University-Industry Collaborations (UICs): A Matter of Proximity Dimensions?

by

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Abstract

Firms and universities interact with each other despite several barriers hindering their collaboration, such as distances in their worldviews, organizational structures and cognitive capabilities. This suggests that these distances can be bridged in some instances and proximity between the actors may help in the formation of university-industry collaborations (UICs). Proximity, being a multidimensional concept – including geographical and a variety of non-geographical dimensions such as cognitive, organizational, institutional and social – plays a bridging role between the two worlds of academia and industry and facilitates the formation of university-industry linkages. UIC, as well, represents an umbrella term that covers many different types of channels and refers to a broad range of activities as well as outputs of the interactions. Moreover, firms are driven by a variety of different motivations that influence their decision to engage in UICs, which adds to the comprehensiveness of UIC concept.

This thesis, thus, examines UICs from the proximity perspective and aims to increase the understanding of proximity in UICs. It analyses the role, importance and influence of proximities with regards to UICs, which differ greatly in terms of their contents, outputs and motivations. Proximity, through its geographical and non-geographical dimensions, helps in the formation of collaborations between firms and universities. Yet, the influence and importance of different forms of proximity depend heavily on the UIC channels in question and the initial motivation of the firm to interact with universities. Additionally, while proximity dimensions influence UIC outputs generated, the collaboration process might also have an impact on changing the proximity between actors.

Despite the overall acknowledgement of the multidimensional character of the proximity concept, it is generally assumed that geographical proximity is a strong facilitator of interactions between academia and

industry. However, several UIC activities, such as co-publishing, can be geographically dispersed since the collaboration of actors over large distances is possible. In addition, multinational enterprises (MNEs) present a rather unique configuration for the analysis of the importance of geographical proximity in UICs owing to their distributed organizational structures across different geographical locations. This dissertation, hence, examines the importance of geographical proximity for MNE's collaboration with universities. Through a case study of co-publication partnerships in the MNE-university setting, the findings demonstrate that the propensity to collaborate with regional vs. non-regional universities varies by the location of subsidiaries. While this may be caused by the differences in the influence of geographical proximity for different subunits within an MNE, it may well be due to some other factors which lead to different outcomes for the geography of UICs. This suggests a need for the inclusion of non-geographical dimensions of proximity in order to explain better the influence of proximity dimensions in UICs alongside the geographical dimension.

Previous studies have seldom taken into consideration the multidimensionality of the proximity concept of and UICs. They rather limited their scope of analysis by covering a limited number of proximity dimensions and UIC channels. This implies that most of the prior studies falls short of providing a thorough analysis of proximity dimensions in UICs. Therefore, following the proximity framework suggested by Boschma (2005), this dissertation presents a novel and comprehensive model that examines the significance of different proximity dimensions across UIC processes. With a quantitative methodology applied via the econometric examination of a survey conducted with 1201 firms, the empirical results highlight the variation in the significance of proximities by UIC channels and outputs. The findings indicate that cognitive proximity and institutional proximity have greater importance for knowledge exploration UICs, while geographical proximity matters less for this type of collaborations. For UICs oriented towards knowledge

exploitation, social proximity is more important, whereas organizational proximity matters less for advice-seeking collaborations.

There is a growing interest in the dynamic aspect of proximity, implying that interaction processes increase the proximity levels between the actors and proximities co-evolve during interaction processes since they are interrelated and interdependent (Balland et al., 2015; Broekel, 2015). However, the dynamics of proximity have not been examined extensively in UIC context. In this dissertation, this aspect has been addressed by looking at the outputs of UIC processes from the perspective of learning effects represented by non-geographical dimensions of proximity as intangible outputs. Drawing on the use of survey data, the results indicate a close relationship between the formalization of interactions and tangible outputs – such as patents – as well as the contribution of interaction processes in the development of non-geographical proximity regardless of the UIC types.

Additionally, the motivations of firms in engaging in UICs vary across firms, and this has implications for who they choose to collaborate with. Different motivations may affect whether the firms collaborate with the university partners located either in proximity or at a distance. Similarly, the existence of non-geographical proximities may affect the spatiality of UICs, suggesting an interplay between geographical and non-geographical aspects of proximity. Yet, these two factors – motivations and non-geographical proximities – have not been examined within the scope of a single study. This dissertation, however, investigates whether and how firm motivations and non-geographical dimensions of proximity affect the geographical aspect of interactions between firms and universities. The results illustrate that UICs motivated by the need for capacity development and relying on cognitive proximity are less sensitive to distance, while geographical proximity matter more for firms intending to create societal impact and building their collaboration on institutional and social proximity.

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1 Introduction

Proximity is important in shaping social relations, personal relationships and economic activities. Being close to each other physically, mentally, culturally and emotionally facilitates the establishment of linkages among various actors. It becomes easier to communicate, smoother to exchange knowledge and understand each other, less costly and less demanding to maintain the interaction when actors are proximate. That is why most relationships, both social and economic, occur between people and organizations that share some kind of proximity.

Proximity is a multi-dimensional phenomenon. Although the geographical aspect comes to mind initially, the concept of proximity denotes much more than just the geographical, physical or spatial closeness. It includes non-geographical dimensions as well. While geographical proximity relates to the space and the geography where the interaction takes place, non-geographical dimensions of proximity refer to the relational features of the actors. They reflect the closeness of the actors' cognitive capabilities, organizational routines, institutional principles and social relations. In non-geographical dimensions, proximity is considered as a relational construct reflecting the features of the relationships between the interacting actors. In this context, this thesis uses the framework of Boschma (2005) that presents four non-geographical dimensions of proximity – cognitive, organizational, institutional and social proximity – alongside geographical proximity.

University-industry collaboration (UIC) represents a peculiar type of interorganizational relationship from a proximity perspective. In general, universities and firms are said to have rather distinct characteristics. Several differences between academic and industrial actors in terms of cognitive abilities, working cultures and institutional principles imply significant distances in many dimensions. Hall (2003) describes these distances with the metaphor of 'two worlds' and, building on that,

Hewitt-Dundas et al. (2019) discuss UICs confronting the 'two-worlds paradox' owing to the barriers to managing these relationships emanating from dissimilarities of worldviews, motivations and transactional difficulties (Bruneel et al., 2010). In this regard, UICs involve interesting proximity structures that are characterized by distance rather than proximity. Thus, UICs represent a paradox from the proximity perspective, given the idea that interacting partners are assumed to need some sort of proximity to collaborate.

Still however, UICs are formed between firms and universities relying on different motivations and rationales. The collaborations take numerous forms, ranging from educational matters, such as the provision of trainings to firm employees, to the conduct of joint research projects, from technology transfer activities to informal consultations. The collaboration efforts lead to various types of outputs, like patents, joint ventures and increased reciprocal understanding of work cultures. Moreover, UICs are realized across various geographical scales, involving firms and universities located in the same cities, regions and states or in different ones.

What the realization of UICs suggests is that the barriers hindering collaboration between firms and universities can be overcome, differences can be resolved and the distances can be bridged, which renders the role of different dimensions of proximity in UICs an interesting puzzle to examine. This further indicates that the analysis of proximity dimensions in UICs may provide substantial insights on what type of proximity configurations are beneficial for the conduct of UICs.

Although different dimensions of proximity are important in facilitating UICs, the collaboration process helps in the development of proximity between the interacting partners. "The main proposition holds that, in the short run, proximity is expected to drive the formation of knowledge networks while, in the long run, knowledge networking in turn increases proximity levels" (Balland et al., 2015, p. 916). The dynamic nature of

proximity dimensions leads to the evolution of proximities during the course of interactions rather than remaining static and unchanged. The interrelatedness of the different proximity dimensions (Torre and Rallet, 2005) further complicates the issue. While proximities are affected by the interaction process, they are also affected by changes in other dimensions, suggesting that they are interdependent. This implies that collaborations that come about due to partners being proximate in one dimension may result in them also becoming more proximate in other dimensions. Menzel (2015) shows how increasing proximity in a certain dimension may reduce or produce distances in other dimensions through different mechanisms. Broekel (2015) argues for the idea of "proximity co-evolution" suggesting that different dimensions of proximity are subject to different co-evolutionary dynamics.

Given the unique proximity setup in UICs, it becomes crucial to understand how proximity relates to UICs with regards to various UIC types, outputs, actor and regional characteristics. It is also important to explore how UICs influence proximities and how geographical and non-geographical dimensions are related.

In the light of this discussion, the overarching research question of this PhD thesis has been formulated as such:

> ***Overall RQ:*** "How are different dimensions of proximity related to university-industry collaborations?"

This thesis comprises of four inter-related papers that aim to answer the overall research question. Table 1 presents an overview of the papers included in the thesis.

- **Paper 1:** Exploring the spatial reach of co-publication partnerships of multinational enterprises: to what extent does geographical proximity matter?

Paper 1 provides a detailed insight on the effect of geographical proximity in UICs for larger companies, such as MNEs. The collaborations between MNEs and universities is an interesting setting for the analysis of the significance of geographical proximity, since MNEs are themselves widely distributed organisations through their subunits. Therefore, it is important to examine how proximity processes work for MNEs engaged in UICs. The findings of the paper show that geographical proximity is influential, but up to a certain point, in driving UICs of MNEs. It also indicates that only considering geographical proximity has been insufficient to explain why this is the case, suggested by the fluctuations in the shares of different geographical scales in the composition of UICs. This points out a need to include non-geographical dimensions of proximity in studying UICs.

- **Paper 2:** Proximity across the distant worlds of university-industry collaborations

Paper 2 takes up the initiative from the last point of Paper 1 and provides a comprehensive analysis that includes five proximity dimensions based on Boschma (2005) and a broad set of UICs, including knowledge exploration, knowledge exploitation, competence enhancement, advice-seeking and marketing interactions. It contributes to proximity literature by using a novel approach in the measurement of proximity dimensions by directly asking the industrial actors' perception of proximity to their university partners. Paper 2 extends the understanding of proximity dimensions for UICs by highlighting that the significance of proximity dimensions varies in relation to the UIC type in question.

- **Paper 3:** What are university-industry collaborations good for? Tangible and intangible outcomes of collaboration types

Paper 3 examines the outcomes of UICs with a focus on non-geographical dimensions of proximity, which are considered as intangible outcomes. The paper contends that different UIC types lead to different kind of outcomes. Specifically, more formal collaboration

forms are more likely to generate tangible outputs, such as innovation and commercialization, than informal UICs. Paper 3 also illustrates that proximities are subject to dynamic processes in UICs. The findings of the paper indicate that there are no significant differences across UIC types and both formal and informal UICs contribute to the development of proximity in non-geographical dimensions.

- **Paper 4:** What drives the spatiality of university-industry collaborations: Proximity or motivations?

Paper 4 explores the geographical dimension of UICs, through a distinction between regional and extra-regional collaborations, from the perspective of the primary motivations of firms and the influence of non-geographical dimensions of proximity. Firms are motivated by several factors – such as to develop their internal capacities or to reach external resources – in engaging in collaborations with universities, which may be influential in determining the spatial reach of UICs. The proximity of the actors in non-geographical dimensions of proximity may also drive the spatiality of UICs across different geographical scales. Therefore, Paper 4 examines to what extent different firm motivations and several non-geographical dimensions of proximity shape the geographical reach of UICs. The findings indicate that the importance of various dimensions of proximity and the influence of different motivations vary for regional and extra-regional UICs. For instance, firms that attach greater value to cognitive proximity and firms that are motivated to develop internal capacities are more likely to engage in extra-regional UICs. On the other hand, firms that regard institutional and social proximity as more important and firms which seek to create a more positive image and societal impact have a greater tendency to collaborate with universities in their regions.

In general, the thesis posits that different dimensions of proximity are important in UICs, but their significance differs depending on the UIC category examined. Various dimensions of proximity play a facilitating

role for UICs to varying degrees. Additionally, proximity dimensions do not remain static in the course of interactions, but the collaboration process increases the levels of proximity in non-geographical dimensions. Furthermore, geographical and non-geographical dimensions of proximity are interrelated, suggesting that either an overlap or a substitution mechanism functions depending on the proximity dimensions in question. Cognitive proximity can enable UICs between geographically distant partners, implying the substitution effect, which is found to be contingent on the collaboration motives. On the other hand, UICs occurring between partners in geographical proximity involve higher institutional and social proximity, which suggests the overlapping of these proximity dimensions. Last, the influence of non-geographical proximity dimensions can be affected by the underlying motivations of UICs.

The remainder of this introductory chapter is structured as follows: Section 2 presents the theoretical framework and highlights the importance of proximity for UICs. Section 3 presents the data and methodology. Section 4 summarizes the papers appended in the thesis. Section 5 concludes by providing a discussion, presenting the contributions and implications and indicating further research avenues.

Table 1 – Overview of the papers included in the thesis

	Paper 1	**Paper 2**	**Paper 3**	**Paper 4**
Title	Exploring the spatial reach of co-publication partnerships of multinational enterprises: to what extent does geographical proximity matter?	Proximity across the distant worlds of university-industry collaborations	What are university-industry collaborations good for? Tangible and intangible outcomes of collaboration types	What drives the spatiality of university-industry collaborations: Proximity or motivations?
RQs	RQ1. How does geographical proximity affect the collaboration networks of multi-national enterprises with universities?	RQ1. How important are the various dimensions of proximity in the emergence of UICs? RQ2. Does the importance of proximity depend on the type of UICs?	RQ1. What benefits do firms experience from UICs? RQ2. Do the perceived benefits vary across different types of UICs?	RQ1. How non-geographical dimensions of proximity and firm motivations affect the geography of UICs?
Relation to overall RQ	Explores the geographical distribution of a specific UIC type (co-publications) for large enterprises	Explains the geography of UICs and the significance of proximity dimensions in a number of UIC categories	Explains to what extent UIC process affects the development of proximity dimensions between the actors	Explains how and to what extent non-geographical dimensions of proximity and motivations influence the geography of UICs

Theoretical focus	How geographical proximity relates to UICs	How geographical and non-geographical proximity dimensions relate to different UICs	How UICs relate to non-geographical proximity dimensions	How non-geographical proximity dimensions relate to geography of UICs
Data	Bibliometric data (co-publications from Thomson Reuters' Web of Science database	Survey data (tailor-made questionnaire with 1,201 Norwegian firms)	Survey data (tailor-made questionnaire with 1,201 Norwegian firms)	Survey data (tailor-made questionnaire with 1,201 Norwegian firms)
Status	Published in Regional Studies, Regional Science 6(1), 281-298, (2019).	Accepted for publication Papers in Regional Science on 16.11.2020	Submitted to Science&Public Policy on 26.09.2020	Work-in-progress
Authors	Utku Ali Riza Alpaydin	Utku Ali Riza Alpaydin & Rune Dahl Fitjar	Utku Ali Riza Alpaydin & Rune Dahl Fitjar	Utku Ali Riza Alpaydin
Author Contributions				
- Concept & Idea	- Alpaydin	- Alpaydin	- Alpaydin	- Alpaydin
- Study design &Methods	- Alpaydin	- Alpaydin	- Alpaydin	- Alpaydin
- Data Collection	- Alpaydin	- Alpaydin	- Alpaydin	- Alpaydin
- Analysis & Interpretation	- Alpaydin	- Alpaydin & Fitjar	- Alpaydin & Fitjar	- Alpaydin
- Manuscript preparation	- Alpaydin	- Alpaydin & Fitjar	- Alpaydin & Fitjar	- Alpaydin
- Critical revision of the intellectual content	- Alpaydin	- Fitjar	- Fitjar	- Alpaydin

2 Theoretical framework

This chapter presents the theoretical framework of the thesis, which draws upon two different sets of literatures: proximity and university-industry collaboration. The thesis is based on the premise that UIC is an interactive process in which proximity between partners plays a facilitating role, whose significance varies depending on different firm types, UIC channels and UIC motivations. In addition, the thesis regards the development of proximity as one type of UIC outputs. The chapter, first, presents a review of the proximity literature with an emphasis on the distinction between the geographical and non-geographical dimensions of proximity and touching upon the current debates on proximity dynamics. Then, it delves into the UIC literature by reviewing discussions on barriers and enablers, motivations and types of UICs. The chapter concludes by presenting the conceptual model, composed of proximity dimensions and UICs, that is used in the thesis.

