

Keeping together

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Keeping together: Which factors characterise persistent university–industry collaboration on innovation?

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Abstract

This paper investigates what distinguishes persistence in relation to university–industry collaboration on innovation from the initiation and discontinuation of a collaboration. The underlying premise is that if a firm continues to collaborate with a university, it must consider that collaboration to be valuable. A quantitative analysis of over 2,600 firms reveals that persistence is relatively common in university–industry collaborations on innovation, with more than a third of firms that engage in university collaboration continuing to collaborate with the same university over two consecutive periods. In addition, the analysis shows that firms' investments in collaborative capabilities and different dimensions of absorptive capacity are instrumental for persistent collaboration with a university. Furthermore, persistent collaboration with a university is strongly associated with the strategic choice to engage in sustained collaboration with a broad range of partner types. Finally, the analysis reveals that geographical proximity between a firm and a university may facilitate the initiation of a collaboration, although the nearest university is not necessarily the most suitable partner. This is illustrated by the finding that geographical proximity between a firm and a university does not matter for keeping together in a persistent collaboration.

Keywords

University–industry collaboration; Absorptive capacity; Collaborative capabilities; University graduates; Geographical proximity; Openness; Technically oriented universities

1. Introduction

The innovation literature suggests substantial advantages associated with university–industry collaboration on innovation, with the most commonly documented advantage concerning product innovation, whether expressed as revenues derived from new or improved products (e.g. Lööf and Broström, 2008) or as the likelihood of introducing new-to-the-market innovations (e.g. Hewitt-Dundas et al., 2019). However, despite the suggested advantages for firms, collaboration with universities does not always prove frictionless and successful. Indeed, successful collaboration sometimes comes at a high cost (e.g. Laursen and Salter, 2004), and universities can be perceived as overly bureaucratic partners (Perkmann and Salter, 2012). The challenges associated with university–industry collaboration involve, for example, differences in institutional logics, including incentives and the orientation towards openness between universities and industry, and different approaches to intellectual property (Bruneel et al., 2010; Criscuolo et al., 2018; Hewitt-Dundas et al., 2019). In addition, the cognitive distance between firms and universities (Boschma, 2005), as well as firms’ lack of absorptive capacity (Cohen and Levinthal, 1990; Rajalo and Vadi, 2017), can also prove significant challenges when it comes to collaboration. Such challenges may prevent the initiation of collaboration or render collaboration difficult to the point that it is discontinued due to the failure to meet expectations.

A recent study 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 represent a learning effect (Hewitt-Dundas et al., 2019). However, relatively little is known about the specific characteristics of those firms that learn how to collaborate with universities to the extent that they consider such collaboration to be so valuable that an explicit strategic choice is made to persistently engage in collaboration with universities. Nor is it known whether a firm’s choice to engage in persistent collaboration with a university applies to the university sector in general or to a particular university.¹ Given that collaboration is a process rooted in the interactions that occur between individuals within the collaborating organisations, it is tempting to assume the existence of a preference for keeping together with the same university partner. Yet, to the best of our knowledge, there is currently no systematic evidence to support such an assumption.

Despite the considerable advances that have been made in recent years in the literature on university–industry collaboration on innovation, a number of unanswered questions remain. Among those questions, there appear to be two major issues. First, the literature tends to treat universities as a uniform entity, thereby ignoring the fact that universities, just like firms, have different characteristics and operate under different conditions. Second, collaboration with a university is treated as something that a firm either does or does not engage in, although in practice it is clearly a process involving several actions and outcomes. The present paper focuses on what distinguishes persistence in relation to university–industry collaboration from the initiation and discontinuation of a collaboration. We interpret persistent collaboration as a strong indicator that the partners perceive the collaboration to be both successful and beneficial. While the notion of bounded rationality might be of relevance here, the collaboration partners would be unlikely to continue a collaboration from which they derive no value. Although we cannot know whether the initiation of a given collaboration will mark the beginning of a persistent

¹ Hewitt-Dundas et al. (2019) state that focusing on university collaboration as a single entity represents a serious limitation when it comes to studying the role of learning effects in relation to university–industry collaboration.

collaboration, the discontinuation of a given collaboration can be interpreted as an indication of either an unsuccessful collaboration or a partnership that has achieved its goals (Belderbos et al., 2015). Regardless, discontinuation represents the opposite of an explicit strategic choice to persistently engage in collaboration with a university.

In this paper, we explore the factors that characterise those firms that engage in persistent collaboration with universities on innovation. The analyses take advantage of unique longitudinal Danish innovation data, which allows for the determination of whether a firm is initiating a collaboration with specific Danish universities, whether it is discontinuing a collaboration or whether a collaboration occurs over consecutive periods (i.e. a persistent collaboration). The analyses focus on Denmark's two main technical universities, which operate in metropolitan and peripheral regions, respectively. Therefore, we also discuss whether the association between firm-specific factors and persistence is related to the regional context.

The utilised innovation data are combined with matched employer–employee register data, which allows for the identification of both firm and employee characteristics. The literature provides substantial evidence concerning the characteristics of those firms that are most likely to collaborate with universities on innovation. Based on such evidence, the typical firm involved in university collaboration is relatively large, dedicates resources to research and development (R&D) activities, has a high share of highly educated employees, generally collaborates openly on innovation and is located geographically proximate to a university (e.g. Drejer and Østergaard, 2017; Johnston and Huggins, 2021; Laursen and Salter, 2004). However, to the best of our knowledge, no prior study has assessed the importance of these factors in relation to the persistence of a collaboration, as opposed to the initiation and discontinuation of one. Therefore, the present analysis is explorative rather than hypothesis-driven. In addition to exploring the factors associated with persistent collaboration, we also investigate the extent to which a firm's persistent collaboration with universities on innovation involves the same universities or a shifting line-up of universities.

This paper contributes to the literature on university–industry interaction by determining what distinguishes persistence in university–industry collaboration from the initiation and discontinuation of a collaboration. It not only documents that more than a third of firms that collaborate with universities do so persistently, but also that such persistence occurs in relation to the same university. In addition, the findings underline how managers who want to incorporate persistent collaboration with universities into their innovation strategy must persistently invest in both the knowledge and social dimensions of absorptive capacity. While the knowledge dimension is related to R&D, the social dimension is related to employees. Firms with employees who are graduates of a specific university have an advantage in terms of connecting their firm with that university. The dependence on individuals does not appear to diminish over time, since having employees from a specific university not only increases the likelihood of initiating a collaboration with that university, but also the likelihood of engaging in persistent collaboration. This is an important finding with regard to innovation policy. Furthermore, this paper confirms that persistent collaboration with universities forms part of a strategic approach to innovation whereby firms incorporate knowledge from a broad range of collaboration partners. Finally, the findings of this paper also contribute to the literature by showing that geographical proximity to universities is mainly of relevance to the initiation of a collaboration, whereas a nearby university is not necessarily the most valuable collaboration

partner in the long run. This may be in part explained by the development of other types of proximities between collaboration partners, which reduces the importance of geographical proximity as a facilitating factor.

2. Conceptual background and theoretical framework

Collaboration with universities on innovation is generally considered beneficial for firms. In addition to positive effects regarding product innovation and the newness of innovation (e.g. Hewitt-Dundas et al., 2019; Lööf and Broström, 2008), there are also less direct effects, including increased R&D spending after collaboration (Scandura, 2016),² increased hiring of university graduates (Evers, 2020) as well as increased legitimacy and enhanced reputation (Johnston and Huggins, 2021; Sine et al., 2003). Studies have also shown that high-tech firms that enjoy strong relationships with universities hold more patents and have lower costs with regard to internal R&D than firms with no such relationships (George et al., 2002). Moreover, collaboration with universities has also been found to be associated with higher productivity and increased originality of innovations among manufacturing firms (Hanel and St-Pierre, 2006). Thus, the potential value that firms derive from collaborating with universities can materialise in many ways, albeit with substantial time lags (Johnston and Huggins, 2021).

