration with a university at year t-2 is also included as a co-variate in the matching procedure to assure a similar prior collaboration experience between the collaboration and control group.

While the share of sales from innovative products has been widely applied as an innovation output variable in the literature, the data for this variable is characterized by a zero-inflated distribution (see Figure 4.4). In such a distribution, most firms report no innovative sales, while there is a small group of

firms that report a considerable amount of innovative sales.[18] The matched sample for the innovation output can, due to this zero-inflated distribution, not directly produce an unbiased estimate via the difference-in-difference between the collaboration and non-collaboration group of firms.

Figure 4.4. Zero-inflated distribution of share of innovative sales



Several zero-inflated models have been proposed and used in the literature to work with these kinds of data distributions. In the current analyses, following Torugsa & Arundel (2013), a zero-inflated binomial model (ZINB) is applied. The basic functionality of this two-step model is that it first runs a binomial model predicting the probability that a firms has zero innovative sales, followed by a model that predicts the non-zero values. Yet, as shares are by definition capped at the 100%, some skewness is introduced, possibly affecting the efficiency of the model leading to potential Type II errors.[19]

Firm performance

The firm performance analyses assess the impact of university-industry collaborations on growth in turnover and employment at the firm level. For each model, the matching procedure assures a balance on the absolute turnover in addition to the generally applied co-variates.

The relative growth is calculated as based on the weighted average of the variable over the time frame with the aim of reducing too large fluctuations in the dependent variables.

$$\text{Turnover growth} = \frac{\text{turnover}_{t+3}}{(\text{turnover}_{t+3} + \text{turnover}_{t-2})/2}$$

[18] This is the case despite the fact that all the firms included in the analysis have innovation or R&D activities. However, innovation activity also includes ongoing and abandoned innovation activities. Furthermore, innovation, in addition to the introduction to products and services, also comprises of the introduction of new or significantly improved process, operations, organisational structures and methods of marketing.

[19] A Type II error is a "false negative" error that occurs when we fail to observe a difference when there is in fact one.

$$\text{Employment growth} = \frac{\text{employment}_{t+3}}{(\text{employment}_{t+3} + \text{employment}_{t-2})/2}$$

Generalisability of findings

With the application of matching it is relevant to discuss the generalisability of the findings, which is also a major concern for other econometric methods. As matching specifically aims at finding counterfactuals for firms that are collaborating with a university, it creates a sampling bias to firms that have similar measurable characteristics as firms that are more likely to collaborate with a university – and these firms, as discussed above, have particular characteristics.

The estimated causal effect is therefore primarily applicable for firms with these kinds of characteristics, and it is questionable whether these findings can be generalized to e.g. to small businesses, with little R&D, that employ few university graduates[20].

Empirical findings

Impact on innovation input – workforce composition

Figure 4.5 summarises the findings of the models estimating the effects of university-industry collaboration on the likelihood of firms focusing their hiring of new employees on university graduates.