2.1 Proximity

The literature developed around the concept of proximity mainly deals with the underlying factors of interactions for collaborative purposes and aims at providing an explanation for the bases of interactions between actors. In general, proximity has been regarded as a foundation stone which actors build their interaction on and as a facilitating mechanism for easing the process of coordination in interactive relationships (Boschma, 2005). The main assumption of the proximity approach is that proximate actors are more likely to interact than distant actors (Heringa et al., 2014). Balland et al. (2015) take this argument forward and argue that more proximate actors will also be more effective in collaborating. Yet, there are limits to the benefits of proximity, which is referred as 'the proximity paradox' (Broekel&Boschma, 2012), suggesting that too much proximity can be detrimental in collaborations since it leads to unwanted situations such as lock-ins. Fitjar et al. (2016) also argue for

an optimal level of proximity found in between excessively high and low proximity.

The importance of proximity in economic activities stems from its facilitative role in interorganizational collaborations. With the critical role of knowledge creation, exchange and interactive learning for competitiveness and innovation, economic actors are stimulated to collaborate with other entities more frequently. This imperative to collaborate has rendered proximity significant in inter-organizational relationships since it allows for a smoother interaction process by eliminating several barriers. "What unites the different dimensions of proximity is that they reduce uncertainty and solve the problem of coordination, and, thus, facilitate interactive learning and innovation" (Boschma 2005, p. 62).

Proximity is often seen as a precondition for knowledge exchange due to a number of reasons (Knoben&Oerlemans, 2006). The most common attribute of proximity in inter-organizational collaborations is that proximity reduces transaction costs and uncertainty. It is less costly to find partners in close proximity (Boutilier&McNaughton, 2006). Proximity also helps reduce the uncertainty involved in interaction processes (Boschma, 2005). Additionally, proximity enables a smoother coordination of interactive relationships and contributes to building trust especially by providing a stable foundation stone on which the relationships are built (Heringa et al., 2014). All these facilitative roles enabled by proximity make it easier for actors to transfer and exchange knowledge, and thus, engage in collaborative linkages for innovation, which generally bear high costs and high uncertainty.

However, the issue of defining proximity is challenging. The early studies in this vein have embodied the term proximity as being close to each other physically, which resulted in an emphasis on the geographical dimension of proximity (Crescenzi et al., 2017). Starting in the 1990s, the concept of proximity has been enlarged to embrace non-geographical

dimensions of the concept as well. In this recent approach, proximity has been treated as a multi-dimensional concept (Molina-Morales et al., 2014; Mattes, 2012) that extends beyond the geographical understanding of it.

Multidimensionality does not mean that different dimensions of proximity are equally important across interaction categories. The significance of different proximity dimensions differs depending on several other aspects, such as individual characteristics of the interacting partners, the bilateral proximity structure between them and the content of the interaction. Therefore, the investigation of the significance of different forms of proximity for any bilateral relationship needs to pay attention to these features.

Additionally, the multidimensional character of the proximity concept does not suggest clear-cut divisions between different dimensions. Different proximities are much more intertwined and interrelated to each other than their classification into different dimensions indicates. For instance, geographical proximity plays a significant role in shaping non-geographical dimensions. By defining the context within which the interactions take place, geographical proximity provides a suitable platform to nurture non-geographical dimensions to varying degrees. In return, non-geographical dimensions of proximity may also drive geographical proximity. For instance, cognitive proximity between firms may result in their co-location to benefit more from knowledge spill overs. Yet, the influence of non-geographical proximity on geographical proximity is rare in practice and harder to realize in reality. Non-geographical aspects are also closely associated with each other. Organizational proximity, for instance, is related to institutional proximity in the sense that organizations belonging to same hierarchical structures also share similar institutional arrangements. Cognitive proximity helps in the development of organizational proximity, such as in the case of the establishment of joint organizations or other types of common hierarchical structures. Social proximity positively influences

the development of other non-geographical dimensions. Higher levels of social proximity may lead to the strengthening of joint institutional norms and values. Social proximity is also heavily influenced by institutional and organizational proximity, since they allow the establishment of trustful relations.

This indicates the difficulty in delineating the borders between geographical and non-geographical dimensions of proximity, suggesting that they are strongly inter-related (Torre and Rallet, 2005). It also illustrates that there are different dynamics taking place among several dimensions of proximity. Furthermore, proximities are in a constant change process during the course of interactions (Balland et al., 2015). Actors' proximity to each other evolves during the interaction process as they learn from each other, bringing them cognitively, organizationally, institutionally and socially closer. Broekel (2015) argues the idea of "proximity co-evolution", suggesting that different dimensions of proximity are subject to different co-evolutionary dynamics. However, the pace and the timing of co-evolution differ starkly in relation to the dimension at stake. For instance, an increase in the geographical proximity, in the form of temporary physical proximity of people, may result in the development of social proximity enhanced by an increased level of trust that is triggered by face-to-face communication. This, in turn, makes the interactions much more likely to repeat in the future and therefore completes a self-reinforcing loop. However, this dynamic aspect of proximity has not been studied much in the related literature. Before discussing the dynamics of proximity dimensions, the next two sub-sections clarify geographical and non-geographical dimensions of proximity to lay down the theoretical background of this thesis.

2.1.1 Geographical proximity

The pioneering studies in the geography of innovation emphasized the importance of co-location and spatial agglomeration of actors for the stimulation of innovative activities at the firm level (Shearmur et al.,

2016). The territorial innovation models like industrial districts, innovative milieux, clusters, learning regions and regional innovation systems stress the idea of geographical proximity as the underlying factor and the precondition for knowledge generation and transfer, which are deemed to result in innovation (Crevoisier&Jeannerat, 2009).

The importance of geographical proximity in facilitating interactions draws on a number of reasons. First, being located physically close decreases transaction costs. Interactions in geographical proximity require less money and time. Second, geographical proximity is argued to be necessary for the exchange of tacit knowledge. Third, it creates a suitable environment for serendipitous and chance encounters between the partners. Therefore, geographical proximity makes partners start to collaborate more easily than distant actors. Additionally, it makes the collaborations less troublesome and more effective.

However, the influence of geographical proximity in facilitating interactions has been challenged by several developments. First, the need for co-location has diminished as a result of the rapid technological developments in communications. The expansion of internet and similar ICT technologies has enabled long-distance communications in the virtual world. This has led some to argue that co-location and geographical proximity can no longer be considered as a requirement for interactions (Torre, 2014), while some others still contend that internet and other ICT means will not likely affect how the economic activities are conducted due to the need for face-to-face contact (Leamer&Storper, 2014). Second, the need for geographical proximity can be compensated by travelling, which creates moments of geographical proximity temporarily (Torre, 2014). The expansion of transportation networks, especially air traffic, has facilitated business travels and enhanced the mobility of actors, which reduces the significance of permanent co-location (Bathelt&Henn, 2014). Last, it has been shown that simple co-location does not suffice for effective knowledge exchange and to ensure interaction among actors situated in close geographical proximity

(Boschma, 2005). Boschma and Ter Wal (2007) argues that knowledge networks may also serve as effective mediums through which knowledge exchange takes place among actors that are not geographically proximate. Fitjar and Rodríguez-Pose (2017) examined whether co-location promotes innovation and found that collaborations that came about due to chance encounters had a limited effect on the innovative performance of firms.

2.1.2 Non-geographical dimensions of proximity

With the increasing recognition that simple co-location would not automatically translate into dense interactions among the actors in a given geographical area, the attention has shifted to non-geographical dimensions of proximity as the underlying drivers of interactive relationships. The closeness between actors in relational terms, such as knowledge bases, organizational structures, institutions and social relations, may foster interactions more than pure geographical proximity (Slavtchev, 2013).

The emphasis on the geographical dimension of proximity has been challenged mainly by a group of scientists working on the "Dynamics of Proximity", sometimes referred to as the French Proximity School which emerged in France in the early 1990s (Ferru&Rallet, 2016). The group contested the predominance of the understanding of proximity only in geographical terms and their efforts have resulted in the analytical deepening and widening of the concept with the addition of new explanations and types of proximity (Knoben&Oerlemans, 2006). Simply being located at the same locality does not ensure knowledge exchange and interactions among partners, but there needs to be other forms of proximity for the purposes of collective learning and innovation (Boschma, 2005; Capello, 2014).

In the first instance, the concept of organized proximity was put forward in addition to geographical proximity. In the words of Torre (2014, p.

98), "Organized proximity refers to the different ways of being close to other actors, regardless of the degree of geographical proximity between individuals."

Then, Boschma (2005) introduced a new taxonomy of the proximity concept, building on the previous work of the French scholars. A key insight in Boschma's approach is the insufficiency of geographical proximity in explaining collective learning. Boschma (2005, p.62) argues that "…geographical proximity per se is neither a necessary nor a sufficient condition for learning to take place". Instead, he presents a new classification based on five forms of proximity, i.e., cognitive, organizational, social, institutional and geographical proximity.

Cognitive proximity denotes the existence of a shared knowledge base between interacting partners (Boschma, 2005). The overlap of two actors' knowledge bases is considered to provide cognitive proximity between them (Broekel&Boschma, 2012). The interacting partners need to have similar knowledge bases in order to be able to communicate effectively and understand each other. Cognitive proximity is also conceived as "the similarities in the way that actors perceive, interpret, understand, and evaluate the world" (Steinmo&Rasmussen, 2016). In this last notion, cognitive proximity is closely linked to the 'absorptive capacity' concept, which denotes firms' ability to identify, exploit and use external knowledge, often represented by the intellectual capital of the employees (Cohen&Levinthal, 1990). Cognitive proximity facilitates communication and coordination in interactive learning by ensuring that the collaborating actors understand and process the knowledge similarly. The commonality of the frames of reference, technologies, and technical jargons are indicative of cognitive proximity.

Organizational proximity is "defined as the extent to which relations are shared in an organizational arrangement, either within or between organizations" (Boschma, 2005, p. 65). Organizations that are subject to the same, or similar, control mechanisms resulting from being part of

common hierarchical structures are said to be organizationally proximate (Tijssen et al., 2016). Formal organizational arrangements – such as control mechanisms and hierarchical structures – creates organizational proximity between the collaborating actors (Fitjar et al., 2016). Organizational proximity plays a crucial role in inter-organizational relationships since it limits opportunism and free riding. Organizational proximity constrains the actions of collaborating actors by serving as a control mechanism that acts as a safeguard against the opportunistic behavior of their partners.

Institutional proximity denotes the sharing of same institutional rules of the game, as well as a set of cultural habits and norms (Boschma, 2005). It encompasses both formal (e.g., laws and regulations) and informal (e.g., shared norms, values and culture) institutional frameworks (Ponds et al., 2007). Actors who work in similar institutional settings are more likely to interact with each other since they know the consequences of non-adherence to institutional conditions. Even though the institutional settings are given, they are not completely rigid. They provide some room of maneuver for the actors to act within the range of some boundaries depending on their attitude, approach and mindset. Therefore, partners belonging to different institutional frameworks can still have some institutional proximity with each other.

Social proximity covers the idea of "social embeddedness of actors in terms of friendship, kinship and experience at the micro-level" (Broekel&Boschma, 2012). It reflects individual-level relationships and the level of trust in these relationships that may be created through prior ties or repeated interactions. Social proximity, and trust, also facilitates interactive relationships by working as a guard against opportunism.

Alongside these two dominant positions regarding non-geographical dimensions of proximity, some scholars have proposed other types of proximity that attempt to account for effective knowledge transfer for innovation purposes. These include cultural proximity (Teixeira et al.,

2008), technological proximity (Cassi & Plunket, 2015), and personal proximity (Werker et al., 2016). What all these explanations are trying to capture is that the actors involved in the process of knowledge exchange need to be proximate to each other or share some commonalities in order to ensure the effectiveness of interactions.

Yet, the positive influence of proximity dimensions in interactive relationships is not limitless, implying that too much proximity may also be harmful. Defined as the 'proximity paradox' (Broekel&Boschma, 2012), the notion indicates that too much proximity in any dimension may lead to lock-in situations, which can counteract the facilitative and fruitful role of proximity in interactions. If cognitive proximity is too high, it limits the potential for novelty since the partners' knowledge bases are alike and they have nothing much to learn from each other. Excessive organizational proximity may bring too much control and a hierarchical bureaucracy of formal arrangements. Too much institutional proximity may also result in a strictly rigid environment by acting as inertia brake. Impartiality or fairness fades away and nepotism may materialize in the occasion of too much social proximity, which may lead to the neglect of better available opportunities.

2.1.3 Dynamics of proximity dimensions

There is also a growing recognition on the dynamic nature of proximity dimensions in the related literature (Balland et al., 2015; Broekel, 2015; Bouba-Olga et al., 2015). Even though most literature has tended to treat proximities as static, the studies on the dynamics of proximity mainly state that proximity between partners is subject to change and does not remain constant, but evolve during the course of interactions. The proximity configuration between actors changes in the process of interaction and engagement with other actors. As they learn from their peers, they enlarge their knowledge base and become cognitively closer to them. They may increase the formalization of the collaborations over time, implying an increase in organizational proximity. The partners get

to know formal institutional principles, as well as the cultural values and norms, of their counterparts, which results in more institutional proximity. The initial trust among the interacting parties may deepen as a result of interactive processes, indicating a higher level of social proximity. Therefore, while proximity plays a crucial role in the establishment of collaborations in the first place, the collaboration process also leads to the development, or evolution, of proximity dimensions over time.

