Bridging the Gap between Firms and Universities

Firm Links with Research and Technology Organisations in Different Types of Regions

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Abstract

This study examined how collaboration with research and technology organisations (RTOs) was associated with industry-university collaboration as part of firms' innovative activities in different types of geographical regions. By combining data from the Danish Research and Innovation Survey and Danish register data at different points in time, the link between firms' collaboration with RTOs and their collaboration with universities in Denmark was studied. Also, the link between the firms' locations in peripheral regions, non-metropolitan university regions or the metropolitan region of Copenhagen and their collaboration with universities in Denmark were also studied. The results suggest that firms that collaborate with RTOs are more likely to collaborate with universities. This paper argues that collaboration with RTOs is associated with a higher likelihood of industry-university collaboration because this experience of collaboration allows firms to overcome barriers for collaboration with universities, which are related to differences in norms and incentive systems between firms and universities. When looking at different types of regions, firms in peripheral and metropolitan regions that collaborated with RTOs were more likely to collaborate with universities. However, firms in non-metropolitan university regions that collaborated with RTOs were not more likely to collaborate with universities.

Keywords: industry-university collaboration; research and technology organisations; peripheral regions; non-metropolitan university regions; metropolitan regions

JEL: O31; R10; R11; R12

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1. Introduction

Differences in norms and incentive systems between firms and universities pose a difficulty in the establishment of industry-university collaboration (Bruneel, D'Este, & Salter, 2010). However, it has been shown that firms are more likely to interact with universities if they interact with organisations other than universities (Laursen, Reichstein, & Salter, 2011; Laursen & Salter, 2004). With few recent exceptions (Hewitt-Dundas, Gkypali, & Roper, 2019), the exact types of organisations that are associated with industry-university collaboration on innovation are not so well known. This study aimed at providing insights on the types of organisations that are related with industry-university collaboration by assessing whether industry-university collaboration on innovation was more likely if firms collaborated with research and technology organisations (RTOs) by answering the following research question:

> *"Is collaboration with RTOs on innovation positively associated with industry-university collaboration on innovation?"*

RTOs are organisations whose functions focus on providing technical services to their client firms and rapidly applicable solutions to problems faced by these firms in their innovative activities. Their functions also include technology diffusion among client firms and applied research (Giannopoulou, Barlatier, & Pénin, 2019). Previous reports suggest that the functions of universities and RTOs are complementary, with universities being more focused on basic research and RTOs on consultancy and testing services (Arnold et al., 2007; Arnold, Clark, & Jávorka, 2010).

The paper also aims at assessing whether the association between firm collaboration with RTOs and firm collaboration with universities might differ in different types of regions. Policymakers have seen in universities an institution that can support innovation and regional development (Breznitz & Feldman, 2012; Charles, 2006; Uyarra, 2010). However, regions differ in their organisational diversity and in their capacity to innovate (Tödtling & Trippl, 2005; Trippl, Asheim, & Miörner, 2015). Peripheral regions are less likely to host universities than metropolitan regions (Charles, 2016; Eder, 2019; Tödtling & Trippl, 2005; Trippl et al., 2015). They are also more likely to host firms operating in sectors traditionally not likely to

draw on university research as part of their innovative activities (Isaksen & Karlsen, 2013; Tödtling & Trippl, 2015). Nevertheless, evidence from Scandinavian countries shows that a higher percentage of firms in peripheral regions collaborate with universities compared to their metropolitan counterparts (Guerrero, 2020; Jakobsen & Lorentzen, 2015). Firms in peripheral regions need to overcome longer distances than their metropolitan counterparts in order to collaborate with universities (Johnston & Huggins, 2016). An improved understanding of the factors associated with industry-university collaboration in different types of regions might help policymakers fine tune universities' regional mission to the characteristics of the regions where they are located. Thus, this study tried to answer a second research question:

> *"Does the association between collaboration with RTOs and industry-university collaboration on innovation vary depending on the type of region where firms are located?"*

This paper combines data from the Danish Research and Innovation Survey, which is the Danish version of the Community Innovation Survey; and the Danish Integrated Labour Market database (IDA, in Danish), a register dataset managed by Statistics Denmark (see Section 3). It is a cross-sectional dataset created with firms that participated in one or more waves of the Danish Research and Innovation Survey between 2010 and 2014. Because this is a cross-sectional dataset, the analyses only aim at identifying statistical associations, not causal mechanisms.

Logistic regressions were run on the likelihood that firms collaborated on innovation with universities in Denmark as part of their innovative activities and depending on whether firms collaborated with RTOs. Secondly, these regression analyses explored whether the association between firm collaboration with RTOs and firm collaboration with universities differed across different types of regions. The results showed that if firms were collaborating with RTOs, they were more likely to be collaborating with universities. However, the results also showed that this association was only valid for firms in peripheral and metropolitan regions. Among the firms that did not collaborate with RTOs, those that were in peripheral regions and non-metropolitan university regions were more likely to collaborate with universities.

A possible explanation of the findings is that firms through collaborating with RTOs become better equipped to collaborate with Danish universities. Concerning the regional differences, collaboration with RTOs is only positively associated with university collaboration in peripheral and metropolitan regions; this might be due to universities in non-metropolitan university regions being more committed to developing collaborative relationships with regional firms (Boucher et al., 2003). This regional commitment of universities could reduce the need for RTOs as intermediaries or bridges that can help overcome the distances between universities and firms. Further research is needed to assess whether the statistical associations found in the study are driven by these mechanisms.

2. Literature review

2.1. Overcoming barriers for collaboration between firms and universities

Firms must overcome several obstacles to incorporate industry-university collaboration into their innovation activities. High absorptive capacity, or the ability to acquire, assimilate and integrate external knowledge into organisational routines (Cohen & Levinthal, 1990), has been found to facilitate interaction with universities (Drejer & Østergaard, 2017; Laursen & Salter, 2004; Mohnen & Hoareau, 2003). Larger firms are more likely to interact with academic institutions because they have the resources needed to exploit university knowledge (Laursen & Salter, 2004; Mohnen & Hoareau, 2003). Science-based industries are also more inclined to draw on university knowledge (Pavitt, 1984; Segarra-Blasco & Arauzo-Carod, 2008). Also, firms that draw knowledge from a wide range of external sources are more likely to collaborate with universities (Hewitt-Dundas et al., 2019; Laursen & Salter, 2004).

Bruneel et al. (2010) and Hewitt-Dundas et al. (2019) point out that a range of orientation-related barriers can potentially prevent collaboration between firms and universities; firms might expect to appropriate and exploit the benefits of discoveries through secrecy, while academic researchers might expect to be able to disseminate the research they generate. The timing of academic research might also be an issue for firm partners, with the latter expecting research that should be rapidly applicable. In addition, there might be a mutual lack of

understanding between both parties regarding work practices. Transaction-related barriers might also pose a challenge to industry-university collaboration, with potential conflicts between universities and their firm partners regarding the ownership of intellectual property. However, these barriers can be lowered if firms and universities can develop routines that facilitate industry-university collaboration through previous experiences of industry-university collaboration. Thus, the findings of Bruneel et al. (2010) and Hewitt-Dundas et al. (2019) suggest that barriers deterring industry-university collaboration can be overcome through specific experiences of it.

Previous research points to other ways of lowering the barriers between firms and universities than those that stem from previous experiences of industry-collaboration. Rosenkopf and Nerkar (2001) and Rothaermel and Alexandre (2009) observe that firms that combine knowledge from internal and external sources are better able to innovate because the combination of internal and external knowledge allows them to stay abreast of technological changes. Laursen et al. (2004) and Laursen and Salter (2011) found that firms that interacted with a wide range of different types of organisations were more likely to interact with universities. Hewitt-Dundas et al. (2019) found that previous collaboration with customers was positively associated with industry-university collaboration among small and medium-sized enterprises (SMEs), whereas among larger firms previous collaboration with consultants was positively associated with industry-university collaboration.

According to Hewitt-Dundas et al. (ibid)**,** firms might be better equipped to search and identify knowledge from universities if they collaborate with specific types of organisations other than universities. The experience of collaborating with these organisations, they argue, enables firms to be better equipped to deal with differences in norms and incentive systems with non-university organisations, but also with universities. Firms should, in turn, be better equipped to identify useful knowledge from, and collaborate with other organisations, including universities. Knowledge intermediaries might be one of the types of organisations that are associated with firms being better equipped to collaborate with universities. Knowledge intermediaries are described as organisations whose functions do not limit themselves to 'translate' the knowledge generated in other organisations in such a way that

the client firm can integrate it but can include technology forecasting, the combination of knowledge from different sources, and matchmaking between different parties (Bessant & Rush, 1995; Giannopoulou et al., 2019; Howells, 2006). Indeed, these organisations have been found to help firms in being better equipped to collaborate with other firms and other types of organisations in innovation networks, thus, overcoming collaboration barriers (Aquilani, Abbate, & Codini, 2017; Hermann, Mosgaard, & Kerndrup, 2016; Nauwelaers, 2011; Parker & Hine, 2014).

Because of their functions, some kinds of knowledge intermediaries, like RTOs, might be more strongly associated with industry-university collaboration than others. Arnold et al. (2007, 2010) and Giannopoulou et al. (2019) describe RTOs as organisations that, similar to higher education institutions, receive public funding to conduct research, involving in some cases peer-reviewed publications. However, unlike higher education institutions, RTOs tend to have a more short-term firm-service orientation, offering testing and consultancy services to their customers in addition to collaborative research. These researchers suggest that links between RTOs and universities are common, whether through informal contacts or formalised collaborative research.