Yet, collaboration with universities can prove challenging, and it remains relatively rare for universities to serve as partners in firms' innovation processes. Firms typically collaborate with organisations that are cognitively close, demonstrate aligned economic interests and share similar institutional logics (Criscuolo et al., 2018). Collaboration with universities provides access to more distant knowledge, although the different institutional logics, for example, related to the incentive structure, openness and disclosure of the generated knowledge and results, render coordination and collaboration both difficult and costly (Bruneel et al., 2010; Criscuolo et al., 2018; Hewitt-Dundas et al., 2019). The lack of absorptive capacity—defined as the ability to recognise the value of, assimilate and apply new knowledge (Cohen and Levinthal, 1990)—within a firm can also be an important barrier to collaboration. Thus, R&D activity has been documented to be associated with the likelihood of engaging in and achieving positive outcomes from collaboration with universities (Bishop et al., 2011; Laursen and Salter, 2004; Laursen et al., 2011; Schartinger et al., 2002). Similarly, the presence of university graduates among the workforce also increases firms' absorptive capacity (Bruneel et al., 2010; Laursen et al., 2011), as well as helping to overcome the institutional barriers between a firm and a university. Moreover, Drejer and Østergaard (2017) identified a clear tendency towards an 'alumni effect' in university–industry collaboration, whereby the presence of employees who are graduates of a specific university is positively associated with a firm's likelihood of collaborating with that specific university. This alumni effect is interpreted as graduates not only enhancing their firm's absorptive capacity but also being repositories of social capital, since collaboration on innovation is a process rooted in the interactions between individuals within the collaborating organisations (Ankrah et al.,

² Studies have found that firms involved in university–industry collaboration increase their R&D efforts in the long run (Scandura, 2016; Steinmo and Rasmussen, 2018), indicating the existence of a mutually reinforcing relationship between R&D and university–industry collaboration. From a university's perspective, firms that have a history of investing in R&D send a signal that is likely to mark them out as more attractive long-term collaboration partners. Thus, these studies indicate that R&D spending can influence a firm's likelihood of persistently collaborating with a university on innovation.

2013). The issues discussed above relate closely to the notions of different types of proximities, particularly institutional, cognitive and social proximity (Boschma, 2005).

Firms tend to collaborate with local universities, which indicates that geographical proximity might help to overcome the barriers to collaboration (Broström, 2010; D'Este et al., 2013; Laursen et al., 2011). Bounded rationality renders a search for local collaboration partners more likely, although it is not necessarily solely a short geographical distance that influences the choice of a partner. Indeed, there are many channels of knowledge transfer between universities and firms. Bekkers and Bodas Freitas (2008) found that firms consider informal contacts and the employment of university graduates to be more important forms of knowledge transfer than joint R&D projects. This finding has implications for collaboration patterns because graduate mobility is often geographically limited, with most graduates remaining in or close to their university region (e.g. Drejer and Østergaard, 2017; Faggian and McCann, 2009; Krabel and Flöther, 2014). Other types of university–industry interactions are also facilitated by geographical proximity, such as student projects as well as student trainees or staff members holding positions in both a firm and a university (Bekkers and Bodas Freitas, 2008). Thus, firms might prefer to collaborate with local universities due to employees' or managers' personal relationships or the desire to attract talented graduates. Although personal relationships often overlap with geographical proximity, being geographically proximate does not necessarily render someone part of the local network (Breschi and Lissoni, 2001; Drejer and Østergaard, 2017; Østergaard, 2009). However, Drejer and Østergaard (2017) found that even after controlling for the hiring of graduates from a local university, geographical proximity still tends to play a role in university–industry collaboration, albeit to varying extents in different types of regions. In addition, a university can play an important role in establishing local collaborations. A university, especially when it has a regional development mission, is often active in terms of building local relationships, appearing in local news and supporting local industry as an aspect of building local legitimacy. Thus, a short geographical distance might make it easier for a firm to initiate a collaboration with a university.

Finally, prior analyses have revealed firms that follow a strategy of being open (to a certain extent) in their search for innovation inputs to be more likely to collaborate with universities (Laursen and Salter, 2004, 2006). This was confirmed by Criscuolo et al. (2018), where it was also found that sourcing knowledge for innovation solely from universities represents one of the least commonly used strategies for firms, while sourcing knowledge from a combination of universities with internal sources, customers and suppliers represents a much more common approach.

A gap in the current literature concerns the role played by the factors discussed above in relation to persistent university–industry collaboration. It has been established in the innovation literature that collaborative innovation networks often evolve over time from business relationships with suppliers, customers and competitors (Tidd, 2001). Repeated interactions increase trust, reduce transaction costs and develop both social bonds and cognitively close knowledge (Tidd, 2001). This gives rise to a path-dependent process whereby previous collaboration increases the likelihood of future collaboration (Belderbos et al., 2015; Hewitt-Dundas et al., 2019; Tidd, 2001). This finding is in accordance with the work of Johnston and Huggins (2018), who found that firms' assessment of the credibility of a given university as a collaboration partner should be considered an individual-level concept that focuses on the individual university researcher. This highlights the importance of

looking at specific universities when seeking to increase the understanding of university–industry collaboration, rather than considering the university sector in general.

Social proximity, as expressed by close social relationships between collaboration partners, expands and strengthens social capital, thereby indicating that the partners will tend to collaborate over a longer period of time or to engage in successive collaborations. If the initial barriers to collaboration are overcome, the collaborating firm gains experience of collaborating with universities (Hewitt-Dundas et al., 2019). The partners develop trust, a shared language and a collaboration structure (Rajalo and Vadi, 2017), all of which facilitates smoother coordination, interaction and knowledge exchange, which can make it easier for a firm to collaborate with the same university again in the future and support the success of the collaboration. This suggests that different types of proximities interact (Johnston and Huggins, 2021), meaning that the social proximity developed during the course of a collaboration may help to overcome the lack of other types of proximities.

Relations will develop between organisations as the collaboration process unfolds, and they may become less dependent on particular individuals over time, which implies that trust can also be viewed as a multilevel phenomenon that emerges through both previous personal and organisational interactions (Gulati and Sytch, 2008). Accordingly, once a collaboration has been established, the related interactions and knowledge exchanges will contribute to building trust and establishing norms of appropriate behaviour, which represent core elements of social capital (Landry et al., 2002). The development of a plethora of boundary-spanning relations may diminish the relative importance of a particular individual's personal network over time. Moreover, investment in a collaboration represents a sunk cost that increases a firm's likelihood of continuing to collaborate with the same university in order to avoid incurring similar costs again.

Persistent collaboration can either create inertia that limits innovation (Tidd, 2001) or support effective learning for innovation (Belderbos et al., 2015). Belderbos et al. (2015) found that persistent R&D collaboration has a positive effect on the innovation performance of all types of partners, which indicates that the positive effects of persistence outweigh the potential negative effects. Similarly, Petruzzelli (2011) found that prior experience involving the joint development of inventions between universities and firms positively influences the value of current joint inventions. This implies that persistence is not only an indication of a successful collaboration, but also that persistence increases the likelihood of continued or increased success in relation to the collaboration. Therefore, it is important to identify the extent to which factors such as R&D, geographical proximity, openness and employee relationships are associated with persistent university–industry collaboration on innovation, as opposed to the initiation and discontinuation of collaborations. This issue is explored empirically in the following sections.