The dynamic interplay between geographical and non-geographical dimensions of proximity can further be characterized as a tension between two alternative mechanisms (Huber, 2012; Hansen, 2015). On the one hand, it is assumed that geographical proximity overlaps with non-geographical dimensions (*overlap mechanism*) in the sense that the former facilitates the establishment or development of the latter. For instance, geographical proximity between the actors helps in the development of social proximity through regular face-to-face contact during casual and planned encounters. Geographical proximity also enhances cognitive proximity between the collaborating actors through the transfer of tacit knowledge. On the other hand, non-geographical dimensions of proximity may substitute for geographical proximity (*substitution mechanism*), suggesting that they can compensate for the lack of geographical proximity. Cognitive proximity enables long-distance collaborations between actors sharing similar knowledge bases through compensating the need for geographical proximity. Similarly, organizational proximity, for instance in the case of multi-national enterprises, helps in the exchange of knowledge between different sub-units that are geographically distant, suggesting that it substitutes for geographical proximity.

This thesis examines the dynamic nature of proximity dimensions on UICs in exploring to what extent the interaction processes help develop the existing proximities between the partners. By studying proximity dynamics from the perspective of learning and considering it as an

outcome of collaborations in Paper 3, this thesis argues that UIC processes contribute to the expansion of non-geographical proximities. The experiences gained during interactions foster the improvement of proximity dimensions. Additionally, the interrelatedness of geographical and non-geographical dimensions of proximity is explored in Paper 4. The findings show that there is an overlap mechanism between institutional and social proximity and geographical proximity, but a substitution mechanism between cognitive and geographical proximity.

In overall terms, the thesis examines to what extent geographical and non-geographical proximity dimensions are influential in inter-organizational collaborations. Through adopting a dynamic perspective on proximities, the thesis also examines how inter-organizational collaborations affect different forms of proximity and the inter-relatedness between these dimensions. The inter-organizational context in which the proximity framework presented above is applied concerns the collaborations between universities and industrial actors.

2.2 University-industry collaborations

University-industry collaborations provide many advantages for firms. Firms benefit from high-level expertise and knowledge that the academy possesses. Universities are the generators of a highly educated labor force to work in different industries after their studies. Universities conduct cutting-edge research on the technological frontiers that might provide benefits to humanity. Universities are also increasingly seen as a source of new firms through academic and student entrepreneurship, with which they provide new jobs and economic growth for their regions. These developments have resulted in an increased emphasis on the role of universities in economic development, innovation and competitiveness.

With the increased recognition that the root of competitiveness is shifting from low-cost production to innovation, knowledge has become a critical

source. Thus, the generation of knowledge and access to it has turned out to be a key element of innovativeness, and consequently competitiveness. Yet, knowledge sources are widely distributed and all the knowledge required to innovate hardly resides within the confines of a single organization or region, resulting in an increased need for collaboration between and among different organizations located elsewhere. In this regard, approaches like open innovation (Chesbrough, 2003) that call for extensive collaboration between actors have gained prevalence both in academic and policy circles. The growing recognition of the increased importance of co-operation between actors for knowledge exchange and transfer purposes in order to be innovative has directed the attention to universities as one of the crucial producers of new knowledge (Zomer&Benneworth, 2011). Universities have started to attract the attention of firms as important partners in strategic linkages for knowledge acquisition purposes. The inability or incapability of business actors to have all the necessary knowledge to be used for innovation purposes internally have resulted in an active search for external collaborations. For the external knowledge sourcing, firms increasingly establish collaborative linkages with different sorts of actors, their supply-chain partners, universities and research organizations and others. This has resulted in an increasing interest in studying university-industry interactions (UICs) in the last 30 years (Muscio, 2013).

The literature on university-industry collaboration has also flourished through the increasing emphasis on the third mission of universities. The third mission thesis argues for universities to contribute more to the socio-economic development/welfare or to improve regional innovation capabilities. The mere existence of universities in regions is regarded as a contribution to local/regional economies owing to their direct economic effect in terms of the employment of academics and the services purchased from the local area. The main advantage of universities for the regions in which they are located was argued to

emerge from their traditional missions of teaching/education (creation of a qualified human capital) and research (new knowledge) (Uyarra, 2010). However, in line with the changes in the expectations to universities, especially from policy-makers (Benneworth et al., 2015), universities are increasingly being called upon to contribute to economic development and competitiveness (D'Este&Perkmann, 2011) and to create wider societal benefits.

2.2.1 Definition, Types and Outputs of UIC

The concept of "university-industry collaboration" has been used as an umbrella term to describe all possible interactions between academic and industrial agents. Schartinger et al. (2002) define university-industry interactions as "all types of direct and indirect, personal and non-personal interactions between organizations and/or individuals from the firm side and the university side, directed at the exchange of knowledge within innovation processes" (p. 304). In a more recent systematic literature review, Ankrah and Al-Tabbaa (2015, p. 387) provides a similar definition of UICs: "the interaction between any parts of the higher educational system and industry aiming mainly to encourage knowledge and technology exchange". In this thesis, UIC is also acknowledged as a comprehensive term that involves many interaction types between academia and businesses.

However, most studies take UIC as a 'self-explanatory' concept and do not provide a precise definition of it (Galán-Muros & Plewa, 2016), which results in an understanding of UIC as a homogenous activity (Kaloudis et al., 2019). Nevertheless, in practice, this creates an influx of all different collaboration types and channels of interactions to be considered under the same banner of UICs. Therefore, various studies present different classifications of UIC types based on their interest and focus (Perkmann and Walsh, 2007).

The studies to date have illustrated that UICs occur in a number of forms, ranging from collaborative research to internships, from patenting/licensing to academic counselling and so on. However, there is a stark difference in the emphasis between the types of UICs that have been examined. The related literature mentions a multitude of UIC types. Yet, only a small section of these types has been studied extensively, leaving the majority of UIC channels understudied. Some of the channels – such as patenting, licensing, co-publications and joint research – have attracted vast scholarly attention mainly due to data availability (Crescenzi et al., 2017). Since these activities are registered in certain databases – such as Espacenet, the European Patent Office (EPO) database –which are open access, or relatively easy to access, many studies have examined these UIC types (Gertner et al., 2011). The concentration on these UIC types has also been caused by the inclination of policy-makers to see tangible results coming out of the investments made for academic and scientific research. The push for producing economic benefits from UICs has led to the promotion of particular types of interactions, such as academic commercialization resulting in patents, licenses, spin-offs or start-ups.

However, as the definitions above suggests, UICs cover much more than easily quantifiable and measurable activities such as patenting and co-publications, suggesting a discrepancy in the representation of UICs types. In this vein, other interaction types, like education-oriented collaborations or informal consultancy, have been understudied in the literature. Paradoxically however, the limited amount of research on these overlooked types of UICs have found that they are more frequently exercised and attributed higher importance by the firms compared to the more widely examined UIC types (Foray&Lissoni, 2010; Thursby&Thursby, 2011; Cohen et al., 2002). This situation has been characterized with the metaphor of the "tip of the iceberg" (Perkmann&Salter, 2012; Norn, 2016), suggesting that frequently studied UIC types such as patents and spin-outs are highly popular and

clearly visible, but scant in real life (Ramos-Vielba and Fernández-Esquinas, 2012). The majority of UICs lies "beneath the surface" (Norn, 2016), and they remain overlooked, creating a discrepancy between the size of actual interactions and the number of academic works studying them and policy documents mentioning them.

Indeed, the majority of interactions between firms and universities takes place in the form of student projects, internships, professional training and informal consultations, which are hard to trace, observe, quantify and analyze (Hewitt-Dundas, 2013). Thune (2011), for example, indicates the insufficient coverage of education-related UICs, although they are practiced more frequently. Foray and Lissoni (2010), as well, indicates the recruitment of graduates as a powerful channel in UICs. Yet, these UIC modes have seldom been examined in the literature (Ramos-Vielba and Fernandez-Esquinas, 2012), which has resulted in a distorted representation of UIC phenomena. A better understanding of links between firms and universities in these overlooked types of UICs may indeed provide more accurate insights into the nature and process of interactions (Gertner et al., 2011). Therefore, it is equally important to re-orient the focus of UIC studies, as well as of the policy approaches that can largely be blamed for the overrepresentation of some UIC types, more towards education-related interactions involving the mobility of people and informal consultancy activities.

The outputs of UICs have generally been equated with the UIC channels in question, making the lines between the interaction process and the results blurry and indefinite (Perkmann et al., 2011; Ankrah&Al-Tabbaa, 2015). The mixing up of the outputs with the interaction process makes it challenging to present a clear-cut typology of UIC outputs independently of the UIC categories. Therefore, research examining UIC outputs also reflects a similar tendency – as in the case of emphasizing a few UIC channels. Certain types of outputs that are significantly easier to observe and measure – such as patents or publications – are examined more frequently than some other outputs (Perkmann et al., 2013). Still

however, UICs have been argued to generate several intangible outputs both for the university and for industrial partners. The interactions between firms and universities lead to several learning effects that are beneficial for UICs. Through interaction, firms and universities develop their abilities to share knowledge and learn to understand their respective cognitive competences (Steinmo&Rasmussen, 2018). They learn how to better manage the collaboration processes. The relationships between industrial and academic organizations may result in the relaxation of institutional regulations, such as the easing or softening of existing practices on intellectual property rights (IPRs). The low levels of confidence between the agents may be boosted and they learn to trust their counterparts (Nilsson, 2019). However, the subset of UIC literature examining outputs has not paid much attention to intangible outputs and therefore, there is a need for studying the learning effects resulting from the interactions. This thesis examines proximity dimensions from the learning perspective by considering increased proximities between the actors as learning outcomes of the collaboration process.

2.2.2 Drivers and Barriers of UICs

The UIC literature has studied the drivers and barriers of collaborations extensively (Bruneel et al., 2010; Muscio, 2013). These studies often refer to several differences between universities and firms that impede firms' interaction with universities in the first place, or that undermine the success of UICs during the interaction process, suggesting that university-industry interactions can be harder to realize than they seem. The frequently mentioned barriers include the differences in incentive mechanisms, motivations, time horizons, the lack of funding and heavy bureaucracy related to interactions (Davey et al., 2018). The divergent institutional conditions that shape the behavior of universities and firms, such as different value sets, time management procedures and approaches to secrecy, prevent academic and business actors from engaging in fruitful collaborations. In the literature, these institutional

differences have mostly been taken for granted and the underlying characteristics of these differences have not been questioned much. Scholars attempting to provide a recipe for successful university-industry interactions have generally explained the success of UICs with external factors, such as the availability of resources (Perkmann et al., 2011), frameworks to govern the relationship (both formal and informal) (Mora-Valentin et al., 2004; Thune, 2011), and relational aspects, such as the degree and intensity of communication (Bonaccorsi&Piccaluga, 1994; Thune, 2011). A limited number studies have considered distance as a barrier or proximity as an enabler of UICs (Cummings&Teng, 2003; Crescenzi et al., 2017; Johnston&Huggins, 2017; D'Este et al., 2013). These studies have mostly focused on the geographical dimension of proximity and considered proximity as a given situation of their relational position vis-à-vis their partners. However, none of the studies have included the actors' own perception of their proximity to their interaction partners. The actors' subjective perspective has mostly been out of sight in the studies examining proximity framework in UICs.

These discussions point to several issues in the UIC literature that this thesis addresses. First, the UIC literature limits itself to a narrow set of channels that represent a minority of actual collaborations. This thesis, however, takes a broader perspective on UIC types that equally addresses less formal types of interactions such as student internships and informal contacts. Second, concomitant with the emphasis on certain UIC types, tangible outputs of UIC have attracted the main focus of UIC literature. The neglect of the intangible benefits leads to an underestimation of the value of interaction processes and the influence of learning effects in UICs. Therefore, this thesis moves away from the existing emphasis on tangibles to also include intangible outputs of UICs. Last, the existing literature on UICs repeatedly studies barriers and drivers without examining the micro-processes and the perceptional aspects of the problems hindering UICs. This study offers a fresh perspective on discussions over barriers and drivers of UICs by introducing the

proximity framework into the analysis that takes into account the subjective perspective of the collaborating actors.

2.3 Proximity in UICs

In this thesis, the proximity framework is applied to the university-industry collaboration context, which is characterized by distance rather than proximity of the involved partners. The differences between firms and universities in various dimensions suggest that UIC, indeed, is a bridge that connects two distant worlds (Hall, 2003). Therefore, firms and universities with a desire to engage in UICs need to overcome a number of barriers. Yet, these barriers have not traditionally been examined from the distance/proximity perspective.

The existing studies have tended to focus on the geographical dimension of proximity over the non-geographical dimensions. What this thesis intends to do is to combine a wider set of UIC channels with a more comprehensive understanding of proximity dimensions. In the context of UICs, this thesis attempts to integrate the proximity framework – by considering geographical and four non-geographical dimensions of proximity – in its analysis.

2.3.1 Geographical proximity in UIC studies

The geographical aspect of proximity has been examined widely in determining the spatial reach and distribution of UICs. It is widely argued that geographical proximity is a strong enabler of UICs (D'Este&Iammarino, 2010; Laursen et al., 2011; Ponds et al., 2007) and consequently, most of the interactions between universities and firms happen in close geographical proximity (Abramovsky&Simpson, 2011). The prominence of geographical proximity in UICs mainly stems from the facilitative role played by space and the stickiness of knowledge, especially tacit knowledge (Gertler, 2003).

These studies tend to emphasize the geographical closeness between universities and firms that are involved in UICs. Most of the studies show that UICs tend to take place in close geographical proximity. D'Este and Iammarino (2010), for example, found that the median distance in university-industry joint research partnerships in the UK is 148 kilometers. A recent report from OECD (2019), where they have examined more than 2,5 million patent applications in 35 OECD member countries and China between 1992 and 2014, has found that 50% of inventive activity by industrial actors is realized within a 30-kilometer distance from a research university.

However, the literature presents mixed results for the significance of geographical proximity for different UIC categories (De Fuentes&Dutrénit, 2016). While some studies state that patenting and licensing are more geographically localized (Jaffe et al., 1993), other studies report contrasting results where they indicate that geographical proximity is not necessary for the very same type of interactions due to the codified nature of the knowledge transferred (Arundel&Geuna, 2004). For informal interactions, as well, the results are contradictory. Slavtchev (2013) found that informal contacts can overcome the distance barrier and happen over larger geographical distances. On the contrary, Ponds et al. (2010) argue that informal interactions are highly localized.