Hence, the norms and incentive systems regulating the functioning of RTOs can be seen as partly overlapping with those of universities but also with those of firms. RTOs might help to bridge the distance between firms and universities directly because RTOs work together with firms and universities in joint collaborative research projects. Through their social ties with university researchers, researchers at RTOs might also link firms and universities. Indirectly, firms that collaborate with RTOs might also acquire experience on how to collaborate with an organisation whose norms and incentive systems are not far from those of universities, eventually applying this experience in collaborations with universities. Either way, the first hypothesis suggests that collaboration between firms and RTOs is positively associated with collaboration between firms and universities:

H1. *Firms that collaborate with RTOs are more likely to collaborate with universities when compared to firms that do not collaborate with RTOs.*

These arguments do not imply that firms are the only party that has to be better equipped to collaborate. Indeed, RTOs might be able to connect university researchers with firms in collaborative research projects. By collaborating with RTOs, university researchers might be better equipped to collaborate with an organisation whose norms and incentive systems are not distant from those of their institutions, eventually applying this experience in collaborations with firms. However, the focus of this study is on the association between firms' collaboration with RTOs and firms' collaboration with universities.

2.2. The association between collaboration with RTOs and collaboration with universities in different types of regions

Peripheral regions are relatively sparsely populated locations with few or no urban agglomerations. Compared to more densely populated locations, these regions tend to host a narrow variety of organisations, whether these are part of the regional innovation system's knowledge generation and diffusion subsystem, such as RTOs or public research institutes, or the knowledge application and exploitation subsystem, such as customers, suppliers and competitors (Guerrero, 2020; Tödtling & Trippl, 2005, 2015; Zukauskaite, Trippl, & Plechero, 2017). They also tend to host firms operating in sectors traditionally not likely to draw on university research as part of their innovative activities (Isaksen & Karlsen, 2013; Tödtling & Trippl, 2015). In addition to these characteristics, peripheral regions tend to be relatively far from large urban agglomerations and the communication infrastructures that these agglomerations contain, such as ports and airports (Doloreux & Dionne, 2008; Shearmur & Doloreux, 2018). According to a recent literature review (Eder, 2019), the *peripheriality* of these regions is both geographic, because these are relatively isolated locations, compared to more densely populated ones, and economic, because of the relatively low density of economic agents in these regions. This economic *peripheriality* is also visible when it comes to the presence of universities, as one of the organisations that are part of the regional innovation system's knowledge generation and diffusion subsystem. Charles (2016) shows that peripheral regions might contain branch campuses, perhaps established for regional development purposes, but these academic institutions are likely to be smaller and have less research capacity than main university campuses, and thereby their capacity to operate as innovation partners is relatively limited.

Metropolitan regions present the opposite picture with large urban agglomerations and a broad variety of organisations in the knowledge generation and diffusion subsystem, including multiple universities (Guerrero, 2020; Tödtling & Trippl, 2015; Trippl et al., 2015). Metropolitan regions also host a broad variety of organisations in the knowledge application and exploitation subsystem, including firms in sectors traditionally linked to university research (Storper, 2018). In addition, these regions are typically well endowed with major communication infrastructures such as ports and airports, ensuring their connectedness to global knowledge networks (McCann, 2008; Rodríguez-Pose & Fitjar, 2013).

Eder (2019) and Nilsson (2006) show that there are regions, in between peripheral and metropolitan regions, that tend to have an urban agglomeration with a university campus. These regions, referred to in this paper as *non-metropolitan university regions*, can also be home to both firms traditionally not linked to universities and firms reliant on university research. Eder (ibid) adds that the university region's main urban agglomeration is also likely to contain major transport infrastructures, ensuring the region's connectedness to global knowledge networks; also, Eder (ibid) points out that the *peripheriality* of these regions is mainly economic, because of the relatively low density of economic agents that these regions contain, compared to more densely populated locations. Thus, non-metropolitan university regions host a variety of organisations that are in-between that of peripheral and metropolitan regions, whether they are part of the regional innovation system's knowledge generation and diffusion subsystem or the knowledge exploitation subsystem.

Section 2.1 argued that firms that interact with organisations with different norms and incentive systems are better equipped to collaborate with universities. In regions with a broad variety of organisations, firms should be better equipped to collaborate with universities by drawing on informal, unplanned exchanges from regional organisations. Hence, in metropolitan regions, unplanned exchanges with regional organisations might help firms be better equipped to collaborate with universities. Unplanned encounters between firms' personnel and that of other regional organisations might put firms in touch with a wide range of organisations. Firms in metropolitan regions can, in turn, be better equipped to collaborate with organisations that operate under other norms and incentive systems, such as universities.

Collaboration arrangements with RTOs might also help firms be better equipped to collaborate with universities; however, unplanned encounters with other regional organisations might already suffice to equip firms for collaboration with universities.

At the other extreme, the small variety of organisations in peripheral regions might not help firms be better equipped to collaborate with organisations with different norms and incentive systems, such as universities, if firms rely on informal, unplanned exchanges with staff from other organisations in the region. However, collaboration with RTOs might provide the experience that firms in peripheral regions need to be better equipped to collaborate with universities. Firms in peripheral regions might be able to draw from experience in collaboration channels with RTOs and find it useful for collaborating with universities. Furthermore, RTOs can also put peripheral regions' firms in touch with universities, for example, through collaborative research. Either way, firms in peripheral regions might be more inclined to collaborate with universities than firms in metropolitan regions if they have collaborated with RTOs.

H2. *Firms in peripheral regions that collaborate with RTOs are more likely to collaborate with universities when compared to similar firms in metropolitan regions.*

Compared to the other types of regions, non-metropolitan university regions present a special situation. The variety of organisations they host should be roughly in-between that of peripheral and metropolitan regions, and unplanned interactions might provide firms with less experience on how to overcome differences in norms and incentive systems with universities compared to firms in metropolitan regions. In this view, collaboration with RTOs for firms in non-metropolitan regions might be (compared to those in metropolitan regions) more positively associated with collaboration with universities, because they might acquire through the RTOs the capabilities that help them be better equipped to collaborate with universities. On the other hand, in non-metropolitan university regions, unplanned interactions might suffice for firms to be equipped to collaborate with universities. In this view, firms in university regions that collaborate with RTOs might not be more likely to collaborate with universities, compared to similar firms in metropolitan regions. Hence, there

are no clear grounds to hypothesise whether firms in university regions that collaborate with RTOs are more likely to collaborate with universities, compared to similar firms in metropolitan regions.

3. Research methods

3.1. Data sources

In this study, data were combined from two datasets managed by Statistics Denmark, the Integrated Database for Labour Market Research (IDA, in Danish) and the Danish Research and Innovation Survey, which is the Danish version of the Community Innovation Survey. The IDA database is a register dataset that combines personal-level data on the Danish population with workplace-level data on the population of firm workplaces in Denmark (Timmermans, 2010). The Danish Research and Innovation Survey is conducted every year by Statistics Denmark and provides data on such indicators as the types of innovation developed by firms, the types of organisations that firms cooperate with as part of their innovative activities and the geographical location of these partners (Eurostat, n.d.; Laursen & Salter, 2004; Statistics Denmark, 2015). Only firms that reported the conduct of innovative activities[1] were included in the analysis, due to the focus of the study on collaboration on innovation and because the Danish Research and Innovation Survey itself only enquires of firms that reported on activities about collaboration on innovation. When constructing the dataset, the approach followed was the same as that was followed in previous work on industry-university collaboration in different types of regions in Denmark by the author (Guerrero, 2020).

The percentage of firms that collaborated with Danish universities as part of their innovative activities has fluctuated between 2010 and 2014, with a tendency for higher collaboration percentages in even years and lower percentages in odd years, for example, shifting from 9% in 2013 to 12% in 2014 (Erhvervsstyrelsen, n.d.). A likely cause for this variation is the

[1] These are the introduction of new or significantly improved products, manufacturing processes, operations, organizational structures or marketing techniques, as well as ongoing or abandoned innovation activities during the survey period.

design of the Danish Research and Innovation Survey questionnaires. During odd years, the questionnaires include more questions about research and development (R&D) activity, and a lower number of firms appear to report collaboration with universities as a likely result of respondent fatigue[2]. Taking into account that firms' propensity to report collaboration on innovation can vary from year to year, a pooled cross-section was constructed, merging all the observations from three samples of the Danish Research and Innovation Survey (the 2012 wave, where managers were asked for innovative activities between 2010 and 2012; the 2013 wave, covering 2011–2013; and the 2014 wave, covering 2012–2014[3]).

The surveys are compulsory, minimising the number of non-responses. Each wave included all the firms in the population with more than 100 full-time equivalent employees (FTEs). The lower the number of FTEs, the lower the likelihood of being selected for a wave (Statistics Denmark, 2012, 2015). Hence, in the pooled data set, all firms with more than 100 FTE would appear three times—one for each wave included—whereas there was a lower likelihood that firms with less than 100 FTEs would appear in two consecutive waves of the survey. The weights provided by Statistics Denmark are used to adjust the observations by firm size and the firm's activity branch in order to ensure that each wave is representative of the firm population in Denmark. However, because the pooled sample included more than one observation for those firms that participated in more than one wave, the weights provided by Statistics Denmark have been modified in the present study, dividing them by the number of waves in which the focal firm had participated in the survey. That is, for a firm that had participated in three waves, the weights provided by Statistics Denmark were divided by three; for a firm that had participated in two waves, the weights were divided by two; and for firm that had participated in one wave the weights were not divided.

[2] This pattern was reproduced in practically all the years in the time series reported by Erhvervsstyrelsen (n.d.). The only exception appeared to be in the shift between 2012 and 2013, since the percentage of firms that reported collaboration with universities was the same between the two years, probably because of the crisis that affected Denmark in those years.

[3] Statistics Denmark derives its statistical population from the Business Statistical Register, defining a frame of enterprises and deleting certain activities and firms with few employees. Statistics Denmark also weights the final frame population (Statistics Denmark, 2015).

This approach provided a number of observations large enough to study phenomena as infrequent as industry-university collaboration on innovation. In the pooled cross-section, 7.3% of the firms collaborated with Danish universities, and only a fraction of them collaborated with RTOs (see Section 3.5)[4]. A crucial limitation in this approach, however, was that it did not allow for the study of causal relationships since the explanatory and dependent variables corresponded to the same wave of the Danish Research and Innovation Survey.