3. Data and methods

The empirical analysis of persistence in relation to university–industry collaboration is performed using data concerning firms located in Denmark and their collaborations with specific Danish universities. More specifically, the analysis focuses on the two most technically oriented universities in Denmark, namely the Technical University of Denmark (DTU) and Aalborg University (AAU), because technical areas account for the majority of university collaborations with industry (e.g. Meyer-Krahmer and Schmoch, 1998; Schartinger et al., 2002).

However, additional analyses concerning the three largest Danish universities are included in the robustness tests. The utilised data are derived from the annual Danish Research and Innovation Survey as well as from register-based employer–employee data concerning both firm and employee characteristics obtained from Statistics Denmark. The survey data cover the periods 2010–2012 and 2013–2015, whereas the register data cover the period 2010–2014.

The Research and Innovation Survey is the Danish equivalent of the European Community Innovation Survey. The data are derived from responses given by 5,000 randomly selected firms from among a population of 22,000 firms. The annual survey is mandatory and based on partly overlapping samples, which allows for individual firms to be followed over time. The higher the number of employees that a firm has, the higher the probability of that firm being sampled. Industries with a high degree of R&D intensity have broader coverage than other industries. A valuable feature of the survey is the fact that it includes a question concerning which *specific* Danish universities firms have collaborated with on innovation activities.

Persistence is defined as collaboration with a university in the two consecutive periods 2010–2012 and 2013–2015. In the survey, collaboration is conditional on innovation activity. Furthermore, collaboration is not necessarily contractually formalised or supported by public funds. Innovation activities are defined as having introduced new or significantly improved products, manufacturing processes, operations, organisational structures or marketing methods within the analysed period, or as having ongoing or abandoned innovation activities during the period covered by the survey. As firms that participate in the survey are asked about all of their innovation activities, they can have several ongoing as well as completed innovation activities at the same time. This is the case for approximately half of the innovative companies. It is not possible to determine from the survey whether the collaboration with a university during the period 2010–2012 involved a completed or an ongoing innovation project (or both). If the collaboration in 2010–2012 involves an ongoing innovation project, then collaboration in both periods 2010–2012 and 2013–2015 may reflect a long-term project collaboration rather than a repeated collaboration. However, in terms of persistence, the differences between long-term and repeated collaborations may not be substantial because projects without progress or perceived value added are likely to be terminated.³

3.1. Contextual setting

Denmark is a small country that is home to only eight universities. DTU and AAU are the main technically oriented universities in the country, and the vast majority of engineering graduates have been trained at one of those two universities. As illustrated in Table 1, the two universities have different characteristics and operate under different conditions in different regional contexts. The latter point allows us to address whether the association between firm-specific factors and persistence varies between metropolitan and peripheral regions.

DTU is a relatively old university located in the densely populated metropolitan region of Copenhagen. In addition to receiving high basic funding from the government, it also attracts a considerable amount of external funding

³ We have tested the validity of this assumption by exploring the relation between persistence and firms' perception of the importance of using universities as a source of innovation. The results show a positive association between persistence and perceived importance.

from firms as well as competitive research grants. It accounts for the highest share of firms collaborating with universities in Denmark.

AAU is a young university located in peripheral North Denmark—the Danish region located the furthest away from Copenhagen. Although it has twice the number of students, it receives less than half of the basic government funding for research that DTU receives. Although the Danish Industry Association (2016) found AAU to be more open to collaboration with firms than DTU, it also attracts less external funding.

Both universities are ranked within the top 50–100 according to the Times Higher Education World University Rankings in Engineering and Technology, with DTU being ranked the highest of the two.

	Aalborg University	The Technical University of Denmark
University characteristics 2015	<ul style="list-style-type: none"> Established in 1974. Multi-faculty university. Basic state funding for research 0.73 billion DKK, 10.7% growth 2010–2015. External funding 0.61 billion DKK, 44.3% growth 2010–2015. 20,750 enrolled students, of whom 8,400 study the technical and natural sciences; 1,900 technical and natural science graduates. Research staff: 640 FTE* within the technical and natural sciences. Ranked 96 in the Times Higher Education World University Rankings in Engineering and Technology 2016–2017**. 	<ul style="list-style-type: none"> Established in 1829. Technical university. Basic state funding for research 1.55 billion DKK, 5.6% growth 2010–2015. External funding 1.92 billion DKK, 23.1% growth 2010–2015. 10,600 enrolled students; 2,500 technical and natural science graduates. Research staff: 2,600 FTE* within the technical and natural sciences. Ranked 53 in Times Higher Education World University Rankings in Engineering and Technology 2016–2017**.
Regional characteristics 2015	<ul style="list-style-type: none"> Peripheral region. 583,000 inhabitants. 15% of population aged 25–34 years have a university bachelor's or master's degree. Industry structure specialised in manufacturing, construction and primary sector. Relatively high number of small firms. Share of innovative firms 44% in 2012 and 39% in 2015. 	<ul style="list-style-type: none"> Metropolitan region (including capital city). 1,768,000 inhabitants. 33% of population aged 25–34 years have a university bachelor's or master's degree. Industry structure specialised in services, particularly ICT, finance and insurance. Relatively high number of large firms. Share of innovative firms 46% in 2012 and 47% in 2015.
Other	<ul style="list-style-type: none"> The only university in the region. Founded with the clear aim of helping to change the development path of the region. 	<ul style="list-style-type: none"> One of four universities in the region. Until 1974, the only institution training engineers at the master's level in Denmark.

Sources: Universities Denmark, Statistics Denmark, Times Higher Educations. Growth in funding is given in fixed prices.

* FTE = Full-time Equivalent employees. ** First available year for Aalborg University.

Table 1. University and regional characteristics.

3.2. Models and variables

The firm-specific factors associated with persistence in relation to university–industry collaboration on innovation are investigated empirically using multinomial logistic regression models. The multinomial logistic regression models allow us to simultaneously analyse the following four possible outcomes:

- i. No university collaboration on innovation in either period.
- ii. Discontinued university collaboration: University collaboration in 2010–2012, but no reported collaboration in 2013–2015.
- iii. Initiation of university collaboration: University collaboration in 2013–2015, but no reported collaboration in 2010–2012.
- iv. Persistent university collaboration: University collaboration in 2010–2012 and 2013–2015.

We analyse two different models. Model 1 explores persistence in relation to university–industry collaboration in general (i.e. with any Danish university), while Model 2 explores persistence with a specific university, *i*. Model 2 is run separately for each university. We include both the general and specific models because the same factors are not necessarily associated with collaborating persistently with the university sector in general and with a specific university. Before presenting the results of Model 2, we analyse the extent to which persistent collaboration occurs with the same or different universities.

The analyses are run on 2,600 firms that participated in the Research and Innovation Survey in both 2010–2012 and 2013–2015.

Model 1. General model: Collaboration on innovation with Danish universities

In Model 1, the dependent variable measures collaboration with Danish universities over the periods 2010–2012 and 2013–2015. In this model, it is not necessary that the same university is a persistent collaboration partner during the two periods. Instead, the model explores persistent collaboration with the university sector in general.