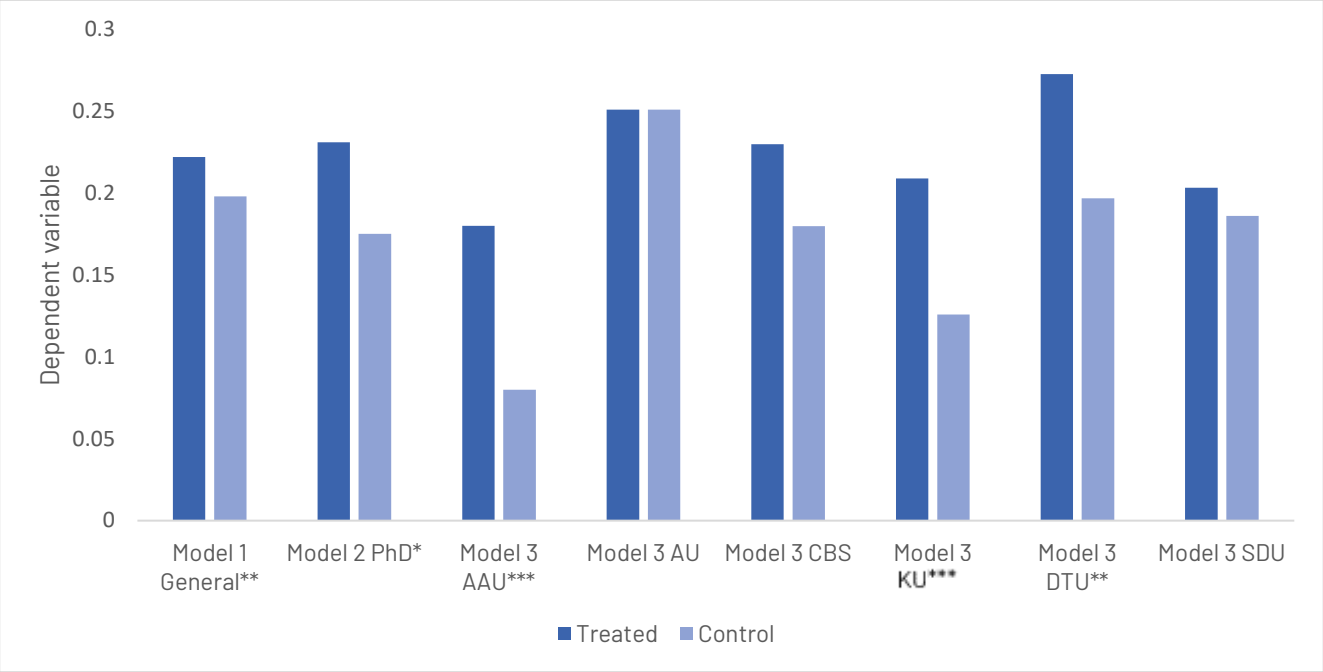
In Model 1, the dependent variable is the share of university graduates among newly recruited staff, whereas the dependent variable in Model 2 is a dummy indicating whether the firm in question hired a PhD. Both models 1 and 2 explore the collaboration with universities in general. Model 3 is the university specific model, where the dependent variable is the share of graduates from the specific, collaborating university among the university graduates hired.

The findings illustrated in Figure 4.5 indicate that firms are more likely to focus their hiring on university graduates when collaborating with a university. Firms are also more likely to focus their hiring of university graduates on graduates from their partner university, although these findings are only statistically significant for Aalborg University (AAU), Copenhagen University (KU) and DTU.

The hiring of university graduates could help increase the firm's absorptive capacity, and, in the case of hiring graduates from the specific university the firm is collaborating with, also help cross institutional boundaries and provide social capital that can play an important role in university-industry knowledge collaborations.

[20] We can also refer to this as the difference between the *average treatment effect* (ATE) and the *average treatment effect on the treated* (ATET)

Figure 4.5. Differences in focus on university graduates in hiring new employees between university-collaborating and non-university-collaborating firms



Significance of the coefficient for university collaboration: *=0.05; **=0.01; ***=0.00.

Impact on innovation output – share of innovative sales

The results shown in table 4.1 indicate that a collaboration with a university (the General model) makes it more likely for firms to have innovative sales, and this applies for sales new-to-world, sales new-to-market as well as sales new-to-firm. The coefficients for the overall likelihood to have innovative sales is highly significant, whereas the coefficients for sales new-to-world, sales new-to-market and sales new-to-firm are significant at the 10% level only.

The university specific models do in most case not find any statistically significant results for university collaboration. Only in the case of AAU are some results significant. Here the model indicates that collaborating with the university increases the likelihood that firms generate sales from new-to-firm innovations, but the opposite effect is observed for new-to-market sales.

Table 4.1. The association between university-industry collaborations and innovative sales (summary of results from a zero-inflated binomial model) – **Zero model**

Negative coefficient *in zero model means that firm is more likely to have innovative sales when collaborating.*

	Model	*General*	*AAU*	*AU*	*DTU*	*KU*	*SDU*
Innovative sales	Zero	-***	-	+	-	+	-
Sales new-to-world	Zero	-*	-	NA	-	NA	-
Sales new-to-market	Zero	-*	+*	+	+	+	-
Sales new-to-firm	Zero	-*	-**	-	+	+	-

Significance: *=0.10, **=0.05, ***=0.01. NA indicates invalid models due to small sample size

Table 4.2 shows that there is no evidence that collaboration with a university in general also impacts the magnitude of the share of innovative sales, neither the overall share of innovative sales nor the share of sales new-to-world, new-to-market or new-to-firm (the General model).

There are a few significant results in terms of the sales new-to-world and new-to-market in the university specific models. For AAU, there is a negative association between collaboration and the share of sales new-to-world. For DTU this association is positive. For Aarhus University (AU), there is a positive association between collaboration and the share of sales new-to-market. No other university specific results are statistically significant.