Additionally, studies examining the determinants of distance in UICs discuss a number of factors that influence the geographical reach of collaborations. The quality – or the research excellence – of the university is counted as a force that attracts the attention of firms from significant distances (Laursen et al., 2011; D'Este&Iammarino, 2010). It is closely linked to the existence of star scientists or researchers at a given university. The firms that would like to collaborate with leading scientists may reach out to them regardless of geographical distance, leading to long-distance UICs. However, university quality may also drive the geographical proximity of actors that result in the diminishing of the distances. Firms that would like to benefit more from knowledge

spillovers from high-quality research tend to locate their R&D facilities around the universities or research centers, especially in knowledge-intensive sectors such as biotechnology or pharmaceuticals (Abramovsky et al., 2007).

The other frequently referred factors that influence the spatial distance between the partners in UICs are firm characteristics. The size of the firms is regarded as a factor that positively influences the tendency of firms to engage in UICs both more frequently and across larger distances. Larger firms, such as multinational enterprises (MNEs), tend to collaborate more often with universities in general (Dell'Anno & del Giudice, 2015). Additionally, their likelihood to engage in UICs across larger distances is higher in comparison to small-and-medium sized enterprises (SMEs) (Hewitt-Dundas, 2013; Johnston, 2020). This is largely explained by the availability of resources that enable larger firms to cover the costs incurred by geographical distance, as well as the level of absorptive capacity of these firms (le Duc & Lindeque, 2018).

This thesis examines the importance of geographical proximity in UICs from several perspectives. First, it investigates the frequency of UICs by differentiating the collaborations at several geographical scales. The thesis examines the propensity of firms to engage in regional or extra-regional collaborations with universities, which enables to analyze the influence of geographical proximity in the formation of UICs. In all papers included in the thesis, a geographical approach is visible. In Paper 1, the influence of geographical proximity has been analyzed for a specific type of UICs, namely co-publication partnerships, involving an MNE and universities around the world. Paper 2 explores the significance of geographical proximity for different UIC categories. In Paper 4, the influence of different motivations and non-geographical dimensions of proximity on the geography of UICs has been examined. What emerges from the discussions and the findings in the papers included in the thesis is that regional interactions comprise the majority of UICs. However, some nuances are visible when the effect of

geographical proximity is considered for different UIC types. The propensity of firms to establish collaborations with universities at different spatial scales – regional, national and international – varies across firms and even for different subunits of a single firm. In Paper 1, geographical proximity is found to exert a different influence on the sub-units of an MNE, suggested by varying shares of co-publications produced in collaboration with universities. Paper 2 finds that geographical proximity matters less for UICs oriented towards knowledge exploration. Paper 4 sheds light on the relationship between geographical and non-geographical dimensions of proximity. The findings of the paper indicate that firms that consider cognitive proximity to their university partners to be more important are more likely to engage in long-distance UICs, while firms that attach more importance to institutional and social proximity have a higher likelihood to collaborate with universities in close geographical proximity.

2.3.2 Non-geographical dimensions of proximity in UIC studies

Non-geographical dimensions of proximity have not received much attention in UIC studies, which indicates a clear gap that needs to be addressed. As mentioned previously, the literature on UICs mainly examines the geographical aspect of UICs and highlights the prevalence of interactions in closer distances by referring to the benefits that geographical proximity entails. However, geographical closeness or simple co-location, per se, is not sufficient for neighboring firms and universities to interact. Even if they are co-located, they might belong to different knowledge networks and lack the communication channels and platforms to start collaborating (Innocenti et al., 2020). Also, firms' demands may not match with the local university's outputs, which may lead firms to interact with universities at a distance (Fitjar&Gjelsvik, 2018). Additionally, geographical proximity becomes inadequate in explaining the case of long-distance relationships between universities

and industrial actors, suggesting that UICs can be explained through other mechanisms than pure geographical proximity.

Cognitive proximity between firms and universities has been captured by looking at the internal R&D capabilities of firms (Laursen&Salter, 2004; Bodas-Freitas et al., 2014). The shares of R&D expenditure or personnel are used as indicators of cognitive proximity with the idea that firms with higher levels of R&D activities are more likely to follow scientific principles similar to academics. Moreover, such firms are more capable of acquiring external knowledge from university sources through their employees with tertiary education as employees with university degrees are seen to strengthen the general absorptive capacity of firms (Drejer&Østergaard, 2017). Additionally, the number or percentage of university graduates in the workforce is indicative of cognitive proximity to universities. It is assumed that the higher the percentage of university level graduates in the workforce of an enterprise, the higher the cognitive proximity to universities. Additionally, Drejer&Østergaard (2017) find that social ties that are created through the employment of graduates from specific universities matter more than the pure share of university graduates in the workforce of a company for UICs. Garcia et al. (2018) provide an alternative measurement of cognitive proximity, where they measure it as the compatibility of the sectors and the academic fields by matching them through a correspondence analysis. By looking at the composition of collaborations established in terms of the sectors of firms and the academic field of their university partners, they created an index value for cognitive proximity, which measures cognitive proximity as the association between a scientific field and an industry. They find that higher cognitive proximity stimulates UICs across higher geographical distances.

In studies of UICs, organizational proximity is represented by the common membership of the same organizational structures, such as collaborative research centers (CRCs) or science parks (Villani et al., 2017). The firms taking part in these organizational bodies are found to

interact more intensively with universities. The new enterprises founded on the results of scientific research, such as academic spin-offs or student start-ups who maintain their linkages with their host universities, constitute other structures exhibiting organizational proximity (Crescenzi et al., 2017; Kuttim, 2016).

Existing research on UICs examines institutional proximity from various angles. For example, in their study of Italian inventors, Crescenzi et al. (2017) equates institutional proximity with belonging to the same organization type (university vs. business). They conclude that UICs are less likely to be realized due to the high institutional distance (Crescenzi et al., 2017). Following the macro-level approach on institutional proximity, some studies examine the concept as the similarity of national level regulations on intellectual property rights (Hoekman et al., 2009) or operating under the same hierarchical authorities – such as being affiliated with the same ministry in a country (Hong&Su, 2013). Hoekman et al. (2009) find that collaborations between two regions located in the same country are more likely than between two regions from different countries, suggesting that institutional proximity influences positively the establishment of UICs. Hong&Su (2013) conclude that being subordinated to the same administrative units – which means operating under the same ministry in China, implies high institutional proximity, and thus, it increases the likelihood of UICs.

Social proximity has often been identified as a significant facilitating factor in UIC literature. Especially previous successful collaborations have been found to develop social proximity between agents in UICs (Crescenzi et al., 2017; Hewitt-Dundas et al., 2019). The existence of a shared social history, such as in the case of graduates from same university (Drejer&Østergaard, 2017) or previous co-working experiences (Crescenzi et al., 2017), is also provided as an indication of social proximity between firms and universities involved in UICs. Yet, many of these studies do not use the concept of proximity in their analysis.

What is missing in these discussions is that the measures used to account for proximity in non-geographical dimensions do not take into account the perceptions of the actors. They rather rely on proxy measures for non-geographical proximities. However, proximity indicates a potentiality that takes meaning through the assessment and corresponding actions of the agents. Therefore, it becomes necessary to include subjective measures of proximity into the discussions on their influence on UICs.

This thesis contributes to the literature focusing on the non-geographical proximity dimensions and UICs (Crescenzi et al., 2017; Garcia et al., 2018; Ponds et al., 2007; Hoekman et al., 2009) through a holistic approach. Additionally, the thesis enriches the discussions on the significance of proximity dimensions by providing an alternative measurement approach based on the perceptions of the actors. In Paper 2, the influence of non-geographical aspects of proximity has been considered across a number of UIC types. The findings show that non-geographical dimensions of proximity matter to varying degrees for different UIC channels. For instance, cognitive and institutional proximity are found to be more important for knowledge exploration UICs, while social proximity matters more for knowledge exploitation activities. Organizational proximity is considered less significant by firms seeking informal advice from universities. Paper 3 includes non-geographical dimensions of proximity to the discussions on UIC outputs, studying the development of proximity and an output of UICs alongside with more tangible outputs. Non-geographical dimensions of proximity are considered as learning effects emanating from UICs. Yet, the paper finds no difference across different UIC types in their contributions to the development of non-geographical proximities. The relationship between non-geographical dimensions of proximity and geographical proximity has been investigated in Paper 4, which concludes that either an overlap or a substitution mechanism operates depending on the type of proximities considered. Paper 4 also investigates the relationship between different firm motivations and non-geographical dimensions of

proximity in determining the geography of UICs. The findings show that even though cognitive proximity is negatively correlated with regional UICs, its influence depends on the collaboration motivations, which render the effect of cognitive proximity insignificant. On the other hand, institutional and social proximity overlap with geographical proximity.

3 Data and Methodological approach

The research design used in this thesis takes into account the comprehensive content of proximity dimensions and UICs. The four papers included in the thesis cover a variety of proximity dimensions, both geographical and non-geographical, and different UIC types and outputs.

As mentioned earlier, many studies utilizing the proximity framework for the analysis of UICs have several limitations. Most of the studies consider either geographical proximity alone or with the inclusion of some non-geographical dimensions of proximity (Ponds et al., 2007; Slavtchev 2013). The works that use a broad apprehension of proximity dimensions, including all dimensions proposed in the framework of Boschma (2005), are limited (Cao et al., 2019; Crescenzi et al., 2017; Steinmo&Rasmussen, 2016; Garcia et al. 2018). Additionally, existing studies on UICs are mainly based on case studies supplied with qualitative analyses (Steinmo&Rasmussen, 2016; Werker et al., 2016) or quantitative analyses of register data (Crescenzi et al., 2017; Hoekman et al., 2009). They fall short of depicting the richness of UICs in terms of types and outputs and fails to provide a comprehensive understanding of what UICs entail. They rather examine some types of UICs in which a limited number of actors are involved. However, in this thesis, a comprehensive research design was chosen to reflect the multidimensionality of the proximity framework and the richness of UICs in terms of types and outputs.

In order to provide a comprehensive analysis that takes into account both different dimensions of proximity and the richness of UICs, and that examines the relationship between them, the thesis uses a quantitative methodology. First, it analyzes a specific UIC output – co-publications – through a case study of a multinational enterprise from the perspective of geographical proximity. The examination of the influence of

geographical proximity on an MNE is intriguing since MNEs themselves are distributed geographically. It is also important to examine MNEs from the proximity perspective, since works on proximity generally focus on SMEs as their unit of analysis. However, as the conclusion of Paper 1 suggests, geographical proximity can explain only some part of the story and the inclusion of non-geographical dimensions of proximity is needed for more robust analysis of how proximity influences UICs. Therefore, the second step is to examine the importance of all five proximity dimensions for a broad range of UICs by using a survey as the main data source in Papers 2-4. The use of survey data enabled us to cover a breadth of proximity dimensions and a multitude of UIC types and outputs for a broad range of firms. Additionally, the survey allowed us to examine the firm perspective more broadly by covering a broad range of firms from various sectors, of different sizes and from different regions. Third, Paper 3 considers UIC outputs and examines how they relate to non-geographical dimensions of proximity as the intangible outputs of UIC processes. Last, the relationships between the geographical and non-geographical dimensions of proximity have been investigated in Paper 4, which introduces firm motivations for engaging with universities as important drivers of the geographical reach of UICs.

3.1 Data and Methodology

The thesis makes use of data drawn from two different sources. The different data sources used in the thesis help present a comprehensive analysis of proximity in UICs. The use of bibliometric data in Paper 1 enables me to analyze the influence of geographical proximity, but remains insufficient to explore non-geographical dimensions of proximity. The use of survey data in Papers 2, 3 and 4, however, compensates this deficiency and represents a suitable tool to conduct a comprehensive study that spans across several proximity dimensions and UIC types for a broad range of firms with different characteristics.

Paper 1 draws on bibliometric data gathered from Thomson Reuters' Web of Science (WoS) database and uses co-publications as a proxy for UICs in line with a growing interest in using co-publications as an indicator of joint knowledge production in UICs (Marek et al., 2017). Bibliometric data stored in this and similar databases contain detailed accounts of the publications – such as information about the authors, the organizations that they are affiliated with and the addresses associated with these organizations – that enable us to trace the geography of scientific outputs. This provides a clear picture of the distribution of scientific linkages and relationships across space. Therefore, using bibliometric data to look at a very specific form of UICs allows much larger geographical areas to be covered, which provides valuable insights on the influence of geographical proximity in UICs.

Paper 1 examines the case study of Equinor (previously Statoil), the state-owned oil and gas company of Norway, and the geographical distribution of its co-publication partnerships with universities within the time period 2008-2016. This particular company has been chosen due to its capacity to represent the oil and gas industry, which constitutes the backbone of the Norwegian economy. In addition, Equinor is among the largest R&D-performing companies in the Norwegian economy (Wicken 2007). Equinor is a good representative of an MNE with office branches distributed around the globe, therefore it suits well to the analysis of the importance of geographical proximity for geographically distributed entities. Equinor has offices all over Norway and in some other countries. The paper examines the collaboration with universities of 23 offices attributed to Equinor scattered in eight different countries in co-publications .

For the analysis, the data were cleaned by implementing some criteria, such as the publication year (between 2008-2016), publication type (only articles), language (only English) and university affiliation at the address line. The articles that do not comply with the search inquiries were eliminated and not taken further into the analysis.

Papers 2, 3 and 4 build on survey data generated from a tailor-made survey of firms, which was developed by drawing on the existing literature on UICs and proximity (full questionnaire is provided in the Appendix). The survey covered Norwegian firms that were sampled from the Norwegian Register of Business Enterprises (Brønnøysund Register Centre), where all Norwegian firms need to register. The sample of the firms was stratified according to several criteria. The first criterion relates to the geographical area covered. Firms located in Aust-Agder, Akershus, Hordaland, Nordland, Oslo, Rogaland, Trøndelag, Troms and Vest-Agder were selected because all of these regions have at least one university within their boundaries, while other regions in Norway did not have a university during the period of the study (2015-2017). These regions also represent the majority of economic activity in Norway since they host slightly more than 65% of all establishments in Norway.

The second criterion was firm size. The survey was conducted with firms with more than five employees. Third, a criterion for sector was imposed. The firms in the following NACE sector codes were included in the sample: (B) Mining and quarrying, (C) Manufacturing, (G) Wholesale and retail trade; repair of motor vehicles and motorcycles, - excluding 47: Retail trade, except of motor vehicles and motorcycles), (J) Information and communication, (K) Financial and insurance activities, (M) Professional, scientific and technical activities, (N) Administrative and support service activities. These industries were selected since they are assumed to have closer connection to universities and therefore firms operating in these industries have a higher tendency to engage in UICs. Furthermore, these are the industries that are included in the Community Innovation Survey (CIS). While most existing studies confine their analysis to the manufacturing industry (Gallego et al., 2013), the inclusion of a variety of sectors enables us to analyze UICs more broadly.