The Danish Research and Innovation Survey included 4901 observations in the 2014 wave, 4788 in the 2013 wave and 4698 in the 2012 wave. After deleting observations with missing or extreme values in the control variables (see Section 3.4), the merged sample had 10610 unweighted observations. Once those observations that did not develop innovative activities were excluded, the pooled cross section had 6611 unweighted observations (11162 weighted observations). Of these, 2175 (3643) were from the 2012 wave, 2214 (3608) from the 2013 wave and 2222 (3911) from the 2014 wave.

3.2. Dependent variable

Like in previous work conducted by the author (Guerrero, 2020), binomial logistic regressions were run on the likelihood that firms reported having collaborated on innovation with one or more Danish universities as part of their innovation activities (UNI). This variable took a value of "1" if the firm reported collaboration with at least one of the eight higher education institutions with full university status in Denmark as listed in the Danish Research and Innovation Survey and reported that this collaboration was relevant for its innovation activities; it took a value of "0" if any of these two conditions were not fulfilled. The names and geographical location of these institutions are specified in Figure 1. Positive values in

[4] Furthermore, a balanced panel dataset with firms that had participated in consecutive waves would have a number of observations substantially smaller than the one obtained through a pooled cross-section (see below), because only large firms were likely to participate in consecutive waves. For instance, a panel dataset with firms that participated in the 2012 and 2014 waves of the Danish Research and Innovation Survey would have consisted of 1,104 firms after deleting observations with missing and extreme values.

UNI should include relationships closer to university-industry links where university researchers and industrial partners are actively involved, although more passive links like those involving the training of university students in firms might also be included (Perkmann & Walsh, 2007).

3.3. Explanatory variables

Respondents in the Danish Research and Innovation Survey were asked to specify if their firms had collaborated with authorised technological service institutes. Because of their characteristics, the authorised technological service institutes could be classified as Danish RTOs. Whereas universities tend to focus on research and education, the authorised technological service institutes have a stronger orientation towards the provision of consultancy and testing services to firms, even if the activities of these two types of organisations might overlap to some extent. Table A1 in the Appendix shows the names of these institutes and the municipalities hosting their offices. When constructing *RTO*, firms that collaborated with authorised technological service institutes and that reported that this collaboration was relevant for their innovation activities were assigned "1"; a value of "0" was assigned if any of these conditions were not fulfilled.

The authorised technological service institutes are government-approved, not-for-profit institutes focused on diffusing new technologies among the Danish industries. As part of their mission, they combine applied research with the provision of services to firms, such as consultancy or testing services. Most of their earnings come from private sources, with a fraction coming from performance contracts with the Danish government. Links between these organisations and universities are common, whether through informal links or formalised, collaborative research (Arnold et al., 2010, pp. 22–23; Åstrom, Eriksson, & Arnold, 2008, pp. 44–67; Nielsen, Christiansen, Boberg, & Rekve, 2018). Examples of formalised links are the general agreement between the network of authorised technological service institutes and the Technical University of Denmark (DTU)[5], the Danish universities'

[5] The strategic contract involved activities such as the exchange of staff, collaboration in R&D, and joint cooperation with firms (Åstrom, Eriksson, & Arnold, 2008, pp. 61–62).

ownership of some of these institutes and the joint ownership together with Danish universities of research and testing facilities[6] (Åstrom et al., 2008, pp. 61–62).

RTO was connected with *REGION*, which reports the type of region where firms were located. Firms were assigned "0" if located in a metropolitan region, "1" if they were in a non-metropolitan university region and "2" if they were in a peripheral region. The reference category corresponded to firms in metropolitan regions. Firms were treated as belonging to a type of region depending on the municipality where their main workplace was located. The data to determine location was drawn from the IDA database.

The description of the regional classification was taken from Guerrero (2019), where the same regional classification was applied. A list of the functional urban areas of Denmark provided by the OECD was used, which also included the municipalities comprising urban areas (OECD, n.d.). The OECD defined functional urban areas as locations with at least 50000 inhabitants, including a core of densely populated contiguous municipalities in which at least 50% of the area had a population density equal to or above 1500 inhabitants/km^2 and an urban hinterland of municipalities in which at least 15% of the employed population commuted to work in the core municipalities. The OECD defined functional urban areas with 500000 inhabitants or more as metropolitan areas (OECD, 2012, pp. 29–34).

In Denmark, the OECD (n.d.) identified five functional urban areas (from largest to smallest): The municipalities of Copenhagen, Aarhus, Odense, Aalborg and Esbjerg, and the surrounding, commuting municipalities that belonged to their functional urban areas, as defined in the previous paragraph[7]. With an average population of 1838739 inhabitants between 2010 and 2014, Copenhagen was the only metropolitan area. At the other extreme, the Esbjerg area had an average population of 168518 inhabitants between 2010 and 2014

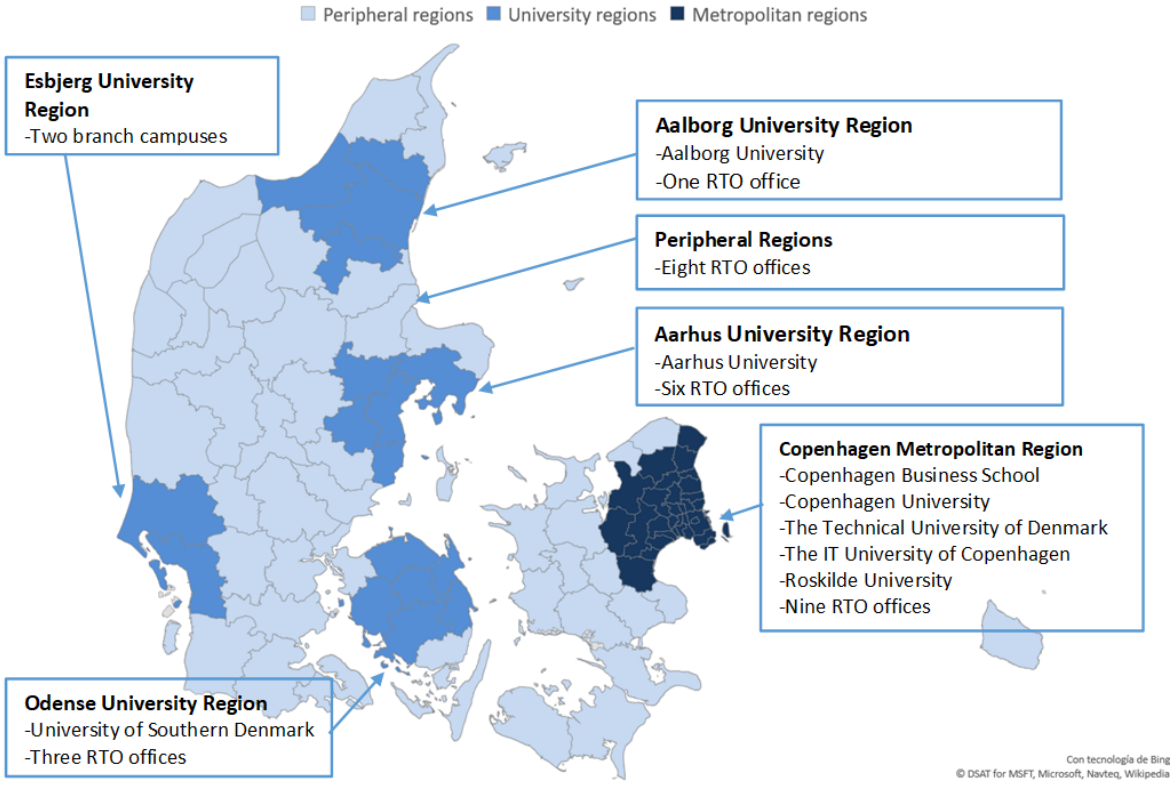
[6] DTU owns the Danish National Metrology institute, and the Bioneer institute, and Aarhus University owns the Alexandra institute. FORCE technology owns, together with DTU and Det Norske Veritas—a Norwegian certification institute—the Blade test centre, a testing facility for wind turbine blades (Åstrom et al., 2008, pp. 61–62).

[7] In January 2019, the OECD list of urban functional urban areas for Denmark (OECD, n.d.) was updated and no longer included the Esbjerg area; however the study used the previous list because the data covered the 2010–2014 period.

(Statistics Denmark, n.d.). The municipalities belonging to the Copenhagen metropolitan area were categorised as the Copenhagen metropolitan region, and the municipalities in other functional urban areas as non-metropolitan university regions. Municipalities that did not belong to any functional urban area were treated as peripheral regions. A map (Figure 1) shows the location of each type of region, as well as the number of universities and RTO premises that can be found in each type of region. Table A2 in the Appendix provides lists of the municipalities included in each functional urban area.

The peripheral regions' traits differed from those of urban regions and the Copenhagen metropolitan region. Figure 1 shows that the peripheral regions did not contain main university campuses; all non-metropolitan university regions except Esbjerg contained main university campuses, and the Copenhagen metropolitan region contained five universities (Danish Ministry of Higher Education and Science, n.d.). More differences are shown in Section 4.1, which displays descriptive statistics for the sample.

Figure 1. Types of regions in Denmark



Sources: Danish Ministry of Higher Education and Science, n.d.; OECD, 2012

3.4. Control variables

Taking into account that firms that draw knowledge from a wide range of external knowledge sources are more likely to collaborate with universities (Hewitt-Dundas et al., 2019; Laursen & Salter, 2004), *COLLAB* reported the number of types of organisations that firms collaborated with as part of their innovative activities, excluding RTOs and universities. This variable was constructed from the same question as the one that identified collaboration with RTOs. The partner types included in *COLLAB* were suppliers, customers, competitors, firms in other industries, consultants, public actors, public service providers, public research institutions and other public partners. Affirmative responses to each one of these questions were coded as "1" if the respondent reported the collaboration to be relevant for the firm's innovation activities. The values were added up, ranging from "0" if firms reported no collaboration with any type of organisation and "9" if firms reported collaboration with all types. The approach applied when constructing *COLLAB* was similar to the one used in Guerrero (2019).