Table 4.2. The association between university-industry collaborations and innovative sales (summary of results from a zero-inflated binomial model) – **Count model**

Coefficient for count model indicates whether collaboration affect the magnitude of the innovative sales

	Model	*General*	*AAU*	*AU*	*DTU*	*KU*	*SDU*
Share innovative sales	Count	-	-	-	+	+	-
Share sales new-to-world	Count	-	-***	NA	+**	NA	-
Share sales new-to-market	Count	-	+	+**	+	+	+
Share sales new-to-firm	Count	+	-	-	-	+	-

Significance: *=0.10, **=0.05, ***=0.01. NA indicates invalid models due to small sample size

Impact on firm performance – turnover and employment growth

Tables 4.3 and 4.4 show the results of the models estimating the association between university-industry collaboration and growth in firm-level turnover and employment, respectively. The model diagnostics indicate that the models are only able to explain a fraction of the heterogeneity observed, which implies that the findings should be interpreted with caution. This is in line with the impact evaluation literature that often stresses the difficulties involved in identifying the underlying factors for explaining firm performance.

With the above caution in mind, the results indicate that firms that collaborate with a university experience a faster growth in turnover and Full-Time-Equivalent employees than similar firms without university collaboration. The results apply only for the General model on university collaboration, whereas no positive significant effects can be found for collaborations with the specific universities. These lacking university-specific effects are largely explained by the fact that we control for whether a firm is also collaborating with other universities. When it comes to employment growth, for all universities except the University of Southern Denmark (SDU), there is a positive and significant effect (although weakly so for AAU, AU and DTU) for collaboration with other universities.[21] This underlines the importance of taking into account other university collaborations when estimating the effect of collaborating with a specific university.

Table 4.3. The association between university-industry collaboration and growth in turnover (OLS regression)

	General	*AAU*	*AU*	*DTU*	*KU*	*SDU*
University-Industry Collaboration	0.09***	-0.08	0.10	-0.03	-0.19**	-0.10
Collaboration with other universities	NA	0.02	0.03	0.02	0.08***	0.02
R&D intensity	94.86***	75.20**	61.29**	51.53*	74.92***	32.88***
Share university graduates	-0.09	0.19	-0.06	-0.40**	-0.10	-0.42**
Turnover	0.00	0.00	0.00	0.00**	-0.00	0.00
Log(FTE)	0.08***	-0.08***	-0.03	-0.11***	-0.06*	-0.00
Export dummy	0.00	-0.00	-0.16*	-0.26***	-0.07	-0.35***
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	1868	226	182	304	178	172
Adjusted R-squared	0.06	0.15	0.24	0.12	0.18	0.14

Significance: *=0.10, **=0.05, ***=0.01.

[21] R&D intensity is the explanatory variable most consistently associated with growth in both turnover and employment across the general as well as university specific models.

Table 4.4. The association between university-industry collaboration and employment growth (OLS regression)

	General	*AAU*	*AU*	*DTU*	*KU*	*SDU*
University-Industry Collaboration/collaboration with specific university	0.05*	-0.09	0.05	-0.04	0.07	0.06
Collaboration with other universities	NA	0.06*	0.06*	0.06*	0.08***	0.03
R&D intensity	55.55**	53.99**	47.73*	47.61*	63.57***	18.82***
Share university graduates	0.05	0.10	0.29*	-0.25	0.12	-0.33*
Turnover	0.00**	0.00	0.00	0.00**	-0.00	0.00
Log(FTE)	-0.12***	-0.11***	-0.07*	-0.16***	-0.08***	0.00
Export dummy	-0.02	0.15	-0.16*	-0.11	0.04	-0.19**
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	1868	226	182	304	178	172
Adjusted R-squared	0.11	0.20	0.36	0.18	0.24	0.14

Significance: *=0.10, **=0.05, ***=0.01.

The impact of university-industry collaborations

This chapter has illustrated that documenting the impact on firms of university-industry collaborations on R&D and innovation is by no means a simple task. As illustrated in Chapter 3, firms' motives for engaging in university-industry collaborations differ, and the collaborations can materialize in a variety of impacts at different stages. Furthermore, the different types of impacts are likely to be interrelated.