Model 1:

$$\text{Collaboration DKUNI} = \alpha + \beta_1(\text{Sharehigh}) + \beta_2(\text{Persistent R\&D}) + \beta_3(\text{Openness 2010–12}) + \beta_4(\text{Openness 2013–15}) + \beta_5(\text{Distance_nearest university}) + \beta_6(\text{region}) + \beta_7(\text{Industry}) + \beta_8(\text{Size}) + \varepsilon$$

The explanatory variables within the general model are those variables that several previous studies have found to be associated with firms' collaboration with universities, namely the share of highly educated employees, the R&D activity and the general openness towards collaboration in the innovation process. Highly educated employees and R&D are indicators of absorptive capacity. Additionally, highly educated employees can also be an indicator of institutional proximity between a firm and universities.

The share of highly educated employees (*Sharehigh*) is measured as the average share of university graduates with at least a bachelor's degree who were employed in the firm during the period 2010–2014. The variable is based on register data. The R&D measure (*Persistent R&D*) is a dummy variable expressing whether a firm has engaged in persistent internal R&D activity during the periods 2010–2012 and 2013–2015. The R&D persistency

variable is defined in a different way to the university collaboration variable, which has four possible outcomes, because very few firms that engaged in persistent university collaboration within the sample were active in terms of R&D during only one period.⁴ The variable is based on data from the Research and Innovation Survey.

Firms' use of multiple types of collaboration partners in relation to innovation (i.e. openness; Laursen and Salter, 2004) is also included as an explanatory variable. In fact, two discrete variables express the number of different types of partners,⁵ excluding universities and other higher education institutions, that the firms collaborated with during the periods 2010–2012 (*Openness 2010–12*) and 2013–2015 (*Openness 2013–15*). The variables are based on Research and Innovation Survey data, and they range from zero to ten.

As the distance to a university may affect a firm's likelihood of engaging in collaboration, the distance to the nearest university is included as a control variable (*Distance_nearest university*). In accordance with the method proposed by Boschma et al. (2014), the value of the logarithm of the road travel time between a firm and the nearest university is subtracted from the highest value for the travel time within the dataset. This yields a value of zero for firms located the greatest distance from a university. The location data are available by postcode area in the register data. The travel time between firms and universities located within the same postcode area is set to one minute, which slightly underestimates the actual travel time.

As the travel distance to a university varies across regions, with firms located in the capital region being only a relatively short distance from the nearest university, we also control for region. Moreover, we control for the broad industry affiliation and firm size (i.e. number of employees), since firm size in particular has been found to be strongly associated with university collaboration (e.g. Laursen and Salter, 2004).

Model 2. Collaboration on innovation with a specific university

In Model 2, the dependent variable measures collaboration with the same university during the periods 2010–2012 and 2013–2015. Model 2 is run separately for each university. In the model, *i* refers to the specific university, while *j* refers to all universities other than *i*.

Model 2:

$$\text{Collaboration } UNI_i = \alpha + \beta_1(\text{Share employees } UNI_i) + \beta_2(\text{Dummy managers } UNI_i) + \beta_3(\text{Sharehigh } UNI_i) + \beta_4(\text{Persistent R\&D}) + \beta_5(\text{Openness 2010–12}) + \beta_6(\text{Openness 2013–15}) + \beta_7(\text{Distance } UNI_i) + \beta_8(\text{Industry}) + \beta_9(\text{Size}) + \epsilon$$

In this model, there are two variables expressing the share of highly educated employees. One variable measures the share of employees who are graduates of the specific collaborating university (*Share employees UNI_i*). This variable allows us to explore the presence of an alumni effect, where emphasis is placed not only on the

⁴ Using an R&D measure with four outcomes (no R&D, persistent R&D, initiation or discontinuation) creates problems with regard to the quasi-complete separation of data points in some model specifications.

⁵ 1. Suppliers, 2. Private customers, 3. Public customers, 4. Competitors, 5. Danish government-approved research and technology organisations, 6. Firms in other industries (excluding customers and suppliers), 7. Private R&D companies, 8. Public research institutions, 9. Public service providers and 10. Other public partners.

importance of highly educated employees (absorptive capacity and institutional proximity), but also on employees with an alumni relation with the relevant university. The second variable controls for the share of highly educated employees who are graduates of universities other than the collaborating university (*Sharehigh UNI_i*). Additionally, as managers may have more influence on who a firm collaborates with than employees without managerial responsibilities, we also include a dummy variable expressing whether the firm has managers who are graduates of the collaborating university (*Dummy managers UNI_i*). All three variables are based on register data.

The persistent R&D variable and the openness variables are measured in the same way as in Model 1.

In contrast to Model 1, where the distance variable is measured as the distance between the firm and the nearest university, the distance measure in Model 2 explores the importance of the geographical proximity between the firm and the actual collaborating university (*Distance UNI_i*). As we measure the distance to the actual collaborating university, the region is not included as a control in Model 2.

As is the case for Model 1, Model 2 controls for the firm size and industry affiliation using register-based variables.

The issue of endogeneity is often a concern in studies of university–industry collaboration on innovation, which is also the case for this study. As the decision to collaborate with a university on the one hand, and R&D activity and the hiring of university graduates on the other hand, may express different ways for firms to strengthen their innovation capabilities and, therefore, be interrelated elements of firms' innovation strategy, there is a potential endogeneity issue in both models. However, we consider this to mainly be a challenge in relation to firms' decision to engage in collaboration with universities in the first place, not a major problem in relation to the decision to discontinue a collaboration or to collaborate persistently.

	Share	Mean	SD
Collaboration DKUNI: 0 (no collaboration in either period)	85.64%		
Collaboration DKUNI: 1 (discontinuation of collaboration)	4.32%		
Collaboration DKUNI: 2 (initiation of collaboration)	4.70%		
Collaboration DKUNI: 3 (persistent collaboration)	5.34%		
Collaboration UNL _i , <i>i</i> = AAU: 0 (no collaboration in either period)	94.21%		
Collaboration UNL _i , <i>i</i> = AAU: 1 (discontinuation of collaboration)	1.62%		
Collaboration UNL _i , <i>i</i> = AAU: 2 (initiation of collaboration)	2.11%		
Collaboration UNL _i , <i>i</i> = AAU: 3 (persistent collaboration)	2.07%		
Collaboration UNL _i , <i>i</i> = DTU: 0 (no collaboration in either period)	92.33%		
Collaboration UNL _i , <i>i</i> = DTU: 1 (discontinuation of collaboration)	1.99%		
Collaboration UNL _i , <i>i</i> = DTU: 2 (initiation of collaboration)	2.78%		
Collaboration UNL _i , <i>i</i> = DTU: 3 (persistent collaboration)	2.89%		
Sharehigh		0.150	0.201
Share employees UNL _i , <i>i</i> = AAU		0.017	0.056
Share employees UNL _i , <i>i</i> = DTU		0.020	0.069
Dummy managers UNL _i , <i>i</i> = AAU		0.035	0.183
Dummy managers UNL _i , <i>i</i> = DTU		0.041	0.199
Sharehigh UNL _j , <i>j</i> ≠ <i>i</i> , <i>i</i> = AAU		0.133	0.189
Sharehigh UNL _j , <i>j</i> ≠ <i>i</i> , <i>i</i> = DTU		0.130	0.180
Persistent R&D		0.216	0.412
Openness 2010-12		0.879	1.904
Openness 2013-15		0.786	1.864
Distance_nearest university		3.556	1.536
Distance UNL _i , <i>i</i> = AAU		0.973	0.746
Distance UNL _i , <i>i</i> = DTU		2.095	1.323
Region: Capital	43.06%		
Region: Zealand	7.24%		
Region: Southern Denmark	20.14%		
Region: Central Denmark	20.48%		
Region: North Denmark	9.09%		
Industry: Other	6.88%		
Industry: High-/medium high-tech manufacturing	11.73%		
Industry: Low-/medium low-tech manufacturing	16.13%		
Industry: Knowledge intensive services	32.63%		
Industry: Other services	32.63%		
Firm size: Less than 50 employees	42.93%		
Firm size: 50-99 employees	18.91%		
Firm size: 100-249 employees	26.50%		
Firm size: 250+ employees	11.65%		
Share of firms with employees from UNL _i , <i>i</i> = AAU	38.60%		
Share of firms with employees from UNL _i , <i>i</i> = DTU	28.76%		
Share innovative firms 2010-12	58.61%		
Share innovative firms 2013-15	52.85 %		

See supplementary material for the correlation matrix.