Secondly, *WAVE* controlled for the last wave of the Danish Research and Innovation Survey in which the firm was surveyed, the reference category corresponding to the 2012 wave.

Finally, the logistic regressions also included controls for the firms' structural characteristics. The values for the variables obtained from the IDA database were based on the data for the largest establishment in each firm:

- The average percentage of graduates in the company workforce over the period covered by the three waves (*SHAREGRAD*), whether firms applied for patents (*PATENTS*) and R&D spending as a percentage of sales (*RDSALES*) were included. These variables were used as proxies for the firms' absorptive capacity in the industry-university collaboration literature and take into account the finding that firms with higher absorptive capacity are more likely to collaborate with universities (Drejer & Østergaard, 2017; Laursen & Salter, 2004). *SHAREGRAD* and *RDSALES* were continuous variables, and *PATENTS* was a dichotomous variable that took the value of "1" for firms that reported applying for patents and "0", the reference category, for firms that reported applying for no patents. The data for *SHAREGRAD*

were obtained from the IDA database, and the data for *PATENTS* from the Danish Research and Innovation Survey. *RDSALES* was based on data from the Danish Research and Innovation Survey combined with the IDA database. For this variable, I only included data for the last year of the corresponding wave of the survey for two reasons. Firstly, because the survey only enquired of firms for their amount of R&D spending in the survey year, calculating average R&D spending for a given period (e.g., between 2010 and 2012, for the 2012 wave) would have entailed including only the 2010, 2011 and 2012 waves of the Danish Research and Innovation Survey, resulting in a lower number of observations. Secondly, the values for *RDSALES* did not change substantially over time (my own calculations, not shown). In order to avoid that the results were driven by outliers, those firms that reported R&D spending levels equivalent to more than 50% of their sales were excluded, following Laursen and Salter (2004) and Mohnen and Horeau (2003). These specifications of control variables have also been used in Guerrero (2019).

- The logarithm of the total number of employees (*LOGFIRMSIZE*) was used as a proxy for firm size (Drejer & Østergaard, 2017; Laursen & Salter, 2004). The data for this variable came from the IDA database and was an average for the period covered in the corresponding wave of the Danish Research and Innovation Survey. This specification of the control variable had also been used in Guerrero (2019).
- Pavitt's sectoral taxonomy (1984) highlighted that firms differed on the extent to which innovation was based on scientific research and R&D work, these knowledge sources being crucial for science-based sectors. In the present paper, an update of Pavitt's taxonomy (Bogliacino & Pianta, 2016) was used to classify the observations by sector. This classification added service and ICT-intensive activities in Pavitt's taxonomy and was amenable to the use of NACE Rev. 2 codes, which have been used by Statistics Denmark to classify workplaces' activity sectors since 2007. *SECTOR* thus classified firms in four categories: supplier dominated (0), scale and information intensive (1), specialised suppliers (2) and science based (3). The reference category was that of specialised suppliers. The data for *SECTOR* was from the IDA database and covered only the last year for the corresponding wave of the Danish Research

and Innovation Survey; however, *WAVE* controlled for inter-year variations in the wave when the firm was surveyed. Table A3 in the Appendix provides information about the NACE two-digit codes aggregated in each *SECTOR* category.

Model 1 tests Hypothesis 1 including *RTO* as the explanatory variable. Model 2 tests Hypotheses 2, 3a and 3b, including an interaction term between *REGION* and *RTO*:

$$\text{Model 1: } UNI_i = \alpha + \beta_{1REGIONi} + \beta_{2RTOi} + \beta_{3COLLABi} + \beta_{4RDSALESi} + \beta_{5PATENTSi} + \beta_{6LOGFIRMSIZEi} + \beta_{7SECTORi} + \beta_{8WAVEi} + \varepsilon_i$$

$$\text{Model 2: } UNI_i = \alpha + \beta_{1REGIONi} + \beta_{2RTOi} + \beta_{3(REGION*RTO)i} + \beta_{4COLLABi} + \beta_{5RDSALESi} + \beta_{6PATENTSi} + \beta_{7LOGFIRMSIZEi} + \beta_{8SECTORi} + \beta_{9WAVEi} + \varepsilon_i$$

Correlation matrices and variance inflation factor tests were run, revealing no multicollinearity issues. A correlation matrix is available in the Appendix (Table A4).

3.5. Descriptives

Table 1 provides descriptive statistics on the sample, showing that a higher percentage of firms in non-metropolitan university regions collaborated with universities on innovation (8.61%), compared to peripheral regions and the Copenhagen metropolitan region. A different pattern was observed concerning collaboration with RTOs on innovation; 8.29% of firms in peripheral regions collaborated with this type of organisation, well above university regions and the Copenhagen metropolitan region, which displayed the lowest percentage of firms collaborating with RTOs (3.78%). Other relevant differences concerned some of the variables that controlled for the firms' absorptive capacity and the distribution of firms by sector. Firms' R&D spending over sales and firms' percentage of graduates was higher in metropolitan regions than in university regions and peripheral regions. Whereas supplier dominated firms were more common in peripheral regions, firms operating in the science-based sector were more common in the Copenhagen metropolitan region.

Table 1. Sample descriptive statistics, characteristics by type of region (N=11162)	Firms in the Copenhagen metropolitan region (N=4681)		Firms in non-metropolitan university regions (N=2674)		Firms in peripheral regions (N=3807)	
	Mean	**Std dev**	**Mean**	**Std dev**	**Mean**	**Std dev**
UNI (dichotomous)	0,0652	0,3297	0,0861	0,3603	0,0737	0,3317
RTO (dichotomous)	0,0378	0,2547	0,0641	0,3146	0,0829	0,3501
COLLAB (continuous)	0,7556	2,1187	0,8213	2,1444	0,7881	2,0645
RDSALES (continuous)	3,0858	10,9824	3,0438	10,9946	1,4129	6,6891
SHAREGRAD (continuous)	21,9742	35,2627	15,9672	30,0971	7,6895	18,2749
LOGFIRMSIZE (continuous)	2,4530	1,5932	2,5183	1,5149	2,6888	1,4354
PATENTS (dichotomous)	0,0540	0,3020	0,0747	0,3376	0,0594	0,3000
SECTOR: Supplier dominated (dichotomous)	0,3366	0,6311	0,4228	0,6344	0,5163	0,6344
SECTOR: Scale and information intensive (dichotomous)	0,1174	0,4298	0,0905	0,3685	0,0888	0,3611
SECTOR: Specialised supplier (dichotomous)	0,3015	0,6128	0,2888	0,5821	0,2866	0,5741
SECTOR: Science based (dichotomous)	0,2446	0,5740	0,1978	0,5116	0,1083	0,3946
Number of observations						
WAVE 2010-12	1444		872		1328	
WAVE 2011-13	1531		860		1217	
WAVE 2012-14	1706		942		1262	

Table 2 provides a closer look at the extent to which firms combined collaboration with universities and RTOs, comparing the percentage of firms that collaborated with RTOs with the percentage of firms that collaborated with RTOs *and universities*. A higher percentage of firms in the Copenhagen metropolitan region that collaborated with RTOs collaborated as well with universities when compared to firms in the other types of regions; it was in peripheral regions where collaboration with RTOs and universities coincided the least.

Table 2. Firms that collaborate with RTOs. Percentage that collaborate with Danish universities, percentage that do not collaborate with Danish universities	Firms in the Copenhagen metropolitan region (N=177)	Firms in non-metropolitan university regions (N=171)	Firms in peripheral regions (N=316)
Collaborates with RTOs, but not universities	38.81%	55.05%	58.36%
Collaborates with RTOs, and universities	61.19%	44.95%	41.64%

4. Results

4.1. Logistic regressions

The results of Model 1, provided in Table 3, support Hypothesis 1 ("*Firms that collaborate with RTOs are more likely to collaborate with universities when compared to firms that do not collaborate with RTOs.*"), since the coefficient for *RTO* was statistically significant

below the 1% threshold and had a positive sign. The model thus suggested that collaboration with RTOs was positively associated with collaboration with universities. However, the estimates cannot give *per se* an idea about how likely it was that firms collaborated with universities if they collaborated with RTOs, compared to firms that did not collaborate with RTOs. Predicted probabilities were thus requested, showing that for a firm with average values in the continuous control variables and reference values in the categorical control variables, the predicted probability of collaborating with universities on innovation was equal to 4.48% if collaborating on innovation with RTOs and 1.52% if not doing so. Note that because the explanatory and dependent variables covered the same period, the positive statistical association between collaborating with RTOs and collaborating with universities on innovation cannot be interpreted as a causal relationship.