The uniqueness of the survey (see Appendix) comes from the approach it adopts. The survey was specifically designed to account for the importance of proximity dimensions in UICs from the perspective of

firms engaged in interactions with universities. The survey questions relate to the motivations of firms and the barriers inhibiting the establishment of university-firm linkages. In the survey, the firms are asked to indicate their interactions with universities in the period 2015-2017 by various UIC types and the geographical location of their university partners. Then, information on their interaction with the university with which they collaborate most extensively is gathered through a series of questions, such as the main channel, the duration and the initiation of the interactions. Since the firms have indicated the name of the university with which they have most extensively collaborated, I was able to detect the exact geographical scale of interactions. With this information, I assigned UICs to geographical scales – regional or extra-regional (including national and international UICs) – based on the location of both partners. The following questions delving into the details of the collaboration with the university have provided a rich and valuable source to examine the influence of proximity dimensions with regards to the contents, outputs and motivations of UICs.

The survey focuses mostly on realized collaborations and it does not pay much attention to the interactions that were not realized. Although the survey asks firms that do not collaborate with any universities about why they do not do so, the non-realized collaborations were not investigated further, which reflects the orientation of the survey to explore the influence of proximity dimensions on the formation and process of UICs. The realization of UICs might be blocked by several factors and the lack, or absence, of proximity between the actors might be considered only one of the factors that prevent UICs. Still however, this results in selection bias of not including the non-realized UICs into the analysis on the influence of proximity dimensions. Yet, this study focuses on the influence of proximity dimensions on the formation of realized UICs and does not consider how the lack of proximity hinders the establishment of university-industry linkages.

The survey investigated the significance of proximity dimensions in UICs and the influence of UICs on the proximity dimensions. Several questions on the outputs/results of UICs and the overall assessment of firms regarding the impact of UICs are also included. Other information about the firms, such as their size, R&D intensity and age, was also collected. However, the originality of the survey is the measurement of proximity dimensions (see section 3.1.1).

The survey covers a time span of three years – between 2015 and 2017. A market research company (Ipsos) implemented the survey through telephone interviews with firm representatives in December 2018. Table 2 reports the number of firms covered in the study. In total, the response rate represents nearly 12% of the sampled firms.

Table 2 – Number of firms covered in by the questionnaire

Status	**Count**	**Share (%)**
Interview conducted	1201	11.87
Interview denied	3028	29.93
Language problems	538	5.32
Technical error / error in number	337	3.33
Call not answered	5013	49.55
Total	10117	100.00

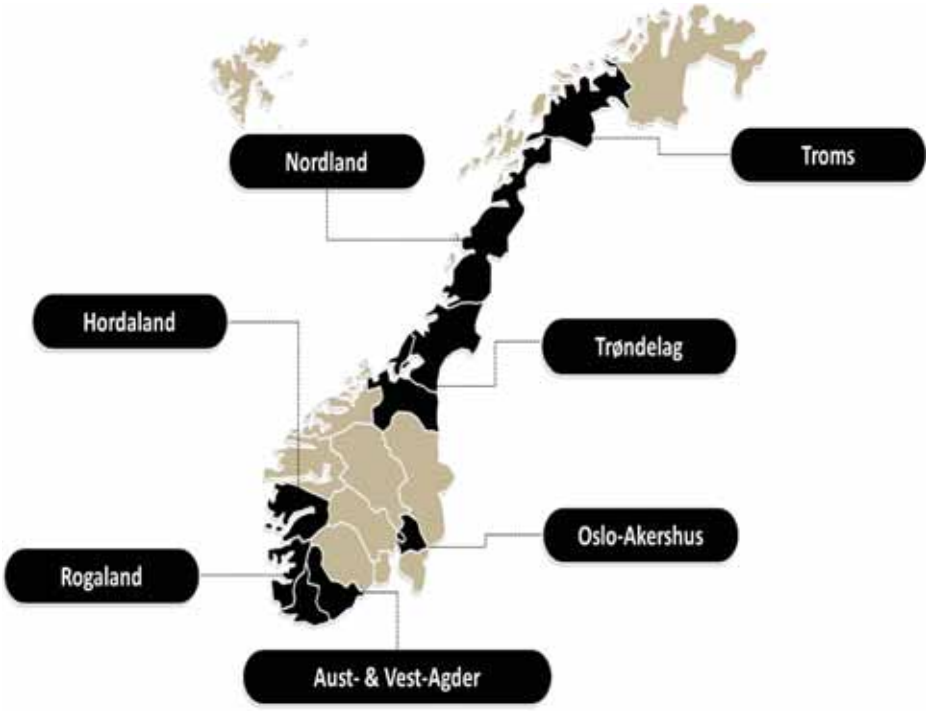

Figure 1 – Map of Norway highlighting the regions covered by the survey

The methodological approach used in this thesis is quantitative. In Paper 1, co-publications are counted with a full-counting approach. Each pair of actors – one university and one MNE branch – that collaborated on a paper was given one point. The pairs were assigned to different geographical scales in which the interaction was realized depending on the location of the MNE subunit and the university partner collaborated. Finally, the number of all pairs were aggregated by different geographical scales, which are divided into four categories: Local, National, Continental and Global.

In Paper 2, I use survey data by running a multinomial logit model. This model allows to account for the effect of various dimensions of proximity on different UIC categories. Since the dependent variables –

different UIC types – are categorical, a multinomial logit model is appropriate. Paper 3 using the same data employs logit and OLS models. In this paper, the influence of interaction process on different outputs – tangible and intangible – have been tested. A logit model is used for the analysis of tangible outputs, while an OLS model is employed for the analysis of intangible outputs, that is the non-geographical dimensions of proximity. Paper 4, drawing on the same data, employs a factor analysis for different UIC motivations and uses a series of logit models in the empirical analysis.

3.1.1 Operationalization of variables

Dimensions of proximity

Partner selection for collaboration purposes is a process in which people are not necessarily aware of the role of their proximity to their chosen collaborators. People have a tendency to interact with others that resemble themselves or who they feel or perceive to be more proximate, suggesting that the connection happens to a large extent through unconscious processes. People are driven by homophily effects towards proximate actors without actually realizing the influence of proximity on these relationships. However, by making respondents self-reflect on how proximity impacts their activities, especially during the partner selection process in inter-organizational collaboration, it becomes easier to consider the influence of proximity dimensions. Even though proximity matters to some extent unconsciously, self-reflection provides a valid methodological tool to detect to what extent proximity is influential in partner selection processes in collaborative activities. Yet, self-reflection on proximity has rarely been used in previous literature, perhaps largely due to the lack of data on such perceptions.

The operationalization of proximity dimensions in existing studies is insufficient to capture the essence of proximity discussions. In this regard, Torre (2019, pp. 331) points out that proximity "is neutral in

essence", implying that it is the subjective perceptions of the actors that triggers its mobilization through their actions. In other words, proximity indicates a potential that needs to be mobilized by the actions of the actors, which is generally shaped by the actors' perception of their proximity to others. However, the literature on proximity seems to abandon the perceptional aspect of proximity and instead assesses proximity through indirect measures. Through the measurement of geographical proximity as distance in kilometers and cognitive proximity as the similarity of patenting activities through patent classes in which the universities and firms register their innovative activities and inventions, current studies rely on rather indirect measures of proximity. However, in this thesis, a unique approach was employed that captures the perceptions of actors through directly asking them the level of importance of different factors for the selection of their partners. The factors that are measured by several indicative phrases reflect different proximity dimensions.

The direct questioning approach, by making actors reflect on their perceptions in the measurement of proximity dimensions, is novel, but it brings in several questions to be aware of. It is hard to be sure about to what extent respondents are able to reflect on their proximity to their collaborators. Since this approach involves ex-post analysis of the interactions – that is after the decision to collaborate has already been made and the interaction process is well underway – respondents might have developed different ideas and beliefs in the course of interactions than their initial thoughts. However, by asking the respondents what had induced them to collaborate with their most significant university partner, the survey hopes to reduce the potential biases through self-reflections. This limitation was also addressed by cross examination of proximity dimensions with more objective measures, for dimensions of proximity on which objective criteria are included in the survey, such as cognitive, social and geographical proximity. Therefore, the validity of subjective and self-reflected measurement of proximity dimensions has

been cross-checked by using some other questions that were used as objective indicators of some dimensions of proximity included in the analysis. In specific, several robustness checks that utilized objective measures of proximity dimensions were conducted in Paper 2.

In line with the aforementioned approach considering the perceptional aspect of proximity, proximity dimensions have been operationalized in a unique manner in Papers 2, 3 and 4. While many studies on proximity dimensions use indirect measures or crude proxies for proximity dimensions, this thesis takes a different approach for measuring dimensions of proximity by using direct questioning. The proximity dimensions are operationalized through several phrases. Similar to the explanations provided by Torre (2019) on the potentiality of proximity and its mobilization through the perceptions and actions of agents, the phrases used for the operationalization of proximity dimensions reflect the perceptions of agents on the importance of different factors for the selection of their collaborators. Rather than trying to measure the potential of proximity through indirect measures of proximity, this thesis attempts to see how these potentials, or actors' perceptions of them, are taken up by the actors in their decision to collaborate with universities. In this regard, Papers 2 and 4 study proximity dimensions through the operationalization reported in Table 3. With this approach, the thesis makes a substantial contribution to develop proximity indicators through survey measures (Werker et al., 2016). One drawback of this approach is that these are self-reported answers of firms, and not combined with any other measures of proximity.

Table 3 – Operationalization of different dimensions of proximity in Paper 2 and Paper 4

Dimension of proximity	***How important have the following reasons been in your decision to interact with this university?***
Cognitive Proximity	Sharing a common knowledge base and expertise with this university.
Organizational Proximity	Being members of the same organizational network/structure (research center, research consortium, association, cluster, science park etc.).
Institutional Proximity	Feeling that the university/faculty/unit has a business-friendly, entrepreneurial mindset.
Social Proximity	Having previous/ongoing interaction with that university.
Geographical Proximity	Being geographically close to our company.

The multidimensionality of proximity also relates to the dynamic nature of proximities. Different dimensions of proximity are not static, but they are subject to different change dynamics. Proximities develop during the course of interactions (Balland et al., 2015). Actors' proximity to each other evolves simultaneously with the interaction process as they learn from each other bringing them cognitively, organizationally, institutionally and socially closer. The interrelatedness of the different proximity dimensions (Torre&Rallet, 2005) further complicates the issue. While proximities are affected by the interaction process, they are also affected by changes in other dimensions. A shift in one proximity dimension may trigger a change, either negative or positive, in another dimension, suggesting that proximity dimensions are interdependent. Similarly, collaborations that emerge from the proximity of partners in a certain dimension may result in a change of proximity configuration between the actors in several other dimensions. However, this dynamic aspect of proximity, especially the influence of interactions on proximities and the interrelatedness of different dimensions, has seldom been studied in the related literature. Paper 3, which analyzes the influence of interaction processes on different dimensions of proximity,

addresses this issue through a dynamic perspective on proximities. The direct questioning approach was also maintained in this paper. The firms were asked about how the interaction affected their relationship to the university along several dimensions reflecting different types of non-geographical proximity. Table 4 indicates the operationalization of proximity dimensions in Paper 3.

Table 4 – Operationalization of proximity dimensions in Paper 3

Dimension of proximity	***To what extent has the interaction with the university contributed to strengthening your relationship with the university?***
Cognitive Proximity	We have got a better understanding of the competences of the university.
Organizational Proximity	We have started a more organized/formal interaction with university.
Institutional Proximity	We have got a better understanding of the values/culture/institutional environment of the university.
Social Proximity	We have developed a higher level of trust in the university.

Paper 1 looks only at geographical proximity in co-publications. In order to detect the prevalence of collaborations realized in geographical proximity, the co-publication collaborations are divided into four geographical scales as Local, National, Continental and Global. Local scale means the collaborations of Equinor bases with the closest university. National scale denotes collaborations with universities in the same country of the Equinor subunit, except for the closest university. The international collaborations are further divided into two scales, Continental and Global. Continental scale denotes the collaborations within the same continent – for instance within Europe or within the Americas, while Global scale encompasses collaborations with universities in other continents, such as between an MNE branch located in Europe and a university located in Canada.

The way that geographical proximity in UICs has been used in Paper 1 has been slightly changed in the remaining papers. In Papers 2 and 3, the geographical scales of UICs comprise of three categories – regional, national and international. In Paper 4, geographical proximity in UICs has been considered through a distinction between the regional and extra-regional levels denoting whether the collaboration was formed between the firms and universities located in the same region or in different regions.

UIC-related variables

The literature on UICs has a tendency to focus on quantifiable and formal aspects of interaction, such as patenting and contract research, which are easier to track, measure and analyze. However, relationships between academia and industry extend beyond these forms of interactions to include other kinds, which are less formal, less frequently recorded and hard to detect. This PhD thesis draws on a broader understanding of the relationships between universities and industrial partners that covers a multitude of UIC types and channels. Table 5 reports the UIC types included in Papers 2, 3 and 4, which reflect the broad and comprehensive nature of the relationships between firms and universities.

Table 5 – UIC types covered in the Papers 2-4

UIC Types
- Consultancy / Contract research
- Joint research projects
- Purchase of university patent, license or other IPRs
- Use of universities' facilities, laboratories, equipment etc.
- Creation/funding of Research Centers Incubation centers / Research, Science and Technology Parks
- Creation of new ventures/firms (Spin-offs, start-ups)
- Joint PhD supervision/Industrial PhDs
- Temporary staff exchanges for research purposes
- Training of firm staff/employees
- Student internships/apprenticeships
- Student projects
- Guest lecturing at universities
- Recruitment of graduates based on a contract/referral
- Co-development and co-delivery of curriculum
- Informal consultations
- Sponsorship, scholarships, fellowships provided to university
- Joint organization of events
- Other interactions

Similar to the widespread practice of limiting UICs to a narrow base of easily observable types, only a subset of UIC outputs are typically covered. Tangible UIC outputs, such as the innovation types (product, process and others), patents, establishment of spin-offs, hiring of graduates and co-publications, dominate the field. This thesis, however, takes a step forward and includes learning effects resulting from the collaboration process as intangible outputs of UICs. Table 6 presents the outputs included in the analysis in Paper 3.

Table 6 – UIC outputs addressed in the study

Outputs	
Tangible outputs	
Innovation	New or significantly improved products/services New or significantly improved processes New organizational methods in business practices, workplace organization or external relations New marketing concept or strategy
Commercialization	Patents, licenses or other IPR at least partly belonging to the company Spin-off / Start-up company (in which your enterprise has a share)
Human resources	Recruitment of graduates/transfer of university staff to your enterprise
Other outputs	Other outputs (open-ended) Joint publications (in which your enterprise's employees/staff are co-authors)
Intangible outputs	
Cognitive Proximity	We have got a better understanding of the competences of the university.
Organizational Proximity	We have started a more organized/formal interaction with university.
Institutional Proximity	We have got a better understanding of the values/culture/institutional environment of the university.
Social Proximity	We have developed a higher level of trust in the university.