Table 2. Descriptive statistics (N=2660).

Table 2 shows that the vast majority of firms in Denmark do not collaborate with universities on innovation. In fact, 85.6% of the firms included in the sample did not collaborate with a university during either of the two investigated periods. Only firms that engage in innovation activities can report collaboration on innovation in the survey. The share of innovative firms decreases from 58.6% to 52.9% between 2010–2012 and 2013–2015. This share is higher than the regional shares of innovative firms indicated in Table 1, which is due to the fact that innovative firms are more likely to be repeatedly included in the survey.

Some 5.8% of the included firms collaborated with AAU during one or both of the investigated periods, whereas the corresponding percentage is 7.7% for DTU. For both of the universities, the percentages of firms that initiated a collaboration and collaborated persistently over the two periods are quite similar. The shares of firms that collaborated with the universities increases slightly from 2010–2012 to 2013–2015. If the lower starting point affects the extent of the persistence in terms of collaboration, it is in a downwards direction.

The average share of highly educated employees within the included firms is 15.0%. The average share of employees educated at DTU is slightly higher than that of employees educated at AAU, although for both of the universities the shares are actually quite low (2.0% versus 1.7% for DTU and AAU, respectively). The proportion of firms with managers from DTU is also higher than the proportion with managers from AAU (4.1% versus 3.5%, respectively).

The share of firms with persistent internal R&D activity is 21.6%. The mean value of openness is 0.879 in 2010–2012 and 0.786 in 2013–2015, which indicates that, on average, firms collaborate on innovation with less than one type of external partner (universities excluded). However, this proportion is skewed, as by definition non-innovation-active firms have no innovation-related collaboration partners.

As expected, the average travel distance between the firms and DTU is considerably lower—indicated by a higher value—than the distance between the firms and AAU. This is a consequence of the former university being located in the capital region, which is geographically smaller and more densely populated than the peripheral North Denmark region. Additionally, due to the high concentration of firms and universities within the capital region (43.1% of the included firms are located in the capital region), the average travel distance to the nearest university is considerably lower than the average travel distance to either of the two investigated universities.

In accordance with the Danish industry structure, service firms and small firms dominate the sample, with 42.9% of the firms having less than 50 employees.

4. Results

Table 3 presents the results of Model 1 concerning the likelihood of a firm collaborating on innovation with a Danish university. The analysis reveals that it is only persistent openness (i.e. a high degree of openness during both investigated periods) that distinguishes persistent collaboration from the initiation or discontinuation of a given collaboration with a university. This suggests that a persistent and broad collaboration pattern in relation to innovation is conducive to persistent collaboration with universities. A special feature of firms' openness is

the fact that it is strongly associated with university collaboration during the same period. Thus, openness in 2010–2012 is positively and significantly associated with discontinued university collaboration (i.e. collaboration in 2010–2012 but not in 2013–2015), while openness in 2013–2015 is positively and significantly associated with the initiation of a collaboration in 2013–2015.

The share of highly educated employees and persistent R&D activity are both positively and significantly associated with persistent collaboration, as well as discontinuing and initiating collaboration, with a Danish university. This implies that firms are less likely to engage in collaboration with a university, however temporary, if they have a low level of absorptive capacity and a low institutional proximity to universities. Nonetheless, it is worth noting that the coefficients are lower for discontinued collaboration with a university than for the initiation of collaboration or persistent collaboration with a university.

The geographical distance between a firm and the nearest university is not significantly related to that firm's likelihood of either initiating, discontinuing or engaging persistently in collaboration with a university. In terms of controlling for the region, we find that firms located in the regions furthest away from the benchmark capital region are more likely to initiate a collaboration with a university and, for two of these regions, to collaborate persistently. This result may reflect that there is a high density of firms and universities in the geographically relatively small capital region—that is, there are also many firms located close to a university that do not engage in collaboration.

There are only a few and weakly significant industry differences. With regard to size, when compared with firms with less than 50 employees, there is a positive effect for what are considered large firms in the Danish context (i.e. firms with 250 or more employees) in relation to both the discontinuation and persistence of collaboration with a university. The effect for persistence is significant at the 5% level, while the effect for discontinuation is significant at only the 10% level. It is worth noting that 60% of the firms in the sample have less than 100 employees, while only 11% have 250 or more employees. A possible reason why we do not find statistically stronger industry and size effects, given that they are often found to be important factors in relation to collaboration with industry, is that the model includes several other explanatory variables that tend to vary with size and industry (i.e. openness, persistent R&D and share of highly educated employees).

Multinomial logistic regression model, benchmark for dependent variable: No university collaboration									
	Discontinue			Initiate			Persistence		
	Estimate		Standard Error	Estimate		Standard Error	Estimate		Standard Error
Intercept	-5.194	***	0.569	-5.315	***	0.591	-8.356	***	0.825
Distance_nearest university	0.010		0.091	-0.099		0.093	0.093		0.108
Sharehigh	1.556	**	0.660	3.695	***	0.596	3.100	***	0.782
Persistent R&D (dummy)	1.043	***	0.273	1.479	***	0.270	2.656	***	0.383
Openness 2010-12 (discrete)	0.801	***	0.052	-0.030		0.073	0.660	***	0.063
Openness 2013-15 (discrete)	-0.149	*	0.081	0.715	***	0.050	0.562	***	0.062
Industry controls (Benchmark: Lowtech manufacturing)									
Other services	-0.798	*	0.434	-0.246		0.425	-0.282		0.502
Knowledge-intensive services	0.041		0.414	-0.574		0.447	-0.884	*	0.521
Hightech manufacturing	0.121		0.413	0.552		0.398	0.064		0.448
Other	-0.434		0.611	0.738		0.540	0.938		0.670
Size controls (Benchmark: Less than 50 employees)									
50-99 employees	0.299		0.366	0.071		0.346	0.275		0.502
100-249 employees	0.348		0.317	0.040		0.294	0.305		0.384
250+ employees	0.683	*	0.350	-0.470		0.404	1.013	**	0.399
Region (Benchmark: Capital)									
North Denmark	0.460		0.425	0.848	**	0.424	0.897	*	0.539
Central Denmark	0.091		0.357	0.626	*	0.337	0.649		0.409
Southern Denmark	0.110		0.377	0.985	***	0.349	0.987	**	0.435
Zealand	0.114		0.491	-0.433		0.662	0.781		0.567
Max rescaled R ²	0.65								
Number of observations (unweighted)	2645								

*** Significant at 1% level, ** significant at 5% level, * significant at 10% level.

Table 3. Regression results of Model 1: Collaboration on innovation with a Danish university 2010–2015.