The analyses show that it is not trivial whether analyses are carried out for university collaboration in general or for collaboration with a specific university – at least not when additional university collaborations are entered as a control.

Collaborating with universities in general is positively associated with having innovative sales – but no association to the magnitude of these sales is revealed. Collaboration with university is also associated with firms focusing their hiring of new employees on university graduates. Finally, firms that have collaborated with one or more Danish universities also experience higher growth rates in turnover and employment compared to similar firms that are not engaged in university collaboration.

Moving to the impacts of collaborating with a specific university, here emphasising the collaboration with AAU, the results are sparser. The analyses do show that firms that have collaborated with AAU are more inclined to hire university graduates – and in particular graduates from AAU – after initiating a collaboration. In terms of an innovation impact, collaboration with AAU is associated with an increased likelihood to introduce products and services that are new to the firm – but a decreased likelihood to introduce products and services that are new to the market. A possible explanation for this is AAU's problem-based approach to research, which, as emphasised in Chapter 3, is reflected in AAU researchers being perceived by their collaboration partners a more 'down to earth' in the collaboration, and more focused on applied research than other universities

While the analyses presented in this chapter do provide some new insights into the measurable impacts of university-industry collaborations, they also underline the challenges associated with isolating such impacts, and point to the need for a further development of the data and methods necessary for conducting analyses of the impact of university-industry collaborations.

An alternative approach to explore whether firms benefit from university collaboration[22]

A recent study has revealed that prior experience of collaborating with a university substantially increases a firm's likelihood of engaging in such a collaboration again, which is considered to be the result of a learning effect (Hewitt-Dundas et al., 2019). Despite the suggested firm advantages for firms of collaborating with universities, it remains difficult to collaborate across institutional logics. Thus, collaboration with universities does not always prove frictionless and successful. Sometimes, successful collaboration comes at a high cost (e.g. Laursen & Salter, 2004), and universities can be perceived as overly bureaucratic partners (Perkmann & Salter, 2012). The challenges in terms of university–industry collaboration involve, for example, differences in institutional logics, including incentives and the orientation toward openness between universities and industry, as well as potential conflicts regarding different approaches to intellectual property (Bruneel et al., 2010; Criscuolo et al., 2018; Hewitt-Dundas et al., 2019). The cognitive distance between firms and universities and firms' lack of absorptive capacity (Cohen & Levinthal, 1990; Rajalo & Vadi, 2017) can also prove significant challenges when it comes to collaboration. Such challenges may prevent the initiation of collaboration or else render collaboration difficult to the point that it is discontinued due to its failure to meet expectations.

The firms that collaborate persistently with universities on innovation demonstrate through their actions that they have overcome the challenges associated with both succeeding to initiate a collaboration and establishing a functioning collaboration. If a firm continues to collaborate with a university, then it must consider that collaboration to be valuable. The potential value that firms can obtain from collaborating with a university can materialise in many ways and with substantial time lags, which may explain why academic studies, including the present chapter, rarely report strong quantifiable outcomes of university–industry collaboration. Relatively intangible positive outcomes, for example, in the form of enhanced legitimacy in the eyes of stakeholders, may be just as likely to manifest as tangible, quantifiable outcomes.

Østergaard & Drejer (2020), in an analysis based on the same type of data as those applied in the present report, document how persistence is relatively common in relation to university–industry collaborations on innovation in Denmark, with more than a third of firms that engage in university collaboration continuing to collaborate with the same university during at least two consecutive periods.

In addition to finding that persistent collaboration with universities involves persistent collaboration with the same specific university, the analysis, which focuses on AAU and DTU, shows that investing in knowledge-intensive collaborative capabilities - as expressed by investing in persistent R&D activity and university-specific human capital - is necessary but not sufficient for persistent collaboration with a university. Furthermore, persistent university collaboration is strongly associated with the strategic decision to collaborate persistently with a broad range of different partners. Moreover, geographical proximity between a firm and a university may facilitate the initiation of a collaboration, although in terms of persistence, the nearest university partner is not necessarily the most suitable partner. This is underlined by the finding that geographical proximity does not matter for keeping together in a persistent collaboration with a specific university.

An overall learning point is that while establishing collaborations between firms and universities may have long-lasting effects, it is not sufficient to simply bring firms and universities together in the hope that connections will be made and collaborations will flourish and generate value for firms.

[22] This section is based on Østergaard & Drejer (2020).

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