In Paper 4, the influence of the primary motivations of firms on the geographical distribution of UICs has been investigated. Since UICs might be driven by various motivations, a comprehensive approach was taken. Again, the respondents were given several phrases to indicate their motivations for collaborating with universities and asked to rate their level of agreement to these statements. In order to reduce the number of motivations and to find patterns in the firms' motivations for collaborating, a factor analysis has been conducted. The results of the analysis indicated a three-factor solution covering six of the seven

motivations. The remaining motivation – getting access to human resources (students and staff) at the university – is excluded from the further analyses. The three factors represent better the underlying rationale for interacting with universities from the perspective of firms and are labelled as 'capacity development', 'external resources' and 'societal impact'. Table 7 reports the operationalization of the motivation variable used in Paper 4.

Table 7 – Operationalization of motivations in Paper 4

Motivation Factor	Why did you decide to interact with universities?
Capacity Development	We want access to new knowledge.
	We want to improve the skills of our employees/develop human resource capacities.
External Resources	We want access to R&D facilities.
	We want to obtain funding/financial resources.
Societal Impact	We want to address societal challenges better.
	We want to increase our image, prestige and reputation.
Human Resources*	We want access to human resources (students and staff) at the university.

*Left out in the econometric model as a result of the factor analysis

This thesis provides a comprehensive analysis of proximity framework in UICs by relying on different type of data sources that were processed through quantitative methods. It broadens the scope of existing studies by combining a wide range of proximity dimensions and several UIC types and outputs simultaneously within the confines of a single study through the embracement of the multidimensionality of these topics. The thesis also enriches the discussions on the measurement of proximity dimensions and the outputs of UICs through the application of direct questioning approach with the help of a survey instrument.

4 Summary

This chapter provides a summary of the papers included in the thesis. Each paper explores the influence of various proximity dimensions in different types of university-industry collaborations. Taken together, the papers contribute to on the understanding of how proximity dimensions affect the firms' collaboration patterns with universities.

4.1 Summary of the papers

In Paper 1, I examine the role of geographical proximity in UICs of multinational enterprises, using data on co-authored scientific publications. While most of the literature suggest that the majority of UICs happen in geographical proximity, this paper argues that the influence of geographical proximity differs. Furthermore, most of the studies examining proximity focuses on SMEs. Yet, little is known about how proximity works for MNEs which are themselves geographically distributed actors. Therefore, in the paper, I examine the geography of co-publication collaborations of a multinational enterprise with universities. The paper analyses the geographical distribution of co-publication partnerships across four geographical scales: local (collaboration with a university in the same region), national (collaboration with another university within the same country), continental (collaboration with a university in another country on the same continent) and global (collaboration with a university in another continent). Through counting the number of co-authored papers and the number of collaboration pairs, the paper assesses the influence of geographical proximity. The results indicate that geographical proximity has an overall effect on co-publication partnerships of an MNE, but its influence varies across the geographically dispersed branches of MNEs. At the same time, the share of continental and global level collaborations combined represents the majority of UICs, which indicates MNEs are less bounded by the limitations of geographical proximity and they can

successfully engage in long-distance collaborations with universities. Additionally, the results show that the subunits of the examined MNE in other countries do not have a tendency to collaborate more with the local universities in places where they are established. Still however, the share of national level collaborations is higher for those branches when compared to national level collaborations of bases located in Norway, suggesting that the establishment of subsidiaries in other countries may open up the possibilities to create collaborative linkages with other universities in those countries.

Paper 2, inspired by the proximity framework put forward by Boschma (2005), examines the importance of five proximity dimensions – cognitive, organizational, institutional, social and geographical – on UICs. The paper investigates whether the significance of proximity dimensions differs by the focal UIC type in question, which we distinguish as knowledge exploration, knowledge exploitation, competence enhancement, advice-seeking and marketing interactions. Drawing on data from a customized survey covering 1201 firms in Norway, the paper presents newinsights about the role of proximity dimensions in driving UICs. An important contribution is the measurement of proximity dimensions by using a direct questioning approach that takes into account the perceptions of the actors. The paper uses multinomial logit regression that indicate the varying degrees of importance of proximity dimensions by the UIC types. While cognitive and institutional proximity matter more for knowledge exploration interactions, social proximity is seen most important by the firms with knowledge exploitation interactions. The results also indicate that geographical proximity is less important in driving knowledge exploration UICs, implying that firms can overcome the problems created by geographical distance.

Paper 3 examines how the UIC process contribute to the emergence of a multitude of outputs and the development of non-geographical dimensions of proximity as intangible UIC outputs. Using the same

questionnaire as in Paper 2 as the data source, this paper, first, seeks to find out what type of outputs UICs lead to. Then, it examines the relationship between UIC types and UIC outputs. Last, the paper explores the influence of co-location on UIC outputs. The results illustrate that UICs lead to not only tangible outputs, such as different types of innovations and patents, but also intangible outputs such as an increased understanding of competences and institutional norms and values of the partners. However, the influence of UIC types in the production of outputs differ. In specific, the results show that formal types of interactions more frequently lead to innovation and commercial outputs, while informal interactions also shape the intangible outputs. The results also indicate that the collaboration process leads to learning effects that help in the development of proximity between collaborating actors. In particular, these intangible outputs can be considered more critical for the success of UICs when the role of proximity dimensions in easing the UICs is taken into account and they need to receive more attention when evaluating the performance and overall impact of UICs.

Paper 4 explores the effect of non-geographical forms of proximity and motivations of firms on the geographical reach of UICs. Drawing on the same data source as Papers 2 and 3, the paper analyzes how and to what extent the differences in importance attached to non-geographical proximity dimensions and in motivations are reflected in the spatiality of linkages between firms and universities. The paper explores whether these differences affect the choice of regional or extra-regional university partners. The results highlight that non-geographical proximity dimensions influence the geography of collaborations in a differentiated manner. The likelihood of engaging in regional UICs is higher for firms that attach more importance to institutional and social proximity to their university partners. The findings indicate a clear pattern on the impact of motivations. While firms collaborating for capacity development purposes are more likely to establish linkages with universities in other regions, firms whose motivation is to create societal

impact are more likely to collaborate with universities in their regions. The paper concludes that both non-geographical forms of proximity and motivations are important determinants of the spatiality of UICs, even though their influence varies depending on the proximity dimension and motivation concerned. Therefore, these factors need to be taken into account in the design of policies attempting to increase the levels and efficiency of university-industry linkages.

5 Concluding discussion

It is widely acknowledged that proximity benefits the formation and implementation of inter-firm linkages (Hansen, 2014; Gallaud & Torre, 2004; Boschma, 2005). However, the influence of proximity, especially non-geographical dimensions, in UICs, which is characterized by distance between firms and universities in several aspects, is not a widely addressed and discussed topic in the related literatures. This PhD thesis, therefore, examines the importance of proximity in UICs by delineating how different dimensions of proximity affect various UIC processes. This thesis highlights that proximity is beneficial for interactions between industrial and academic actors. However, the influence of proximity dimensions differs depending on the UIC type. The role of both geographical and non-geographical dimensions of proximity in UICs varies depending on several factors. The influence of proximity dimensions differs by the type of the collaboration between firms and universities and by the primary motivations of firms for collaborating. In return, the collaboration process helps in the development of proximity dimensions, indicating that UICs are also beneficial for increasing the proximity between collaborating actors.

The thesis bridges two wider sets of literature, namely proximity and UIC literatures, with a broad perspective and addresses how firms perceive and put into practice the different dimensions of proximity in their collaborative relations with universities. Among a wider set of drivers of UICs, this thesis picks up the proximity framework as its point of departure and investigates to what extent proximities are important in driving UICs. Therefore, this thesis explores the underlying mechanisms of UICs through the proximity lenses. Additionally, it adopts a dynamic perspective on proximity and examines the development of proximity dimensions, particularly the non-geographical dimensions, throughout the UIC processes.

The four papers included in the dissertation contribute to the overall goal of the thesis from different angles. The papers indicate how different dimensions of proximity among the collaborating partners contribute to UIC processes and outputs. Paper 1 examines the relationship between geographical proximity and a specific UIC output – co-authored publications by firm employees and academics. Paper 2 covers a broader spectrum in terms of both proximity dimensions, by including all five proximity dimensions proposed by Boschma (2005), and UIC types (considering a total of 18 different channels grouped under five exclusive categories). It investigates the roles played by proximity dimensions in driving different categories of UICs. Paper 3, following a similar conceptual framework as in Paper 2, explores the linkages with a variety of UIC types and the outputs generated, with a focus on the non-geographical proximity dimensions as intangible outputs of UIC processes. Paper 4 examines the effect of non-geographical dimensions of proximity and firm motivations in the geographical distribution of UICs in terms of regional and extra-regional interactions. In overall terms, the papers underline the significance of proximity dimensions for UICs, whose effect varies by UIC types, proximity dimensions and the motivations for interaction. The results show that proximity is important for UICs and that different dimensions of proximity influence UICs to varying degrees.

5.1 Theoretical contributions

The thesis contributes to research on the role of firms' proximity to universities in UICs. The theoretical contributions to the proximity literature include the successful implementation of the proximity framework in the UIC context and the differentiated influence of proximity dimensions for different UIC processes. The thesis also contributes to the UIC literature through providing additional evidence for a variety of UIC channels and expanding the understanding on UIC outputs by incorporating insights from the proximity framework.

5.1.1 Contributions to proximity literature

The thesis indicates that the proximity framework can successfully be applied in UICs, representing a rather different setting from the proximity perspective. The proximity framework can effectively inform the discussions on UIC barriers and drivers, and on the formation of UICs in different proximity contexts. Moreover, the findings highlight that proximity dimensions, both geographical and non-geographical, are important in UICs. However, the influence and importance of proximity dimensions varies by different UIC categories. The thesis also extends our understanding on how geographical proximity affects large and geographically distributed corporations, such as MNEs.

The differences in the importance of proximity dimensions for UICs suggest that geographical and non-geographical dimensions of proximity need to be considered comprehensively in studies on the influence of proximity in UICs. Additionally, these studies can benefit from incorporating the perceptions of the firms on how they regard the proximity to their partners in the measurement of proximity dimensions. Last, the dynamics of proximity dimensions should be acknowledged in theory and investigated more deeply empirically for the case of UICs.

5.1.2 Contributions to UIC literature

The thesis demonstrates that the wide spectrum of UIC modes, channels, types and the differences among them regarding the goals, motivations and characteristics need to be acknowledged in order to provide a better understanding of UIC processes. Studies examining proximity dimensions in UICs should pay attention to the heterogeneity of firms and universities – the in-group differences of firms and universities in terms of capabilities, organizational structures, values, norms and social relations. Additionally, studies exploring MNEs' collaborative relationships with universities need to discern the location of the MNEs'

subsidiaries as suggested by different influences of geographical proximity.

The thesis highlights that the distinction between UIC types and UIC outputs should be made clear and concise. The heavy emphasis on tangible UIC outputs – such as patents and other commercialization types – should be balanced with the intangible benefits of UICs, such as the learning effects during the interactions.

5.2 Implications for policy and practice

This section discusses the implications of the results, findings and new insights of the study for policy and practice. These implications include broadening the focus of UICs, supporting the more prevalent UIC channels actively, enhancing the capabilities of firms in order to develop proximity with universities, and complementing regional UICs with extra-regional linkages.

First, the extensive emphasis on patents and IPRs in the measurement of UICs needs to be replaced with a broader approach that covers a wider set of interactions between universities and firms. The higher propensity and frequency of firms to engage in collaborations with universities for education/professional training purposes or through informal mechanisms makes it necessary to embrace a more comprehensive focus in policies aimed at increasing the level and intensity of UICs. These policies need to acknowledge that UIC is an umbrella term that covers a wide spectrum of interaction channels with different inherent characteristics that require specific policy mechanisms to be developed to support them. Instead of one-size-fits-all type of policies on UICs, a more fine-tuned policy portfolio needs to be developed. Particularly, the policies should target how to make the most out of the more frequent types of UICs for the economic benefits of the firms and the broader societal benefit, rather than pushing and prioritizing UICs to produce more patents and similar commercial outputs.

Closely related to the first point, education-related UICs oriented towards the enhancement of capabilities from the firm perspective and their outputs, such as recruitment of graduates, provision of professional training to industrial employees and student projects/internships are more commonly realized. From a proximity perspective, education-oriented interactions can be considered as important mechanisms that helps in closing the cognitive, institutional and social distances between firms and universities. Therefore, these interactions realized in the educational domain should be effectively supported and be turned into more systematic relationships. They must be seen as initial and welcoming signals that deeper collaborations between firms and universities can be established.

Third, the results of the dissertation show the significance of proximity dimensions for UICs, implying that firms that aspire to interact with universities need to develop their proximity to universities. When doing so, they also need to take into consideration that different dimensions of proximity matter to varying degrees for the variety of UIC categories. For instance, firms aiming to partake in joint research collaborations with universities should devote significant efforts to develop their in-house absorptive capacity to bring them cognitively closer to universities. On the other hand, firms need to increase their social proximity in order to effectively collaborate with universities in knowledge exploitation channels. Firms that seek informal advice from universities do not need to invest in creating formal organizational structures for the purposes of increasing organizational proximity to their university partners, while organizational proximity might facilitate the interactions aimed at knowledge exploitation.

Furthermore, this thesis highlights the evolution of proximity dimensions through the interaction processes, signifying that it is possible to develop proximity between the collaborating firms and universities. During the course of the interaction process, the collaborating partners get to know each other better and become more capable of assessing each other's

cognitive capabilities, organizational structures and institutional principles. Therefore, policies that aim at fostering generic linkages or even simple networking between academic and industrial actors may be designed and implemented that would have fruitful repercussions in the future.

Additionally, this dissertation has policy implications from a regional development and innovation perspective. The results of the study highlight the dominance of regional level interactions between universities and firms, suggesting that the majority of firms rely on the knowledge and expertise of universities in their locality. Therefore, policies should target achieving the most out of these local/regional relationships by respecting the capabilities and needs of the actors belonging to knowledge-exploration (universities) and knowledge-exploitation (businesses) subsystems (Asheim, 2007). For example, they may target to intensify the effectiveness of education-related, competence enhancement interactions to respond better to the human capital needs of regional industries, where the absorptive capacity of the firms is low.

On the other hand, such dense local relationships may also lead to detrimental situations such as lock-in problems, as suggested by the proximity paradox concept. Therefore, policies should be directed to support the establishment of extra-regional linkages to ensure the flow of external knowledge into the region in order to prevent possible lock-in situations. Policies that attempt to build up the capabilities of their universities to engage in long-distance research collaborations might be considered a viable strategy in this regard.