Previous studies addressing the issue of persistent collaboration with universities (e.g. Hewitt-Dundas et al., 2019) have been unable to determine whether persistent collaboration applies to the university sector in general or to a specific university. The data utilised in the present analysis reveal that 92.3% of firms involved in persistent collaboration with a Danish university collaborate persistently with the same university.⁶ Some 86.5% of firms

⁶ Or with the same universities, since a firm can collaborate persistently with more than one university at a time. Most studies either implicitly or explicitly assume that firms collaborate with only one university, although it is not uncommon to collaborate with several universities at the same time (Drejer and Østergaard, 2017; Guerini et al., 2013).

that collaborate persistently with universities outside of Denmark also collaborate persistently not only with a Danish university but with the same Danish university or universities.

Therefore, although a firm can collaborate persistently with more than one university, the results of this analysis clearly show that persistence in relation to collaboration applies to at least one recurring university partner and not to alternating universities. However, this does not necessarily imply that the same factors are associated with persistent collaboration with the university sector in general and with persistent collaboration with the same university. This issue is explored further in the following paragraphs.

The results of the analyses involving Model 2 concerning collaboration with specific universities are reported in Tables 4 and 5. These results confirm the finding of Model 1 concerning the relation between openness and collaboration, i.e. also when it comes to collaboration with a specific university, openness is strongly associated with collaboration during the same period. Accordingly, persistent collaboration with the same university is associated with a persistently high degree of openness. Model 2 also confirms the findings of Model 1 with regard to the role played by persistent R&D activity. More specifically, R&D is positively and significantly associated with discontinuing, initiating and persisting with a collaboration with the same university, although when compared with initiation and persistence, the coefficients are lower and less significant for discontinued collaborations with both investigated universities.

When it comes to the importance of highly educated employees, Tables 4 and 5 show that it is the share of employees from the specific university, not a high share of highly educated employees in general, that is associated with the likelihood of collaboration. For DTU, this applies to both discontinuation, initiation and persistence in relation to collaboration. For AAU, there is no statistically significant association with discontinued collaboration. For both universities, the coefficients are higher for initiating and, to a larger degree, persistent collaboration. Although the general share of highly educated employees is also positively and significantly associated with initiating a collaboration with AAU, the findings indicate that employees not only play a role in contributing to firms' general absorptive capacity and to the institutional proximity to universities, but can also play a role in connecting their alma mater to the firm currently employing them. This alumni effect on university collaboration was also documented by Drejer and Østergaard (2017).

There are differences between the two types of regions with the regard to the relevance of managers' educational background to collaboration. The presence within firms of managers educated at the specific university is positively and significantly associated with both initiating a collaboration and collaborating persistently with the peripherally located AAU, whereas there is only a weakly significant association with persistent collaboration with DTU. Accordingly, the managerial alumni effect appears to be stronger in the periphery than in the metropolitan region, which could indicate that managers' social networks are more important in relation to collaboration with a university located in the periphery.

As there is an alumni effect for both initiation and persistence, we cannot confirm that relations develop over time so as to become more embedded within organisations and, therefore, reduce the importance of individuals.

We also find a positive and significant association between the geographical proximity to the specific university and the initiation of a collaboration. This is in accordance with the results of previous studies, which have found that firms tend to collaborate with a local university (Broström, 2010; D'Este et al., 2013). The difference in the statistical significance of the results between AAU and DTU indicates that the geographical proximity between collaboration partners is particularly important in terms of facilitating the initiation of collaboration in the periphery. To sum up, in relation to initiation, the results indicate that geographical and certain types of social proximity (related to managers) are more important when it comes to initiating a collaboration with the peripherally located AAU than with DTU. Especially in terms of the difference in importance of geographical proximity, this could also be linked to differences in the universities' missions, as AAU has a clearer mission concerning contributing to regional development than DTU.

Somewhat surprisingly, there is a positive and significant association between the discontinuation of a collaboration and geographical proximity. This could be the result of it being relatively easy to initiate a one-off collaboration with a local university, which would lead to more initiations followed by subsequent discontinuations. We explore the nature of discontinuation further by checking the extent to which firms that discontinue collaboration with one university after 2010–2012 switch to initiating a collaboration—or continue an existing collaboration—with another university in 2013–2015. Of the firms that discontinue collaboration with DTU after 2010–2012, 94.3% do not collaborate with AAU in 2013–2015. The corresponding percentage for AAU is 88.4%. If we look at collaboration with any Danish university, 79.1% of the firms that discontinue collaboration with AAU do not collaborate with other Danish universities in the next period. For DTU, the corresponding percentage is 86.8%.

In relation to the findings of previous studies, it is interesting that we find no significant association between geographical proximity and persistent collaboration. This implies that a long geographical distance between a firm and a specific university does not hamper persistent collaboration between the two, which suggests that there is a learning-to-collaborate effect (Hewitt-Dundas et al., 2019) whereby the importance of geographical proximity as a facilitating factor becomes less important as the collaboration partners become closer in other dimensions of proximity (Boschma, 2005). This occurs regardless of the type of region.

With regard to industry effects, there is a clear pattern across the two universities of service industries—both knowledge-intensive and other services—being negatively associated with collaboration. This is also seen, albeit with weaker statistical significance, in Model 1 for university collaboration in general. This could reflect the technical fields' domination of university–industry collaborations. Furthermore, the relatively aggregated industry categories could conceal underlying industry differences within the data. In terms of size, there is only a consistent finding of the largest firms being positively associated with the discontinuation of collaboration. As mentioned above and shown in the robustness test, this can be explained by the model including several explanatory variables that typically vary with size. Thus, it is not firm size in itself that drives collaboration.

Multinomial logistic regression model, benchmark for dependent variable: No collaboration with AAU									
	Discontinue			Initiate			Persistence		
	Estimate		Standard Error	Estimate		Standard Error	Estimate		Standard Error
Intercept	-6.213	***	0.698	-6.447	***	0.635	-6.805	***	0.787
Distance UN _{l<i>i</i>} , <i>i</i> = AAU	0.322	*	0.188	0.442	***	0.158	0.193		0.203
Share employees UN _{l<i>i</i>} , <i>i</i> = AAU	3.501		2.150	5.046	***	1.645	6.847	***	1.619
Dummy managers UN _{l<i>i</i>} , <i>i</i> = AAU	0.575		0.599	1.430	***	0.480	2.014	***	0.514
Sharehigh UN _{l<i>j</i>} , <i>j</i> ≠ <i>i</i> , <i>i</i> = AAU	0.104		0.984	1.807	**	0.878	0.172		1.022
Persistent R&D (dummy)	0.761	*	0.432	1.712	***	0.404	2.020	***	0.585
Openness 2010-12 (discrete)	0.589	***	0.066	-0.169	**	0.075	0.405	***	0.075
Openness 2013-15 (discrete)	-0.188	**	0.087	0.557	***	0.060	0.367	***	0.074
Industry controls (Benchmark: Lowtech manufacturing)									
Other services	-1.200	*	0.702	-0.475		0.563	-1.482	**	0.692
Knowledge-intensive services	-0.274		0.609	-1.054	*	0.601	-1.350	**	0.626
Hightech manufacturing	0.318		0.561	0.108		0.513	-0.849		0.575
Other	0.142		0.772	1.027		0.627	0.351		0.796
Size controls (Benchmark: Less than 50 employees)									
50-99 employees	-0.394		0.717	0.099		0.491	-0.397		0.693
100-249 employees	0.180		0.527	0.036		0.428	-1.010	*	0.592
250+ employees	1.478	***	0.489	-0.092		0.513	0.379		0.525
Max rescaled R ²	0.51								
Number of observations (unweighted)	2646								

*** Significant at 1% level, ** significant at 5% level, * significant at 10% level.

Table 4. Regression results of Model 2: Collaboration on innovation with Aalborg University (AAU) 2010–2015.