Table 3. Logistic regressions, collaboration with universities in Denmark (sample with all types of regions)		**Model 1**	**Model 2**
	Intercept	-5.9015***	-6.0431***
Benchmark: REGION (Copenhagen)	REGION (Non-metropolitan university)	0.3226***	1.8268***
	REGION (Peripheral)	0.3684***	0.6050***
Benchmark: RTO (No collaboration)	RTO (Collaboration)	1.1149***	0.4182***
Benchmark: REGION (Copenhagen)*RTO	REGION (Non-metropolitan university)*RTO		-1.5779***
	REGION (Peripheral)*RTO		-0.5908**
	COLLAB	0.6743***	0.6809***
	RDSALES	0.0447***	0.0443***
	SHAREGRAD	0.0146***	0.0149***
Benchmark: No patents	PATENTS	0.9736***	0.9910***
	LOGFIRMSIZE	0.3370***	0.3359***
Benchmark: SECTOR (Specialised supplier)	SECTOR (Supplier dominated)	-0.0723	-0.0293
	SECTOR (Scale and information intensive)	-0.7844***	-0.8295***
	SECTOR (Science based)	-0.1450	-0.1912
Benchmark: WAVE 2010-2012	WAVE 2011-2013	0.2226*	0.2672**
	WAVE 2012-2014	0.6651***	0.6978***
	N	11162	11162
	AIC	3257.427	3230.965
	SC	3352.578	3339.709
	-2 Log L	3229.427	3198.965
*: significant at 10% level, **: significant at 5% level, ***: significant at 1% level			

Moving to Model 2, Hypothesis 2 was not supported ("*Firms in peripheral regions that collaborate with RTOs are more likely to collaborate with universities, when compared to similar firms in metropolitan regions.*"). Although both *RTO* and *REGION (Peripheral)* were statistically significant below the 1% threshold and had a positive sign, the interaction term *REGION (Peripheral)*RTO* had a negative sign and was statistically significant below the 5% threshold. Therefore, there were no indications of a positive mediating effect between collaborating with RTOs and a firm's location in a peripheral region. The findings were similar for *REGION (University)* and the interaction term *REGION (University)*RTO*. Model 2 also suggested that there was no positive mediating effect between being located in an university region and collaborating with RTOs.

To assess the robustness of the findings, I provide in Table 4 the estimates of *RTO* in split samples for each type of region, together with its average marginal effects (AMEs). The AMEs show how much the probability of the outcome of interest (here, *UNI*=1) would increase if the value of the explanatory variable of interest, *RTO*, changed from 0 to 1 for all the observations in the split sample (Bogers, 2017; Karaca-Mandic, Norton, & Dowd, 2012; Leeper, 2017).

Although *RTO* has a positive sign in all the samples in Table 4, it was only in the models for firms in peripheral regions and for firms in the Copenhagen metropolitan region that *RTO* was statistically significant. Moreover, whereas the AMEs for the samples of firms in peripheral and metropolitan regions were statistically significant below the 1% threshold and similar in size, the AME for the sample of firms in non-metropolitan university regions was statistically insignificant, and its size was well below those of firms in peripheral and metropolitan regions. Collaboration with RTOs was associated on average with a 11.01% higher probability of collaborating with universities for firms in peripheral regions, and with a 10.89% higher probability for firms in the Copenhagen metropolitan region. The full models are displayed in the Appendix in Table A5.

Table 4. Logistic regressions, collaboration with universities in Denmark (samples by type of region, extract of selected results)	Model 3: Firms in peripheral regions	Model 4: Firms in non-metropolitan university regions	Model 5: Firms in the Copenhagen metropolitan region
Intercept	-6.5863***	-5.6956***	-5.4562***
RTO (Estimate split samples)	1.4757***	0.0953	1.7138***
RTO (Average marginal effects)	0.1101***	0.0063	0.1089***
N	4681	2674	3807
AIC	1084.502	921.237	1058.821
SC	1153.714	985.934	1129.299
-2 Log L	1060.502	897.237	1034.821
*: significant at 10% level, **: significant at 5% level, ***: significant at 1% level			

Concerning firms in non-metropolitan university regions, Table 4 not only shows a lack of positive mediating effects between being located in this type of region and collaborating with RTOs. Among firms in non-metropolitan university regions, collaborating with RTOs was not positively associated with collaborating with universities. The results could suggest that in non-metropolitan university regions, unplanned interactions between firms' personnel and that of other organisations might provide as much experience on how to overcome the barriers for collaboration with universities as in metropolitan regions, owing to the variety of organisations present in metropolitan regions. However, another explanation could be put forward, based on the presence of universities in non-metropolitan university regions (Eder, 2019). Previous research has pointed out that universities in non-metropolitan university regions are often committed to support regional firms' innovation through education and research activities (Boucher, Conway, & Van Der Meer, 2003; Nilsson, 2006). These universities can also support existing clusters of science-based firms or promote the creation of new ones (Guerrero & Evers, 2018). In other words, the activities conducted by universities in non-metropolitan regions entail that industry-university collaboration is more likely to occur without the mediation of RTOs in these types of regions.

In Models 1 and 2, the control variables largely follow the direction expected in the literature. As observed in previous research on industry-university collaboration, firms that collaborate with different types of non-university organisations are more likely to collaborate with universities (Laursen & Salter, 2004). Concerning firms' characteristics, larger firms are

more likely to collaborate with universities (Mohnen & Hoareau, 2003; Segarra-Blasco & Arauzo-Carod, 2008). The same goes for firms with a higher absorptive capacity, regardless of whether the variable is R&D spending over sales (Laursen & Salter, 2004), the percentage of employees holding a university degree (Drejer & Østergaard, 2017) or whether the firm has applied for patents (Mohnen & Hoareau, 2003). Note that the association between the control variables and *UNI* might also have to do with the fact that the sample firms are innovative firms. As shown in the literature (Hewitt-Dundas et al., 2019; Mohnen & Hoareau, 2003) and in Table A6 in the Appendix where innovative and non-innovative firms are compared, the characteristics of innovative firms largely overlap with characteristics that are positively associated with industry-university collaboration. These characteristics include: high absorptive capacity, large size (Hewitt-Dundas et al., 2019; Laursen & Salter, 2004; Mohnen & Hoareau, 2003) and affiliation in sectors where science is a source of innovation (Laursen & Salter, 2004; Mohnen & Hoareau, 2003; Pavitt, 1984). Compared to non-innovative firms, fewer innovative firms were present in peripheral regions, while more of them were in university regions and the Copenhagen metropolitan region.

4.2. Sensitivity analyses

Firms in a supplier-dominated sector have been observed to show a lower propensity to draw on universities for innovation, compared to firms in sectors like those that are science based or with a specialised supplier (Bogliacino & Pianta, 2016; Pavitt, 1984). An additional model tested whether the association observed in Model 2, between *REGION (Peripheral)*RTO* and *UNI* might be explained by differences in sectoral composition between the different types of regions. The model (not displayed due to space limitations; detailed results available upon request) added an interaction term between *REGION* and *SECTOR*. Compared to Model 2, the sign and statistical significance of *REGION (Peripheral)*RTO* did not change.

Firms are more likely to collaborate with universities and other organisations on innovation if they have received support from governmental schemes (Mohnen & Hoareau, 2003). Public subsidies have to compensate for the costs involved in financing collaborative research with universities (Bruneel, D'Este, & Salter, 2016). Hence, it could be that public subsidies support collaboration between firms and universities with the involvement of

RTOs. An additional model tested whether the association between *RTO* and *UNI* and the association between *REGION (Peripheral)*RTO* and *UNI* were explained by firms' access to public subsidies. The model (not displayed due to space limitations; detailed results available upon request) included *FUNDING*, a variable that captured the amount of external funding that firms received as a percentage of their sales as well as the interaction terms *REGION*FUNDING* and *RTO*FUNDING*. The sign and statistical significance of *RTO* and *REGION (Peripheral)*RTO* did not change.

Just like firms that collaborate with universities might do so because they are equipped to collaborate with different types of organisations (Hewitt-Dundas et al., 2019), firms that collaborate with RTOs might do so because they are also equipped to collaborate with different types of organisations. While *COLLAB* already controlled for firms' propensity to collaborate with other organisations than RTOs and universities[8], an additional model included the interaction term *RTO*COLLAB* (not displayed due to space limitations; detailed results available upon request). The sign and statistical significance of the explanatory variables did not change.

Finally, an additional model was run in a sample of firms that covered the 2011 wave, the 2012 wave and the 2013 wave (not displayed due to space limitations; detailed results available upon request). Contrary to Model 2, *REGION (Peripheral)* was not statistically significant, and the same was true for *REGION (Peripheral)*RTO*. The results suggest that the findings from the regression analyses might be sensitive to the time period they cover. Nevertheless, firms in peripheral regions that collaborated with RTOs were, as in the original Model 2, not more likely to collaborate with universities than similar firms in the Copenhagen metropolitan region.

[8] As in Guerrero (2019), a version of the model included a quadratic term for *COLLAB (COLLABSQ)*, controlling whether there might be a quadratic relationship between the number of types of non-university organisations that a firm collaborated with, and its propensity to collaborate with universities. Although *COLLABSQ* was statistically significant and had a negative sign, its inclusion in the model had no implications for the sign and statistical significance of the explanatory variables. Hence, *COLLABSQ* was excluded in order to ensure the parsimony of the model.

5. Discussion and conclusion

5.1. Results discussion

This research aimed at adding to the literature by exploring whether collaboration with RTOs was positively associated with industry-university collaboration, and whether collaboration with RTOs and collaboration with universities was mediated by firms' regional location. The study thus aimed at answering the following research questions:

> *"Is collaboration with RTOs on innovation positively associated with industry-university collaboration on innovation?"*
>
> *"Does the association between collaboration with RTOs on innovation and industry-university collaboration on innovation vary depending on the type of region where firms are located?"*

In connection to the first research question, Model 1 showed a positive association between firms' collaboration with RTOs and industry-university collaboration. A possible explanation for this finding is that RTOs might help to bridge the distance between firms and universities directly through collaborative research projects and because of the social ties connecting RTO researchers and universities. RTOs might also help to bridge the gap between firms and universities because the firms that collaborate with RTOs might acquire experience on how to collaborate with an organisation whose norms and incentive systems are not far from those of universities, eventually applying this experience in collaborations with universities. Either way, the character of RTOs as organisations whose norms and incentive systems are in-between those of firms and universities (Arnold et al., 2007, 2010; Giannopoulou et al., 2019) entail that firms that collaborate with RTOs are better equipped to collaborate with universities.