Regional policy-makers should sustain a compatibility between the regional and extra-regional dimensions of UICs depending on their capabilities and needs, when developing strategies to strengthen their regional innovation systems. Particularly, policies for the enhancement of UICs need to concentrate on diminishing the distances that present the

entry-barriers for UICs in most cases. Staff mobility schemes and more effective graduate placement practices may help in the empowerment of firms' absorptive capacity, which would develop cognitive proximity between firms and universities. Universities should be granted more flexibility in their practices concerning their interactions with businesses in order to alleviate the problems caused by institutional distance. The formation of intermediary organizations, such as collaborative research centers, that would involve members from both academic organizations and industrial actors might be encouraged to generate organizational proximity. Small-scale pilot schemes or low-risk collaboration projects that act like a catalyst in creating the first contact between firms and industries might develop social proximity by overcoming the enduring issue of distrust between the agents of UICs.

5.3 Limitations and further research questions

This thesis comes with some limitations that need to be taken into account when assessing the results. Therefore, this section discusses these limitations and the further research avenues that may address them.

First of all, UIC represents only one of the strategies for accessing external knowledge for firms. Firms principally look to other firms to gain new knowledge and to complement their internal capabilities. This thesis, however, solely focuses on the collaborative activities between firms and universities and does not attempt to compare the significance of proximity dimensions in UICs to inter-firm collaborations. Further research that would undertake such a comparative endeavor and compare the influence of proximity dimensions in UICs and inter-firm linkages may present the significance of universities vis-à-vis other knowledge sources for firms' knowledge access strategies more precisely.

This thesis relies on subjective measurement of proximity dimensions. The introduction of the agents' perceptions of their proximity provides valuable contributions to understand the underlying processes leading to

the establishment and sustainment of UICs. Therefore, the further development of the measurement of proximity dimensions based on the perceptional approach presents a valuable line of research that can be taken over through further studies.

Similarly, this dissertation draws on the proximity framework developed by Boschma (2005), but the proximity literature offers alternative classifications of proximity dimensions. Especially, several other proximity types have been suggested in the related literature for non-geographical dimensions. Dimensions such as technological proximity (Knoben&Oerlemans, 2006; Johnston&Huggins, 2018), personal proximity (Werker et al., 2016; Schamp et al., 2004) and cultural proximity (Cao et al., 2019) are not included in this thesis. Further research may want to include them to enrich their conceptual framework.

In addition, this research represents an initial step in the examination of the dynamic aspect of proximity in UICs. It attempts to assess whether UICs contribute to the development of non-geographical proximity dimensions at a certain point in time. However, the dynamic and evolutionary aspects of proximity dimensions need to be examined over longer periods of time that require a different research design. The collection of longitudinal data through a case study design or implementation of consecutive waves of the same questionnaire – such as in the case of Community Innovation Surveys (CIS) that are repeated every two years – that collects data regularly might provide more insightful results for the evolution of proximity dimensions in UICs.

Closely related to the dynamics of proximity in UICs, this thesis does not pay attention to the proximity paradox, the occasions where too much proximity may undermine the UICs. This research does not also attempt to provide a recipe for the optimum level of proximity dimensions in UICs. These aspects remain as under-investigated topics in the literature, which offer interesting avenues for further research.

The indicated limitations of the study can be addressed in further studies, which would strengthen the contributions that this thesis makes to the related literature. This thesis represents a first endeavor to analyze the role of various dimensions of proximity across different UIC channels, and further research can provide additional insights on this issue. The dissertation sheds light on how proximity matters for MNEs engaging in UICs together with showing its importance for a large sample of firms. It enriches the discussions on proximity measures by incorporating the perceptions of actors into the measurement through a direct questioning approach. Last, the thesis takes an initial step in the analysis of dynamics of proximity in the UIC context.

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Appendix

QUESTIONNAIRE

PART 1: FIRM IDENTIFIERS (to be filled by interview company from register data)

1. When was your enterprise established? YEAR ……

2. In which sector does your enterprise operate? NACE CODE ……

3. Where is your enterprise located? Please indicate the postcode and municipal code.
   POST CODE …… MUNICIPAL CODE ……

4. What is the organization number of your enterprise? ORG. NUMBER ……

5. In which group of employment does your enterprise belong to?
   1= 5-9 employees, 2= 10-49 employees, 3= 50-99 employees, 4= 100+ employees

6. In which region is your enterprise located?

PART 2: INTERACTION WITH UNIVERSITIES

7. Did your company have contact with universities in the last 3 years (2015-2017)? (please exclude one-off contacts)

…… Yes

…… No

»»» If NO, go to Question 8. ***»»» If YES, go to Question 9.***

8. Why did not you have any contact with universities? Please indicate the level of agreement with the following statements:

	Completely agree	Partly agree	Neutral	Partly disagree	Completely disagree	Don't know
We do not have any need to interact with universities.	……	……	……	……	……	……
We do not have any capacity to interact with universities.	……	……	……	……	……	……
We do not know how to contact universities.	……	……	……	……	……	……
We do not know how universities can help us.	……	……	……	……	……	……
We do not believe that universities have the competence to respond to our needs.	……	……	……	……	……	……
We lack funding/financial resources to interact with universities.	……	……	……	……	……	……
We find universities hard to interact with due to heavy bureaucracy.	……	……	……	……	……	……
We find universities hard to interact with due to different motivations, time horizons.	……	……	……	……	……	……
We are located far away from universities.	……	……	……	……	……	……

»»» Continue with <u>Question 26.</u>

9. Why did you decide to interact with universities? Please indicate the level of agreement with the following statements:

	Completely agree	Partly agree	Neutral	Partly disagree	Completely disagree	Don't know
We want access to new knowledge.	……	……	……	……	……	……
We want to improve the skills of our employees/develop human resource capacities.	……	……	……	……	……	……
We want access to R&D facilities.	……	……	……	……	……	……
We want access to human resources (students and staff) at the university.	……	……	……	……	……	……
We want to obtain funding/financial resources.	……	……	……	……	……	……
We want to address societal challenges better.	……	……	……	……	……	……
We want to increase our image, prestige and reputation.	……	……	……	……	……	……

10. In the last 3 years, what kinds of research-oriented interactions were you involved in with universities? (Please indicate the location for each type of interaction)

	Your Region	Elsewhere in your country	Elsewhere in Europe	Outside Europe	No Interaction	Don't know
Consultancy / Contract research (we paid, but were not involved in the research)	……	……	……	……	……	……
Joint research projects (we were involved in the research)	……	……	……	……	……	……
Purchase of university patent, license or other Intellectual Property Rights	……	……	……	……	……	……
Use of universities' facilities, laboratories, equipment etc.	……	……	……	……	……	……
Joint PhD supervision/Industrial PhDs	……	……	……	……	……	……
Temporary staff exchanges for research purposes	……	……	……	……	……	……

11. In the last 3 years, what kinds of education-oriented interactions were you involved in with universities? (please tick all the relevant options)

	Your Region	Elsewhere in your country	Elsewhere in Europe	Outside Europe	No Interaction	Don't know
Training of firm staff/employees	……	……	……	……	……	……
Student internships/apprenticeships	……	……	……	……	……	……
Student projects (Bachelor and Masters level)	……	……	……	……	……	……
Guest lecturing at universities	……	……	……	……	……	……
Recruitment of graduates based on a contract/referral	……	……	……	……	……	……
Co-development and co-delivery of curriculum (courses, modules, study programmes)	……	……	……	……	……	……

12. In the last 3 years, what other kinds of interactions were you involved in with universities? (please tick all the relevant options)

	Your Region	Elsewhere in your country	Elsewhere in Europe	Outside Europe	Don't know	No Interaction
Informal consultations	……	……	……	……	……	……
Sponsorship, scholarships, fellowships provided to university	……	……	……	……	……	……
Joint organization of events (seminars, conferences)	……	……	……	……	……	……
Creation/funding of Research Centers Incubation centers / Research, Science and Technology Parks	……	……	……	……	……	……
Creation of new ventures/firms (Spin-offs, start-ups)	……	……	……	……	……	……
Other interactions*	……	……	……	……	……	……

»»» Follow-up question to Question 12 option "Other interactions*":

a. *Can you specify what kind of other interactions were you involved in with universities?……

PART 3: DETAILS OF INTERACTION WITH UNIVERSITY

Please answer the questions 13-20 by thinking of the university that your enterprise most extensively interacts with. (If you interact with two universities equally, please consider the interaction that is more valuable/crucial for your enterprise.)

13. Which university do you interact with most extensively?

…… Arkitektur- og designhøgskolen i Oslo	…… Nord Universitet
…… Handelshøyskolen BI	…… NTNU Norges teknisk-naturvitenskapelige universitet
…… Høgskolen i Innlandet	…… OsloMet – storbyuniversitetet (tidl. Høgskolen i Oslo og Akershus)
…… Høgskolen i Molde – Vitenskapelig høgskole i logistikk	…… Universitetet i Sørøst-Norge
…… Høgskulen på Vestlandet	…… Universitetet i Agder
…… Høgskulen i Volda	…… Universitetet i Bergen
…… Høgskolen i Østfold	…… Universitetet i Oslo
…… Høyskolen Kristiania	…… Universitetet i Stavanger
…… NHH Norges Handelshøyskole	…… Universitetet i Tromsø - Norges arktiske universitet
…… NLA Høgskolen	
…… NMBU - Norges miljø- og biovitenskapelige universitet	

…… If other, please state the name of the university
……
…… Don't know

»»» If answered "Don't know", continue with <u>Question 24</u>.

14. What has been the most dominant kind of interactions with this university?

…… Consultancy / Contract research (we paid, but were not involved in the research)
…… Joint research projects (we were involved in the research)
…… Purchase of university patent, license or other Intellectual Property Rights
…… Use of universities' facilities, laboratories, equipment etc.
…… Joint PhD supervision/Industrial PhDs
…… Temporary staff exchanges for research purposes
…… Training of firm staff/employees
…… Student internships/apprenticeships
…… Student projects (Bachelor and Masters level)
…… Guest lecturing at universities
…… Recruitment of graduates based on a contract/referral
…… Co-development and co-delivery of curriculum (courses, modules, study programmes)
…… Informal consultations
…… Sponsorship, scholarships, fellowships provided to university
…… Joint organization of events (seminars, conferences)
…… Incubation centers / Research, Science and Technology Parks
…… Creation of new ventures/firms (Spin-offs, start-ups)
…… If other, please state the interaction
……
…… Don't know

15. For how long has your enterprise been interacting with this university?

…… Please indicate the number of years since interaction started

……

…… Don't know

16. Who initiated the interaction?

…… The university approached us.

…… We approached the university.

…… A third party approached both of us. Please specify

……

…… Don't know

17. Is there any external funding acquired to cover the costs of interaction? (answer no if more than 80% is funded by your organization)

…… Yes

…… No, 80% of the costs are covered by my own organization.

…… Don't know

18. What was the main external source of funding to conduct the interaction with the university?

…… University funding

…… Local/regional public funding

…… National public funding

…… International funding

…… Other external funding

…… Don't know

19. With which faculty/unit do you interact most extensively at that university? (In case of a different university structure, tick the option which is closest to the real one.)

…… Faculties of Engineering, Science and Technology
…… Faculties of Health Sciences, Medicine
…… Faculties of Economics, Administrative, Social Sciences and Law
…… Faculties of Education
…… Faculties of Humanities and Art
…… Technology Transfer Office (TTO) // Science/Research/Technology Park // Incubator
…… Other. Please specify ……
…… Don't know

20. How did you first meet the university employees that you interact with most frequently?

…… We met at a conference/seminar/other event.
…… We read a publication by the university researchers in a journal/magazine/newspaper.
…… We were referred to contact the university employees by a third party.
…… We already knew each other socially.
…… We studied at the same university/worked at the same organization.
…… Other. Please specify ……
…… Don't know

PART 4: DYNAMICS BETWEEN INTERACTION AND PROXIMITY DIMENSIONS

21. How important have the following reasons been in your decision to interact with that university as an organization?

(Different dimensions of proximity at the organizational level are considered here)

	Very important	Fairly important	Not very important	Not at all important	Don't know
Sharing a common knowledge base and expertise with this university.	……	……	……	……	……
Using the same language/jargon and understanding each other easily.	……	……	……	……	……
Being members of the same organizational network/structure (research center, research consortium, association, cluster, science park etc.).	……	……	……	……	……
Feeling that the university/faculty/unit has a business-friendly, entrepreneurial mindset.	……	……	……	……	……
Having previous/ongoing interaction with that university.	……	……	……	……	……
Having employees graduated from that university.	……	……	……	……	……
Being geographically close to our company.	……	……	……	……	……

22. How important have the following reasons been in your decision to interact with the university employees that you interact with most frequently?

(Different dimensions of proximity at the individual level are considered here)

	Very important	Fairly important	Not very important	Not at all important	Don't know
Having a similar educational background/graduated from similar departments.	……	……	……	……	……
Share common values and norms.	……	……	……	……	……
Being from the same region.	……	……	……	……	……
Having a shared past as previous colleagues from work/university.	……	……	……	……	……
Being friends or acquaintances.	……	……	……	……	……

23. To what extent has the interaction with the university contributed to strengthening your relationship with the university? Please indicate the level of agreement with the following statements.

(Effects of interaction on different dimensions of proximity is considered here)

	Completely agree	Partly agree	Neutral	Partly disagree	Completely disagree	Don't know
We have got a better understanding of the competences of the university.	……	……	……	……	……	……
We have become friends.	……	……	……	……	……	……
We have got a better understanding of the values/culture/institutional environment of the university.	……	……	……	……	……	……
We have developed a higher level of trust in the university.	……	……	……	……	……	……
We have started a more organized/formal interaction with university.	……	……	……	……	……	……
We have moved to a location closer to the university.	……	……	……	……	……	……

PART 5: IMPACT ASSESSMENT OF INTERACTION WITH UNIVERSITIES

24. What kind of results/outputs, if any, have emerged from the interactions of your enterprise with universities? Tick all the relevant options.

…… Patents, licenses or other Intellectual Property Rights at least partly belonging to the company
…… Joint publications (in which your enterprise's employees/staff are co-authors)
…… Spin-off / Start-up company (in which your enterprise has a share)
…… Recruitment of graduates/transfer of university staff to your enterprise
…… New or significantly improved products/services
…… New or significantly improved processes (production processes, distribution method or supporting activity)
…… New organizational methods in business practices, workplace organization or external relations
…… New marketing concept or strategy
…… No results/outputs yet (ongoing interaction)
…… Don't know
…… Other. Please specify ……

25. How would you assess the general impact of interaction with universities on your enterprise? Please choose one of the following options:

…… Overall mostly negative
…… Overall mostly positive
…… Don't know

PART 6: OTHER INTERACTIONS

26. Did your enterprise interact with enterprises or organizations other than universities in the last 3 years (2015-2017)? Please indicate the location for each type of organization that your enterprise interacted.