Multinomial logistic regression model, benchmark for dependent variable: No collaboration with DTU									
	Discontinue			Initiate			Persistence		
	Estimate		Standard Error	Estimate		Standard Error	Estimate		Standard Error
Intercept	-6.692	***	0.661	-6.009	***	0.538	-8.160	***	0.801
Distance UN _i , $i = \text{DTU}$	0.346	***	0.134	0.234	*	0.124	0.233		0.154
Share employees UN _i , $i = \text{DTU}$	6.466	***	1.556	8.816	***	1.364	10.696	***	1.606
Dummy managers UN _i , $i = \text{DTU}$	-0.256		0.550	0.176		0.512	0.925	*	0.493
Sharehigh UN _j , $j \neq i$, $i = \text{DTU}$	-0.282		0.892	0.150		0.947	-0.049		1.064
Persistent R&D (dummy)	1.006	***	0.370	1.625	***	0.369	2.132	***	0.544
Openness 2010-12 (discrete)	0.527	***	0.057	0.016		0.066	0.487	***	0.072
Openness 2013-15 (discrete)	-0.017		0.077	0.600	***	0.057	0.490	***	0.071
Industry controls (Benchmark: Lowtech manufacturing)									
Other services	0.034		0.608	-1.019	*	0.532	-0.969		0.677
Knowledge-intensive services	-0.210		0.625	-1.570	***	0.547	-1.640	**	0.676
Hightech manufacturing	0.588		0.584	-0.235		0.452	-0.135		0.549
Other	0.400		0.801	0.615		0.606	0.862		0.786
Size controls (Benchmark: Less than 50 employees)									
50-99 employees	0.393		0.507	0.031		0.478	0.038		0.681
100-249 employees	0.183		0.446	0.354		0.382	0.021		0.529
250+ employees	1.199	***	0.432	0.212		0.494	0.748		0.547
Max rescaled R ²	0.57								
Number of observations (unweighted)	2647								

*** Significant at 1% level, ** significant at 5% level, * significant at 10% level.

Table 5. Regression results of Model 2: Collaboration on innovation with Technical University of Denmark (DTU) 2010–2015.

The correlation table, which is included in the supplementary material, reveals that none of the explanatory variables included in the same models are highly correlated. As an additional test for any possible multicollinearity issues, we conduct a step-wise removal of variables (please see supplementary material). This reveals a relation between openness in 2010–2012 and 2013–2015 in both models. For Model 2, the removal of all other variables, except size and industry controls, renders shorter geographical distance being positively associated with persistent collaboration, albeit only weakly so for AAU.

4.1. Robustness tests

This paper focuses on firms' collaboration with Denmark's two main technical universities. However, to test the robustness of the findings, we also run Model 2 for the three largest universities in Denmark, namely Copenhagen University, Aarhus University and the University of Southern Denmark. All three universities are multi-faculty institutions, and they all place a lower emphasis on the technical sciences than AAU and DTU. The results confirm

the findings concerning the roles played by persistent R&D and openness as well as the lack of a statistically significant association between geographical proximity and persistent collaboration. The findings concerning both employees and managers vary across the three universities.

As an additional robustness test, Model 1 and Model 2 are tested for all five universities using the share of science, technology, engineering and maths (STEM) employees from the specific university, rather than the share of all employees from that university, as an explanatory variable. The results confirm the results presented in Tables 4 and 5. Finally, we test the robustness of the results for AAU and DTU using different model specifications. Separate models of the initiation of collaboration only are run for each university. These models confirm the findings concerning initiation reported in Tables 4 and 5. Moreover, these findings, when combined with the findings mentioned above concerning the discontinuation of collaboration with one university rarely being followed by the initiation of collaboration with another university, indicate that the models do not violate the assumption regarding the independence of irrelevant alternatives.

The results of the above-mentioned robustness tests are available in the supplementary material. In relation to openness, we also test whether the strong relation between openness and collaboration in the same period can be explained by firms not being innovative in the period where no collaboration occurs. However, the results remain stable when the models are run on a dataset that only includes firms that are innovative in both periods.

5. Concluding discussion

The innovation literature stresses how, to a large extent, innovation is a collaborative process. Although customers and suppliers represent the most common innovation partners, the role of universities in relation to firms' innovation has received a great deal of attention, with some scholars suggesting the university sector to be an underutilised source of innovation (Huggins and Kitagawa, 2012). Yet, collaboration with a university is a complicated process when it comes to both establishing and maintaining the collaboration. One contribution made to the innovation literature by the present paper is that we explore university–industry collaboration with regard to three different actions, namely initiation, discontinuation and persistence.

Due to differences in institutional logics between firms and universities, university–industry collaboration on innovation is not always frictionless and successful. Thus, those firms that initiate a collaboration with a university can either learn to handle such differences and choose to include persistent university collaboration as part of their innovation strategy or opt to discontinue the collaboration. Discontinuation may be due to either the accomplishment of a specific aim through the collaboration or the failure to establish a well-functioning collaboration wherein the benefits exceed the associated costs. In contrast to discontinuation, persistent university–industry collaboration is an indicator of successful collaboration.

This paper also documents how persistence is relatively common in relation to university–industry collaboration on innovation, with more than a third of firms that engage in collaboration with universities continuing to collaborate with the same university, either on ongoing or multiple innovation projects, during at least two consecutive periods. The analyses further show that the discontinuation of a collaboration with one university is rarely followed by the initiation of a collaboration with another university. In other words, although collaboration

with more than one university at the same time is relatively common, switching between university partners is relatively uncommon.

In addition to finding that persistent collaboration with universities involves persistent collaboration with the same specific university, the main findings of the analyses are as follows. First, investment in knowledge-intensive collaborative capabilities, as expressed by investing in both persistent R&D activity and university-specific human capital, is necessary but not sufficient for persistent collaboration with a university. R&D and university-specific human capital reflect two different dimensions of absorptive capacity. R&D reflects the traditional perception of absorptive capacity as a general ability to absorb and utilise external knowledge. University-specific human capital is more likely to reflect a field-specific absorptive capacity while at the same time overlapping with social and institutional abilities to access and incorporate university knowledge. Thus, the distinction between absorptive capacity and social and institutional proximity becomes blurred, indicating the need for a more 'holistic understanding of proximities' (Johnston and Huggins, 2021, p. 48).

Second, persistent collaboration with universities is strongly associated with the strategic decision to collaborate persistently with a broad range of different partners, which underlines the importance of openness for innovation (Laursen and Salter, 2006). The analyses document the co-occurrence of openness and university-collaboration (i.e. openness does not mainly serve as 'preparation' for later collaboration with universities). This result could be a reflection of the finding reported by Criscuolo et al. (2018), who noted that cognitively proximate knowledge sources, such as customers and suppliers, can help firms to integrate knowledge from cognitively more distant partners, such as universities. In other words, collaboration with universities is facilitated by collaboration with multiple other types of partners. Furthermore, the co-occurrence of openness and university collaboration indicates that the facilitation provided by the other partner types is a simultaneous process, not an experience that can be 'stored' for later use.

Third, geographical proximity between a firm and a university facilitates the initiation of a collaboration, although in terms of persistence, the nearest university is not necessarily the most suitable partner. This is underlined by the finding that geographical proximity is not associated with keeping together in a persistent collaboration with a specific university. However, location may still matter for university–industry collaboration. In the peripheral North Denmark region, there are fewer potential local collaboration partners available from the perspective of the university. Yet, AAU was created with a clear regional mission. This may contribute to explaining why we find a statistically stronger association between the initiation of a collaboration and geographical proximity to AAU when compared with DTU. Furthermore, graduates from a university with a strong local mission may develop a partiality for that university, which could explain why we find a stronger alumni effect for managers from AAU than for managers from DTU.