In connection to the second research question, Model 2 showed that the association between collaboration with RTOs and industry-university collaboration varied with regional location, yet not in a way that fits the expectations formulated in Hypothesis 2. Collaboration with RTOs was not more strongly associated with industry-university collaboration among firms in peripheral regions, compared to firms in the Copenhagen metropolitan region, despite the

differences in organisational diversity between the two types of regions (Guerrero, 2020; Tödtling & Trippl, 2005, 2015; Zukauskaite et al., 2017). A possible explanation for this finding might relate precisely to the differences in organisational diversity between peripheral regions and the Copenhagen metropolitan region. In the Copenhagen metropolitan region, it might be easier for firms to collaborate with innovation partners other than a university, owing to the region's relatively high levels of organisational diversity. On the other hand, in regions with narrower levels of organisational diversity, like peripheral regions, firms might be more inclined to establish collaborative arrangements with universities owing to the absence of potential collaboration partners in their region (Johnston & Huggins, 2016; Shearmur & Doloreux, 2016). Extra-regional collaboration channels with universities might be for them a way to deal with the lack of potential collaboration partners in their own region (Jakobsen & Lorentzen, 2015).

Among firms in non-metropolitan university regions, collaboration with RTOs was not positively associated with industry-university collaboration. A possible explanation for the findings is that collaboration with RTOs might not be as conducive for industry-university collaboration as in the other types of regions, because firms in such types of regions tend to be co-located with universities that are particularly proactive in supporting regional firms through collaborative research links (Guerrero & Evers, 2018; Nilsson, 2006). Note however that not all universities in university regions are necessarily inclined to develop collaborative links with regional firms (Boucher et al., 2003). In the case of Denmark, some universities outside the Copenhagen region, like Aalborg University, are known to have developed for decades a wide array of educational and research activities supporting innovation in regional firms. Other universities outside the Copenhagen metropolitan region, such as the University of Southern Denmark, started to increase their third mission activities later on (Gregersen, Linde, & Rasmussen, 2009). Furthermore, Danish universities differ in the extent to which their firm partners are located in the same region (Drejer, Holm, & Nielsen, 2014, pp. 62–69).

5.2. Limitations and further research

This paper can only provide preliminary explanations for the statistical associations identified in the regression analysis. Further research is required to understand better why collaboration between firms and RTOs was positively associated with industry-university collaboration among firms in peripheral and metropolitan regions but not among firms in university regions. After all, this paper used a cross-sectional dataset to identify factors potentially associated with industry-university collaboration, and it is beyond the scope of this study to unearth causal processes. Supplementary studies using panel data could contribute to overcoming this limitation since the data for the explanatory and dependent variables would correspond to different points in time. The datasets should, however, have a number of observations large enough to run regression analyses with interaction terms like the ones included in this paper. A complementary approach could entail combining quantitative analyses with case studies on the processes that facilitate that firms in peripheral regions, non-metropolitan university regions and metropolitan regions start and develop collaborations with RTOs and universities and then collaborations with RTOs and universities might have stronger relations with each other.

In the paper, it was also suggested that among firms in university regions, collaboration with RTOs was not associated with collaboration with universities, because universities in university regions were proactive in establishing links with regional firms through, for instance, collaborative research. Further studies could run separate regression analyses on whether firms in each of the university regions are, if collaborating with RTOs, more likely to collaborate with the university located in their region. These studies could help to assess whether, for instance, collaboration with RTOs is not associated with collaboration with Aalborg University among firms in its region. This approach would not be without challenges, nevertheless. Because there would be fewer observations, it is less likely that the models could detect any relations between the explanatory and dependent variables. Moreover, case studies would still be necessary in order to explore how differences in university behaviour are conducive to the establishment of links between these universities and the firms of their regions without the mediation of RTOs.

Further research might also help to rule out alternative explanations for the findings identified in this paper. That firms in peripheral regions were as likely to collaborate with universities as their metropolitan counterparts might have to do with the fact that geographical distances in Denmark are relatively short, compared to other countries. Therefore, few peripheral regions in Denmark might be considered truly peripheral, from a geographical point of view; that is geographically isolated (Eder, 2019). In this context, many firms in peripheral regions might be at a commuting distance from a relatively broad range of organisations, all the more, if their managers are willing to cross longer geographical distances than metropolitan firms in order to interact with other organisations (Johnston & Huggins, 2016; Shearmur & Doloreux, 2016). This line of reasoning also brings non-metropolitan university regions closer to the Copenhagen metropolitan region in terms of organisational diversity. A supplementary study could explore the relevance of geographical distance for industry-university collaboration in Denmark, through comparative analyses with innovation survey data from similar, but larger countries, such as Norway or Sweden.

Comparative research might also be beneficial in order to assess how generalizable are the findings to other countries with different types of RTOs. Other countries like Norway have a strong network of RTOs with strong links to the national universities (Fagerberg, Mowery, & Verspagen, 2009). SINTEF, the main research institute in Norway was linked to the Norwegian University of Science and Technology in 1996, when its parent organisation, the Norwegian Institute of Technology, was added to that university (Arnold et al., 2010; Åstrom et al., 2008; Nielsen et al., 2018).

Finally, Denmark has only one metropolitan region. It is unclear whether the associations observed in this study would hold for countries with more than one metropolitan region. Cross-country studies could explore how inter-regional differences in industry-university collaboration would hold in countries with more than one metropolitan region.

5.3. Implications for the literature, advice for policymakers

The paper clearly has implications for the literature on industry-university collaboration (e.g., Drejer & Østergaard, 2017; Hewitt-Dundas et al., 2019; Johnston & Huggins, 2016). By collaborating with RTOs, firms appear to be better equipped to overcome the barriers for collaborating with universities. Moreover, the fact that RTOs' relevance appears to vary depending on the type of region suggests that different processes governing collaboration between firms and RTOs might be at work, offering an interesting avenue for further research.

The findings of the study can also be of use to policymakers. One of the intended roles of the Danish RTOs is to facilitate linkages between firms and universities, and the evidence reviewed in this paper suggests that firms are indeed able to fulfil this goal, in particular among firms in the Copenhagen metropolitan region and in peripheral regions (Åstrom et al., 2008, pp. 60–62). Among firms in these two types of regions, promoting collaboration between firms and RTOs might be a way of facilitating industry-university collaboration. Promoting industry-university collaboration among firms in peripheral regions might, in turn, be a way of incentivising innovation among firms in peripheral regions, supporting those policies that aim at tackling the increasing regional disparities in Denmark (Knudsen, Christensen, & Christensen, 2018). The findings might also be useful to policymakers in other countries. As noted in the introduction, policymakers see in universities an institution that can support innovation and regional development (Breznitz & Feldman, 2012; Charles, 2006; Uyarra, 2010). Yet, universities develop their regional mission in different types of regions, and the factors associated with industry-university collaboration might vary by type of region.

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Disclosure statement

Declarations of interest: none.

Appendix

Table A1: Danish RTOs, municipalities where they have offices (source: Approved technological institute websites, Nielsen et al., 2018)		
Name	**Specialisation**	**Premises**
Alexandra institute	IT for public and private organisations	Aarhus, Copenhagen
Bioneer	Biomedicine, pharma, biotechnology, medical technology	Brøndby
DBI (The Danish Institute of Fire and Security Technology)	Security, fire saftey engineering and prevention	Aarhus, Fredericia, Frederikshavn, Hvidovre
DFM (Denmark's National Metrology Institute)	Calibration, metrology	Hørsholm
DHI (Institute for Water and Environment)	Water: Inland, marine, urban, industry	Aarhus, Hørsholm
Force technology	Maritime and construction, life science and processing, oil and gas, electronics, energy and environment, public sector	Aalborg Øst, Aarhus N, Brøndby, Esbjerg, Frederikshavn, Hørsholm, Kalundborg, Kgs. Lyngby, Middelfart, Munkebo, Nordborg, Odense C, Vejen
Danish technological institute	Construction, materials, production, life science, energy, agrofood	Aarhus, Høje-Taastrup, Odense, Skejby, Sønder Stenderup

Table A2: List of municipalities per functional urban area (source: OECD, 2012)	
Copenhagen metropolitan area	Albertslund, Allerød, Ballerup, Brøndby, Copenhagen, Dragør, Egedal, Fredensborg, Frederiksberg, Frederikssund, Furesø, Gentofte, Gladsaxe, Glostrup, Greve, Helsingør, Herlev, Hillerød, Hvidovre, Høje-Taastrup, Hørsholm, Ishøj, Køge, Lejre, Lyngby-Taarbæk, Roskilde, Rudersdal, Rødovre, Solrød, Tårnby, Vallensbæk
Non-metropolitan university regions	
Aarhus	Aarhus, Favrskov, Odder, Skanderborg, Syddjurs
Odense	Assens, Faaborg-Midtfyn, Kerteminde, Nordfyns, Nyborg, Odense
Aalborg	Aalborg, Brønderslev, Jammerbugt, Rebild
Esbjerg	Esbjerg, Fanø, Varde

Table A3: Sectoral classification (source: Bogliacino & Pianta, 2016)	NACE Rev. 2, two-digit level code
Science based	
Manufacture of chemicals and chemical products	20
Manufacture of basic pharmaceutical products and pharmaceutical prep.	21
Manufacture of computer, electronic and optical products	26
Telecommunications	61
Computer programming, consultancy and related activities	62
Scientific research and development	72
Specialised suppliers	
Manufacture of electrical equipment	27
Manufacture of machinery and equipment n.e.c.	28
Manufacture of other transport equipment	30
Repair and installation of machinery and equipment	33
Real estate activities	68
Legal and accounting activities	69
Management consultancy activities	70
Architectural and engineering activities; technical testing and analysis	71
Advertising and market research	73
Other professional, scientific and technical activities	74
Rental and leasing activities	77
Office administrative, office support and other business support activities	82
Scale and information intensive	
Manufacture of paper and paper products	17
Printing and reproduction of recorded media	18
Manufacture of coke and refined petroleum products	19
Manufacture of rubber and plastic products	22
Manufacture of other non-metallic mineral products	23
Manufacture of basic metals	24
Manufacture of motor vehicles, trailers and semi-trailers	29
Publishing activities	58
Audiovisual activities	59
Broadcasting activities	60
Information service activities	63
Financial service activities, except insurance and pension funding	64
Insurance, reinsurance and pension funding, except compulsory social security	65
Activities auxiliary to financial services and insurance activities	66