5.1. Implications for theory

The present findings indicate that due to treating university collaboration as something that a firm either does or does not engage in, our understanding of the role played by geographical proximity may be oversimplified. Prior studies have found that firms are more likely to collaborate with local universities. Drejer and Østergaard (2017) partially associated this with a geographically bound alumni effect, although the findings of this paper indicate that innovation theory may implicitly overemphasise the search process and, therefore, the initiation of university–industry collaboration. A focus on initiation may result in a bias towards a particular type of firm that has less experience with collaboration, whereas other factors may actually be more important in relation to

experienced collaborators (Rajalo and Vadi, 2017). In particular, investment in collaborative capabilities characterises experienced collaborators. This finding extends the insights of previous studies that identified an association between absorptive capacity and collaboration over longer geographical distances (e.g. Laursen et al., 2011). It also relates to the understanding of how the interplay between different types of proximities evolves over the course of a given collaboration. As outlined above, this analysis has revealed that, both empirically and theoretically, it is difficult to separate different types of proximities. This is further exemplified by the role of human capital discussed below.

Absorptive capacity, as expressed by persistent R&D activity, is associated with initiation, discontinuation and persistence in relation to collaboration, which confirms the findings of several studies that R&D activity is close to being a prerequisite for engaging in collaboration with universities (e.g. Bishop et al., 2011). However, the present paper demonstrates that the association with R&D activity, as expressed by the size of the regression coefficients, is particularly strong when it comes to persistent collaboration. Similar findings are reported in terms of the role played by alumni in relation to collaboration.⁷ The alumni effect is associated with social capital embedded into social relations and networks. The social dimension of a relation not only involves knowing who knows what—which represents an important first step towards finding a relevant collaboration partner and initiating a collaboration—but also the development of a closer trust-based personal connection, which allows for the mutual exchange of knowledge and ideas and so is likely to affect the success and, accordingly, incentive to continue the collaboration. This adds an interesting social dimension to absorptive capacity. Zahra and George (2002) argued for the importance of social integration mechanisms in relation to increasing the internal efficiency of knowledge assimilation, which is termed realised absorptive capacity. The findings of the present paper indicate that social capital in the form of the number and extent of a firm's relations with a university is also an important mechanism for assessing and utilising university knowledge.

Finally, in relation to the association between firms' general openness in their innovation process and their collaboration with universities (e.g. Laursen and Salter, 2004), the co-occurrence of the two indicates that persistent collaboration with universities is part of a strategic approach whereby firms incorporate knowledge from a broad range of collaboration partners into their innovation process and where collaboration with some partner types can facilitate collaboration with other, more cognitively distant, partners. However, the discussion of different dimensions of absorptive capacity above indicates that although firms develop general collaborative capabilities through openness, they do not fully compensate for university-specific collaborative capabilities.

5.2. Implications for policy

The findings of this study also have important implications for innovation policy. Establishing collaborations between firms and universities can have long-lasting effects. However, it is not sufficient to simply bring firms and universities together in the hope that connections will be made and resultant collaborations will flourish. As documented, firms rarely collaborate with universities. Moreover, such collaboration is contingent on a set of firm-specific factors, some of which are difficult to influence through policy in the short term.

⁷ However, the robustness test shows that these findings are not equally valid for all types of universities.

Firms that become persistent university collaborators do so with the same university. In addition, employees may play a central role as the mediators of such collaboration, since the association between university graduates and university collaboration is most strongly expressed in relation to the specific university from which employees graduated (i.e. the alumni effect).

University graduates can also enhance firms' absorptive capacity, although R&D activity remains a crucial factor with regard to enabling firms to collaborate with universities on innovation. This is particularly important when it comes to selecting those types of firms that are most likely to benefit from policies intended to enhance university–industry collaboration. Despite political ambitions concerning broadening the scope of firms' collaborations with universities, this paper highlights the difficulty of such a task in practice, and it is unlikely that firms with low levels of absorptive capacity will be able to benefit from such efforts. However, since the results show that persistent R&D is also strongly associated with discontinuing a university collaboration, an increased policy focus on R&D-based absorptive capacity alone is unlikely to increase the likelihood of more persistent university–industry collaborations. Policy measures intended to support a combination of different dimensions of absorptive capacity (i.e. 'pure' knowledge and social mechanisms) are more likely to increase both the number of initiated collaboration and the proportion of persistent university collaborations. It is difficult to imagine firms' engaging in persistent R&D activity without having any highly educated employees, although the results show that the type of highly educated employees matters more than the average proportion of them. Programmes that support firms' hiring of university graduates could be a step towards overcoming the barriers to collaboration and initiating a collaboration with a specific university. However, network initiatives that revitalise existing employees' social capital with regard to universities may be a more efficient policy measure. For peripheral regions, given the findings, it could be particularly relevant to focus on revitalising managers' social capital. Specific initiatives to support this could include the facilitation of and funding for alumni events and networks, continuous education programmes at universities and part-time university positions for employees in firms (i.e. shared employment in industry and at universities).

5.3. Implications for managers

The implications of this study for managers largely mirror those for policymakers. If a firm wants to develop an innovation strategy that incorporates persistent collaboration with universities on innovation, it is necessary to persistently invest both in its general level of absorptive capacity and in developing and utilising its social capital. Personal relationships remain important because it is ultimately people, not organisations, that collaborate. The importance of people is stressed by the finding that alumni who have a managerial role in the firm, as well as alumni in general, are positively related to persistent collaboration with the specific university from which they graduated. However, it should be noted that although such investments appear necessary, they are not a guarantee of a persistent and, therefore, presumably valuable collaboration. Combining such investments with a conscious innovation strategy of openness towards not only universities but also a broad range of supplementary partner types increases the likelihood of engaging in collaborations that persist.

5.4. Limitations and further research

Due to the nature of the Research and Innovation Survey data, this study was limited to focusing on two consecutive time periods, which meant that it was not possible to study persistence over a longer period or to

explore the extent to which the initiated collaborations represented the beginnings of persistent collaborations. Another limitation concerns the possibility that the surveys conducted in 2012 and 2015 were answered by different respondents who lacked complete information on who the firm had collaborated with on innovation. This could lead to 'false' initiations and discontinuations. The lack of information on which individuals were involved in actual innovation collaborations also represents a limitation. Hence, a question for further research concerns the extent to which persistence in relation to collaboration occurs between the same or different departments and individuals in both firms and universities over time. Furthermore, it is relevant to explore the issue of whether different factors are associated with collaborations initiated by individual university researchers, by firms' employees/managers or via the mediation of university technology transfer offices. Different ways of initiating a collaboration may affect the levels of engagement of the different collaboration partners and, therefore, the likelihood of persistence. Qualitative approaches could prove valuable in casting further light on these issues. The nature of the collaborations is not reported in the applied survey data, save for the fact that they are related to firms' innovation activity. Thus, the collaborations could be formalised to varying degrees (Bodas-Freitas et al., 2013), just as they could vary in terms of their importance for the firm. These factors are also likely to be related to the likelihood of persistence and, therefore, relevant to explore further in future research. Finally, another question for further research, which is highly relevant to academics as well as to managers and policymakers, concerns the extent to which persistent collaboration with universities can be associated with the different dimensions of firm performance.

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