Table A3: Sectoral classification (Cont.)	NACE Rev. 2, two-digit level code
Suppliers dominated	
Manufacture of food products	10
Manufacture of beverages	11
Manufacture of tobacco products	12
Manufacture of textiles	13
Manufacture of wearing apparel	14
Manufacture of leather and related products	15
Manufacture of wood and of products of wood and cork, except furniture	16
Manufacture of fabricated metal products, except machinery and equipment	25
Manufacture of furniture	31
Other manufacturing	32
Wholesale and retail trade and repair of motor vehicles and motorcycles	45
Wholesale trade, except of motor vehicles and motorcycles	46
Retail trade, except of motor vehicles and motorcycles	47
Land transport and transport via pipelines	49
Water transport	50
Air transport	51
Warehousing and support activities for transportation	52
Postal and courier activities	53
Accommodation and food service activities	55, 56
Veterinary activities	75
Employment activities	78
Travel agency, tour operator reservation service and related activities	79
Security and investigation activities	80
Services to buildings and landscape activities	81

Table A4: Correlation matrix of explanatory and control variables									
	REGION	RTO	COLLAB	RDSALES	SHAREGRAD	PATENTS	LOGFIRMSIZE	SECTOR	WAVE
REGION	1								
RTO	0,1168***	1							
COLLAB	0,0094	0,4675***	1						
RDSALES	-0,0948***	0,1077***	0,2064***	1					
SHAREGRAD	-0,2676***	-0,0193	0,1143***	0,2145***	1				
PATENTS	0,0396*	0,5556***	0,1711***	0,0975***	0,0471***	1			
LOGFIRMSIZE	0,0863***	0,1039***	0,0939***	-0,1109***	-0,1278***	0,1795***	1		
SECTOR	-0,1847***	0,0982***	0,0655***	0,2715***	0,3148***	0,2275***	-0,2831***	1	
WAVE	-0,0313**	0,0149	0,0007	0,0027	-0,0947	-0,0068	-0,0392***	0,0147	1
*: significant at 10% level, **: significant at 5% level, ***: significant at 1% level									

Table A5: Logistic regressions, collaboration with universities in Denmark (samples by type of region, Average Marginal Effects)		Model 6: Firms in peripheral regions		Model 7: Firms in non-metropolitan university regions		Model 8: Firms in the Copenhagen metropolitan region	
		Average Marginal Effects	Confidence Intervals	Average Marginal Effects	Confidence Intervals	Average Marginal Effects	Confidence Intervals
Benchmark: RTO (No collaboration)	RTO (Collaboration)	0.1101***	[0.0748; 0.1454]	0.0063	[-0.0279; 0.0406]	0.1089***	[0.0643; 0.1536]
	COLLAB	0.0364***	[0.0323; 0.0405]	0.0485***	[0.0430; 0.0541]	0.0314***	[0.0281; 0.0348]
	SHAREGRAD	0.0026***	[0.0021; 0.0031]	0.0008***	[0.0003; 0.0013]	0.0002	[-0.0001; 0.0004]
Benchmark: No patents	PATENTS	0.0550***	[0.0203; 0.0898]	0.0725***	[0.0300; 0.01150]	0.0584***	[0.0295; 0.0873]
	RDSALES	0.0030***	[0.0017; 0.0043]	0.0015**	[0.0003; 0.0026]	0.0026***	[0.0020; 0.0032]
	LOGFIRMSIZE	0.0229***	[0.0140; 0.0318]	0.0270***	[0.0157; 0.0382]	0.0107***	[0.0048; 0.0167]
Benchmark: SECTOR (Specialised supplier)	SECTOR (Supplier dominated)	0.0096	[-0.0117; 0.0308]	0.0336**	[0.0056; 0.0617]	-0.0311***	[-0.0522; -0.0100]
	SECTOR (Scale and information intensive)	-0.0190	[-0.0531; 0.0150]	-0.0157	[-0.0613; 0.0298]	-0.0608***	[-0.081; -0.0386]
	SECTOR (Science based)	-0.0435***	[-0.0694; -0.0175]	0.0287*	[-0.0048; 0.0622]	-0.0204**	[-0.0401; -0.0006]
Benchmark: WAVE 2010-2012	WAVE 2011-2013	0.0118*	[-0.0013; 0.0390]	-0.0011	[-0.0296; 0.0273]	0.0160	[-0.0013; 0.0332]
	WAVE 2012-2014	0.0679***	[0.0457; 0.0900]	0.0334**	[0.0045; 0.0624]	0.0181	[0.0017; 0.0346]
*: significant at 10% level, **: significant at 5% level, ***: significant at 1% level							

Innovative firms might possess traits that are associated with a higher likelihood of collaborating with universities (Hewitt-Dundas et al., 2019; Mohnen & Hoareau, 2003). Hence, t-tests and chi-square tests were run to explore statistically significant differences between innovative and non-innovative firms in the explanatory and control variables (Table A5 in the Appendix). *COLLAB* was not included there because firms were only enquired about collaboration on innovation in the Danish Research and Innovation Survey. Innovative firms differed from their non-innovative counterparts in all the absorptive capacity controls. They were, on average more R&D intensive; a higher proportion of their workforce held university degrees, and more of these firms applied for patents. Other than that, innovative firms were on average larger than their non-innovative equivalents, and more of them operated in the science-based, specialised supplier and scale- and information-intensive sectors. In contrast, a smaller proportion could be classified as supplier dominated.

Table A6: Descriptive statistics, differences between innovative and non-innovative firms	**Innovative firms (N=11162)**		**Non-innovative firms (N=13548)**		**Chi-square tests, T-tests**
	Mean	**Std Dev**	**Mean**	**Std dev**	***: significant 10% level, **: significant 5% level, ***: significant 1% level**
RDSALES (continuous)	2,5052	9,7250	0,2698	4,2873	***
SHAREGRAD (continuous)	15,6635	30,0026	10,4633	31,2037	***
LOGFIRMSIZE (continuous)	2,5491	1,5248	2,4121	1,6316	***
PATENTS (dichotomous)	0,0608	0,3106	0,0053	0,1192	***
SECTOR: Supplier dominated (dichotomous)	0,4185	0,6411	0,5209	0,4825	***
SECTOR: Scale and information intensive (dichotomous)	0,1012	0,3919	0,0956	0,4825	***
SECTOR: Specialised supplier (dichotomous)	0,2934	0,5917	0,2809	0,7375	**
SECTOR: Science based (dichotomous)	0,1869	0,5066	0,1029	0,4979	***
REGION: Peripheral (dichotomous)	0,3411	0,6161	0,3871	0,7992	***
REGION: Non-metropolitan university (dichotomous)	0,2395	0,5546	0,2258	0,6861	*
REGION: Copenhagen (dichotomous)	0,4194	0,6413	0,3872	0,7993	***

References

Aquilani, B., Abbate, T., & Codini, A. (2017). Overcoming cultural barriers in open innovation processes through intermediaries: A theoretical framework. *Knowledge Management Research and Practice*, *15*(3), 447–459. https://doi.org/10.1057/s41275-017-0067-5

Arnold, E., Brown, N., Eriksson, A., Jansson, T., Muscio, A., Nählinder, J., & Zaman, R. (2007). *The Role of Industrial Research Institutes in the National Innovation System*. *Vinnova*.

Arnold, E., Clark, J., & Jávorka, Z. (2010). *Impacts of European RTOs. A Study of Social and Economic Impacts of Research and Technology Organisations*. Technopolis group.

Åstrom, T., Eriksson, M. L., & Arnold, E. (2008). *International Comparison of Five Institute Systems*. Danish Agency for Science, Technology and Innovation. Retrieved from http://en.gts-net.dk/wp-content/uploads/2014/04/IntComparison2.pdf

Bessant, J. R., & Rush, H. (1995). Building bridges for innovation: the role of consultants in technology transfer. *Research Policy*, *24*, 97–114. https://doi.org/10.1186/s13661-015-0442-1

Bogers, M. (2017). *Orchestrating public-private R & D networks government-affiliated intermediary organizations as a policy intervention*. Master thesis, Utrecth University, Utrecth. Retrieved from https://dspace.library.uu.nl/handle/1874/364065

Bogliacino, F., & Pianta, M. (2016). The Pavitt Taxonomy, revisited: patterns of innovation in manufacturing and services. *Economia Politica*, *33*(2), 153–180. https://doi.org/10.1007/s40888-016-0035-1

Boucher, G., Conway, C., & Van Der Meer, E. (2003). Tiers of engagement by universities in their region's development. *Regional Studies*, *37*(9), 887–897. https://doi.org/10.1080/0034340032000143896

Breznitz, S. M., & Feldman, M. P. (2012). The engaged university. *Journal of Technology Transfer*, *37*(2), 139–157. https://doi.org/10.1007/s10961-010-9183-6

Bruneel, J., D'Este, P., & Salter, A. (2010). Investigating the factors that diminish the barriers to university-industry collaboration. *Research Policy*, *39*(7), 858–868. https://doi.org/10.1016/j.respol.2010.03.006

Bruneel, J., D'Este, P., & Salter, A. (2016). The impact of financial slack on explorative and exploitative knowledge sourcing from universities : evidence from the UK, *25*(4), 689–706. https://doi.org/10.1093/icc/dtv045

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

Charles, D. (2016). The rural university campus and support for rural innovation. *Science and Public Policy*, *43*(6), 763–773. https://doi.org/10.1093/scipol/scw017

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, *35*(1), 128–152. https://doi.org/10.2307/2393553

Danish Ministry of Higher Education and Science. (n.d.). The Danish Higher Education System. Retrieved May 8, 2018, from https://ufm.dk/en/education/higher-education/the-danish-higher-education-system

Doloreux, D., & Dionne, S. (2008). Is regional innovation system development possible in peripheral regions? Some evidence from the case of La Pocatière, Canada. *Entrepreneurship & Regional Development*, *20*(3), 259–283. https://doi.org/10.1080/08985620701795525

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

Drejer, I., & Østergaard, C. R. (2017). Exploring determinants of firms' collaboration with specific universities: Employee-driven relations and geographical proximity. *Regional Studies*, *51*(8), 1192–1205. https://doi.org/10.1080/00343404.2017.1281389

Eder, J. (2019). Innovation in the Periphery: A Critical Survey and Research Agenda. *International Regional Science Review*, *42*(2), 119–146. https://doi.org/10.1177/0160017618764279

Erhvervsstyrelsen. (n.d.). Proportion of innovative companies with innovation cooperation by area and partner. Retrieved February 25, 2019, from http://regionalt.statistikbank.dk/statbank5a/default.asp?w=1920

Eurostat. (n.d.). Community Innovation Survey. Retrieved March 25, 2018, from http://ec.europa.eu/eurostat/web/microdata/community-innovation-survey

Fagerberg, J., Mowery, D. C., & Verspagen, B. (2009). *Innovation, Path Dependency and Policy: The Norwegian Case*. New York: Oxford University Press.

Giannopoulou, E., Barlatier, P. J., & Pénin, J. (2019). Same but different? Research and technology organizations, universities and the innovation activities of firms. *Research Policy*, *48*(1), 223–233. https://doi.org/10.1016/j.respol.2018.08.008

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

Guerrero, D. F. (2020). Industry–University Collaboration in Rural and Metropolitan Regions: What is the Role of Graduate Employment and External Non-university Knowledge? *Journal of Rural Studies*, (Article in Press. Special issue on Innovation in Peripheries and Borderlands). https://doi.org/https://doi.org/10.1016/j.jrurstud.2020.03.007

Guerrero, D. F., & Evers, G. (2018). *Co-creation of Localised Capabilities between Universities and Nascent Industries: The Case of Aalborg University and the North Denmark Region* (RUNIN Working Paper Series No. 03/2018). https://doi.org/10.3990/4.2535-5686.2018.03

Hermann, R. R., Mosgaard, M., & Kerndrup, S. (2016). Partnerships for environmental technology development in the shipping industry: two Danish case studies. *Int. J. Innovation and Sustainable Development*, *10*(3), 260–280. https://doi.org/10.1504/IJISD.2016.079581

Hewitt-Dundas, N., Gkypali, A., & Roper, S. (2019). Does learning from prior collaboration help firms to overcome the 'two-worlds' paradox in university-business collaboration? *Research Policy*, *48*, 1310–1322. https://doi.org/10.1016/j.respol.2019.01.016

Howells, J. (2006). Intermediation and the role of intermediaries in innovation. *Research Policy*, *35*(5), 715–728. https://doi.org/10.1016/j.respol.2006.03.005

Isaksen, A., & Karlsen, J. (2013). Can small regions construct regional advantages? The case of four Norwegian regions. *European Urban and Regional Studies*, *20*(2), 243–257. https://doi.org/10.1177/0969776412439200

Jakobsen, S. E., & Lorentzen, T. (2015). Between bonding and bridging: Regional differences in innovative collaboration in Norway. *Norsk Geografisk Tidsskrift*, *69*(2), 80–89. https://doi.org/10.1080/00291951.2015.1016550

Johnston, A., & Huggins, R. (2016). Drivers of University–Industry Links: The Case of Knowledge-Intensive Business Service Firms in Rural Locations. *Regional Studies*, *50*(8), 1330–1345. https://doi.org/10.1080/00343404.2015.1009028

Karaca-Mandic, P., Norton, E. C., & Dowd, B. (2012). Interaction terms in nonlinear models. *Health Services Research*, *47*(1), 255–274. https://doi.org/10.1111/j.1475-6773.2011.01314.x

Knudsen, M. P., Christensen, J. L., & Christensen, P. (2018). *RIO Country Report 2017: Denmark*. EUR 29187 EN, Publications Office of the European Union, Luxembourg. https://doi.org/10.2760/54161

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

Laursen, K., & Salter, A. (2004). Searching high and low: What types of firms use universities as a source of innovation? *Research Policy*, *33*(8), 1201–1215. https://doi.org/10.1016/j.respol.2004.07.004

Leeper, T. J. (2017). Interpreting regression results using average marginal effects with R's margins. Retrieved June 7, 2019, from ftp://cran.r-project.org/pub/R/web/packages/margins/vignettes/TechnicalDetails.pdf

McCann, P. (2008). Globalization and economic geography: The world is curved, not flat. *Cambridge Journal of Regions, Economy and Society*, *1*(3), 351–370. https://doi.org/10.1093/cjres/rsn002

Mohnen, P., & Hoareau, C. (2003). What type of enterprise forges close links with universities and government labs? Evidence from CIS 2. *Managerial and Decision Economics*, *24*(2–3), 133–145. https://doi.org/10.1002/mde.1086

Nauwelaers, C. (2011). Intermediaries in regional innovation systems: Role and challenge for policy. In P. Cooke, B. T. Asheim, R. Boschma, R. Martin, D. Schwartz, & F. Tödtling (Eds.), *Handbook of Regional Innovation and Growth* (pp. 467–482). Cheltenham, UK: Edward Elgar Publishing Limited.

Nielsen, R. H., Christiansen, D. S., Boberg, D., & Rekve, K. (2018). *Technology for Danish businesses: performance statement by the Danish GTS institutes*.

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

OECD. (n.d.). Functional urban areas by country. Retrieved April 6, 2018, from http://www.oecd.org/cfe/regional-policy/functionalurbanareasbycountry.htm

OECD. (2012). *Redefining "Urban": A New Way to Measure Metropolitan Areas*. *OECD Publishing*. https://doi.org/10.1787/9789264174108-en

Parker, R., & Hine, D. (2014). The Role of Knowledge Intermediaries in Developing Firm Learning Capabilities. *European Planning Studies*, *22*(5), 1048–1061. https://doi.org/10.1080/09654313.2012.758688

Pavitt, K. (1984). Sectoral patterns of technical change: Towards a taxonomy and a theory. *Research Policy*, *13*(6), 343–374. https://doi.org/10.1016/0048-7333(84)90018-0

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

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

Rosenkopf, L., & Nerkar, A. (2001). Beyond local search: Boundary-spanning, exploration, and impact in the optical disk industry. *Strategic Management Journal*, *22*(4), 287–306. https://doi.org/10.1002/smj.160

Rothaermel, F. T., & Alexandre, M. T. (2009). Ambidexterity in Technology Sourcing: The Moderating Role of Absorptive Capacity. *Organization Science*, *20*(4), 759–780. https://doi.org/10.1287/orsc.1080.0404

Segarra-Blasco, A., & Arauzo-Carod, J. M. (2008). Sources of innovation and industry-university interaction: Evidence from Spanish firms. *Research Policy*, *37*(8), 1283–1295. https://doi.org/10.1016/j.respol.2008.05.003

Shearmur, R., & Doloreux, D. (2016). How open innovation processes vary between urban and remote environments: slow innovators, market-sourced information and frequency of interaction. *Entrepreneurship and Regional Development*, *28*(5–6), 337–357. https://doi.org/10.1080/08985626.2016.1154984

Shearmur, R., & Doloreux, D. (2018). KIBS as both innovators and knowledge intermediaries in the innovation process: Intermediation as a contingent role. *Papers in Regional Science*, (March 2017), 1–19. https://doi.org/10.1111/pirs.12354

Statistics Denmark. (n.d.). Statbank. Retrieved March 26, 2018, from http://www.statbank.dk/statbank5a/SelectTable/Omrade0.asp?PLanguage=1

Statistics Denmark. (2012). *Documentation of statistics for Innovation Statistics 2012*. Copenhagen. Retrieved from https://www.dst.dk/en/Statistik/dokumentation/documentationofstatistics/innovation-in-the-private-sector

Statistics Denmark. (2015). *Documentation of statistics for Innovation in the private sector 2015*. Copenhagen. Retrieved from https://www.dst.dk/en/Statistik/dokumentation/documentationofstatistics/innovation-in-the-private-sector

Storper, M. (2018). Separate Worlds? Explaining the current wave of regional economic polarization. *Journal of Economic Geography*, *18*(2), 247–270. https://doi.org/10.1093/jeg/lby011

Timmermans, B. (2010). *The Danish integrated database for labor market research: Towards demystification for the English speaking audience* (DRUID Working Paper No. 10–16). Danish Research Unit for Industrial Dynamics (DRUID).

Tödtling, F., & Trippl, M. (2005). One size fits all? Towards a differentiated regional innovation policy approach. *Research Policy*, *34*(8), 1203–1219. https://doi.org/10.1016/j.respol.2005.01.018

Tödtling, F., & Trippl, M. (2015). *How do firms acquire knowledge in different sectoral and regional contexts? No 2015/25, Papers in Innovation Studies, Lund University, CIRCLE - Center for Innovation, Research and Competences in the Learning Economy*.

Trippl, M., Asheim, B. T., & Miörner, J. (2015). *Identification of Regions with Less Developed Research and Innovation Systems* (No. No 2015/1). *Papers in Innovation Studies, Lund University*. Lund University. Center for Innovation, Research and Competences in the Learning Economy (CIRCLE).

Uyarra, E. (2010). Conceptualizing the regional roles of universities, implications and contradictions. *European Planning Studies*, *18*(8), 1227–1246. https://doi.org/10.1080/09654311003791275

Zukauskaite, E., Trippl, M., & Plechero, M. (2017). Institutional Thickness Revisited. *Economic Geography*, *93*(4), 325–345. https://doi.org/10.1080/00130095.2017.1331703