	Your Region	Elsewhere in your country	Elsewhere in Europe	Outside Europe	No Interaction	Don't know
Other enterprises within your enterprise group	……	……	……	……	……	……
Suppliers	……	……	……	……	……	……
Clients or customers	……	……	……	……	……	……
Competitors or other enterprises in your sector	……	……	……	……	……	……
Consultants	……	……	……	……	……	……
Public/Private Research Institutes	……	……	……	……	……	……
Public Organizations, Governments, Authorities	……	……	……	……	……	……
Non-governmental organizations, Civil society organizations	……	……	……	……	……	……
Other enterprises or organizations*	……	……	……	……	……	……

»»» Follow-up question to Question 26 option "Other enterprises or organizations*".

a. *Can you specify what kind of other enterprises or organizations did your enterprise interact?
……

PART 7: FIRM CHARACTERISTICS

27. How many full time employees are there in your enterprise?
    Number of full time employees
    ……

28. Approximately what is the share of total R&D expenditures in the budget of your enterprise?
    Share of total R&D in budget
    …… %

29. Approximately what share of your employees have a university degree or higher?
    Share of employees with a university degree
    …… %

THANK YOU!

PAPERS 1 – 4

PAPER 1

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Exploring the spatial reach of co-publication partnerships of multinational enterprises: to what extent does geographical proximity matter?

Utku Ali Rıza Alpaydın

ABSTRACT

There is an increasing interest in defining the determinants of university–industry collaborations (UICs). One recent tendency is to embrace the proximity approach while explaining the process of coordination in UICs. Most studies generally take on the role of geographical proximity and try to explain its effects by looking at the universities. These studies try to identify the firms that universities collaborate with and define the determinants of these collaborations in line with the firm characteristics. However, this paper, rather than taking universities as the main unit of analysis, takes a firm-centric approach and examines the co-publication collaborations of a multinational enterprise (MNE) with universities. The paper explores the spatiality of these collaborations and geographical proximity's influence on the collaboration networks of MNEs. Using the case study of a multisite MNEs' co-publications with universities through bibliometric data, it provides some refinements about the influence of geographical proximity. The analysis shows that geographical proximity plays a significant role in UICs for MNEs. The findings also indicate that, despite its overall importance, the effects of geographical proximity differ for the branches of the same firm. The collaboration patterns of different units show divergence regarding the share of collaborations at various geographical scales. This suggests that following a more nuanced perspective in UIC studies, dealing with geographical proximity may be useful in clarifying its effects.

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INTRODUCTION

Innovation is a key driver of corporate competitiveness in the 21st century. Firms resort to innovation in order to remain viable in the market and grow their businesses, and knowledge emerges as a key asset for those firms that thrive to be innovative (Pezzillo Iacono, Schiuma, Martinez, Mangia, & Galdiero, 2012). However, a single firm, irrespective of how large it is, does not possess all the knowledge resources required to innovate successfully. Therefore, firms embrace several strategies to access external knowledge as a part of their competitiveness strategies. These knowledge-access strategies constitute an important element of firms' competitive strategies

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and generally include the establishment of collaborative linkages with others to obtain access to their knowledge sources. In this regard, the determinants of collaboration, with the aim of obtaining external knowledge, become one of the significant factors of competitiveness for firms (Pezzillo Iacono et al., 2012).

Universities, which play a fundamental role in knowledge generation (Uyarra, 2010), represent important sources of knowledge for innovating firms. In a broader sense, universities represent an important innovation asset for their surrounding territories, particularly when their role in knowledge production and dissemination, in the form of knowledge spillovers, is taken into account. Thus, understanding the drivers and barriers of university–industry collaborations (UICs) is important to understand the overall territorial contributions of universities. In this regard, proximity is generally acknowledged to be important in determining knowledge exchange between partners (Boschma, 2005); therefore, it may be expected that proximity affects a firm's knowledge-access strategies.

Proximity is often used as an explanation of how multinational enterprises (MNEs) access knowledge, locating their sites in areas where it would be easy to tap into local knowledge networks (Broström, McKelvey, & Sandström, 2009). However, this appears too simple because it treats MNE sites as disconnected from corporate hierarchy, where there are knowledge transfers within the firm. The issue of proximity to which site is also a critical question. Therefore, in order to understand better how proximity functions in determining UICs for MNEs, this paper examines whether and how collaboration patterns with universities differ for subunits of MNEs.

Further, MNEs are exemplars of corporate innovation actors. They also play a significant role in the global innovation system through their effects in the internationalization of research and development (R&D) activities. With presence in various countries worldwide, MNEs pose a challenge to testing the influence of proximity in interorganizational knowledge-exchange relationships. Most studies that deal with the location choices of the R&D subsidiaries of MNEs argue that MNEs tend to locate in regions where they can easily tap into local knowledge networks (Broström et al., 2009). However, considering MNEs as unitary actors makes it difficult to explain the local/regional dimension of geographical proximity, since MNEs have an international reach and a global outlook with their presence in various countries. Thus, the arguments in favour of the dominance of local and regional interactions end up being questioned for MNEs that engage in collaborations with universities at various geographical scales. Thus far, studies have failed to provide a comparative examination of collaboration patterns for various branches within a single MNE and the overall impact of geographical proximity in these patterns.

Therefore, this paper seeks to understand whether or not geographical proximity plays a substantive role in determining UICs of MNEs, and asks the following specific research question: 'How does geographical proximity affect the collaboration networks of MNEs with universities?' In order to answer this question, the paper develops a framework based on existing literature on proximity and MNEs (in the second section), and conducts a case study to examine the co-publication collaborations of a Norwegian-origin MNE in the oil and gas sector with universities through a location-based comparison (in the third section). The fourth section presents the co-publication collaboration patterns of the case and the distribution of collaborations across geographical scales. The fifth section discusses the findings of the analysis and questions related to the viability of the influence of geographical proximity across geographical locations. The sixth section concludes by shedding a light on the differentiated effects of geographical proximity for UICs of MNEs.

The novelty of this paper lies in the fact that it adopts a firm-centric approach rather than taking universities as reference actors, while considering co-publications as the proxy for analysis. The traditional division of labour between universities and industry in UICs assumes that publication is the responsibility of academics. In line with this assumption, most of the studies approach UICs from the viewpoint of universities. On the contrary, this paper adopts a reverse attitude with the concept that corporate researchers working in the private sector also publish

either alone or in cooperation with academics. Therefore, this paper examines the publications produced in cooperation with academia.

The main argument of this paper is that geographical proximity is significant for UICs of MNEs, but it is difficult to establish a unified significance of geographical proximity for the various locations of MNEs. There is no persistent pattern in the collaboration networks among the various units of MNEs. With regard to certain bases of the MNE studied in this paper, local collaborations outweigh collaborations with universities located at a distance. However, this is not the case particularly for the bases that are located outside the headquarters country, for which collaborating with national and global universities is the dominant collaboration pattern. Moreover, it is found that there are more international collaborations, specifically collaborations with universities in the same continent as the MNE base, than collaborations at local and national scales. Therefore, attempts to define the spatial scope of UICs only by examining the geographical proximity between partners provide a limited explanation of the phenomenon and they must be supported with a comprehensive perspective that attempts to capture various dimensions of proximity and specific circumstances of the partners.

THE ISSUE OF PROXIMITY FOR UICs INVOLVING MNEs

Competitiveness by knowledge through collaboration

The competitiveness of firms, regions and nations is assumed to be directly linked to their innovative capacities (Maskell & Malmberg, 1999). A firm, a region or a nation is believed to become and remain competitive as long as it innovates, and innovation depends on knowledge. Therefore, knowledge processes – creation, diffusion and exchange – are fundamentally important for the innovation performance of firms and ultimately their competitiveness (Pezzillo Iacono et al., 2012). Access to knowledge resources then becomes critical for firms in determining their innovativeness and competitiveness. Firms can obtain knowledge by creating it through internal R&D or by collaborating with external parties. Collaboration may be with other firms (clients, customers, suppliers or competitors) or public sector organizations, research institutes or universities (Fitjar & Gjelsvik, 2018).

Universities are regarded as salient partners and important sources for firms because they provide new knowledge (Bouba-Olga, Ferru, & Pépin, 2012; Kuttim, 2016). Universities and other higher education institutions can provide external knowledge for firms through the former's cutting-edge research activities and specialized research infrastructure facilities. Although the significance of universities for firms in accessing knowledge has been acknowledged, the collaboration levels between universities and industries remain low (Avenyo et al., 2015). Accessing knowledge from universities is potentially useful but practically difficult mainly because of a number of barriers hindering effective collaboration and undermining the success of interactions. For example, Bruneel, D'Este, and Salter (2010) mention two types of barriers, namely 'orientation-related barriers' that originate from different incentive systems and 'transaction-related barriers' related to intellectual property (IP) issues. Ankrah and Al-Tabbaa (2015) combine factors that either facilitate or inhibit UICs under seven categories[1] from their systematic literature review. The barriers are generally regarded as undermining effective collaborations between academic and industrial partners; in order to overcome these barriers, it is argued that partners must be in some sort of proximity (Laursen, Reichstein, & Salter, 2011).

Proximity in university–industry collaborations

The concept of proximity, which refers to 'closeness of actors and is often assessed by the similarity between the actors' (Fitjar, Huber, & Rodríguez-Pose, 2016, p. 5), constitutes one of the explanations for successful knowledge collaborations. While writing on the influence and role of proximity in collaborations, Boschma (2005, p. 62) provides a widely accepted argument: 'What

unites the different dimensions of proximity is that they reduce uncertainty and solve the problem of coordination, and, thus, facilitate interactive learning and innovation.'

Proximity enables knowledge transfer because partners need a common ground, and different dimensions of proximity could provide this shared platform. There are various kinds of typologies of how proximity may be achieved. Partners could be located geographically close to each other, which makes it more conducive and easier to exchange knowledge. Moreover, several studies on proximity claim that the geographical closeness of actors would be sufficient to be more innovative and, hence, more competitive, mainly due to knowledge spillovers (Fritsch & Franke, 2004). It is argued that the type of knowledge required for innovation – that is, tacit knowledge – is difficult to communicate over long distances, since it 'can only be produced in practice' (Maskell & Malmberg, 1999, p. 172). It is possible to transfer this type of knowledge only through demonstration and observation, which requires face-to-face interaction among the actors, and can only be achieved if the actors are co-located (Gertler, 2003). Shaw and Gilly (2000) mention that in addition to geographical proximity, there must be some kind of organized proximity based on the logics of belonging and similarity. According to Torre (2014, p. 98), 'organized proximity refers to the different ways of being close to other actors, regardless of the degree of geographical proximity between individuals'.

Boschma (2005) introduced a new taxonomy to the proximity literature and his contribution gained prevalence in academic circles. Boschma (2005, p. 62) mentions the inability of geographical proximity in explaining collective learning by stating, 'geographical proximity per se is neither a necessary nor a sufficient condition for learning to take place'. He proposes a classification based on five forms of proximity, that is, cognitive, organizational, institutional, social and geographical proximity. Cognitive proximity refers to the similarity of knowledge bases and perceptions of the actors. It is closely related to the notion of absorptive capacity. For individuals or firms, in order to absorb new knowledge, there must be some kind of cognitive proximity between the interacting parties. This is essential to understand new knowledge successfully and process it accordingly. Organizational proximity denotes the idea of organizational relationship, such as being part of the same hierarchical structure within a company group (Tijssen, Yegros-Yegros, & Winnink, 2016). It is argued to help in limiting opportunistic behaviour when exchanging knowledge. Institutional proximity is associated with formal (e.g., laws and regulations) and informal (e.g., shared habits, norms) macro-level frameworks (Ponds, Van Oort, & Frenken, 2007). Since institutions set the rules of the game, the actors in institutional proximity are expected to behave similarly and are more likely to interact. On the other hand, social proximity reflects individual-level relationships and carries the idea that the level of trust, friendship and kinship among the actors/firms creates social proximity, which in turn encourages them to easily interact and exchange knowledge (Boschma, 2005).

In addition to these two dominant positions regarding non-geographical dimensions of proximity, there have been other types of proximity that have attempted to account for effective knowledge transfer for innovation purposes. Some of these contributions include cultural proximity (Teixeira, Santos, & Oliveira Brochado, 2008), technological proximity (Cassi & Plunket, 2015) and personal proximity (Werker, Ooms, & Caniëls, 2016). It can be claimed that what all these explanations are attempting to capture is that the actors involved in the process of knowledge exchange must be proximate to each other in one way or another either geographically or in terms of other dimensions, such as cognitively or socially.

Despite the numerous accounts on proximity, geographical proximity has emerged as a kind of primate proximity that is considered a key driver for ensuring successful knowledge exchange. The studies combining UICs with proximity literature favour geographical proximity, suggest a regional bias and emphasize the prominence of local and regional collaborations over others. Depending on previous researches, Slavtchev (2013) argues that UICs tend to be realized primarily in the local sphere.

The preference of firms to collaborate with geographically close universities (Garcia, Araujo, Mascarini, Gomes Dos Santos, & Costa, 2018; Steinmo & Rasmussen, 2016) can be attributed to several conditions. The first explanation concerns the interaction costs of collaboration and suggests that knowledge exchange between universities and firms is expensive and that these expenses increase with distance (Fitjar & Gjelsvik, 2018; Laursen et al., 2011). The longer the distance between collaborators, the higher the costs associated with travel expenses, time, cultural differences and language barriers (Muscio, 2013).

The second explanation relates to the difficulties of transferring knowledge mainly due to the tacit aspect of knowledge exchanged. According to this view, tacit knowledge requires close proximity of partners because its transfer necessitates personal contact and direct interaction of partners (Abramo, D'Angelo, & Solazzi, 2012; Laursen et al., 2011). Therefore, the co-location of collaborating partners is more conducive to face-to-face interactions, both intended and unintended, which makes the transfer of tacit knowledge more plausible and smoother. Petruzzelli (2011), echoing Howells (2002), argues that geographical proximity is necessary even for the exchange of codified knowledge, since a certain element of tacitness facilitates the interpretation of codified knowledge.

Toward a more nuanced model of proximity in UICs from the perspective of MNEs

The accounts that attribute great importance to geographical proximity in knowledge transfer lack a sense of how geography functions from the perspective of actors who are not fixed in space, such as universities and MNEs. It is known that universities create knowledge in global communities and, similarly, MNEs are multisite corporations. Therefore, the question of which units are in proximity to which university becomes critical. It would be rather simplistic to assume that the effect of geographical proximity on UICs is constant or similar for all types of firms (Johnston & Huggins, 2017), and even for different branches of the very same firm, like an MNE. Firms do not decide to collaborate with the nearest university merely by taking advantage of geographical proximity (Fromhold-Eisebith & Werker, 2013).

Related literature provides a number of factors that affect partner search and selection of the MNEs and, therefore, the geographical reach of their collaborations with universities. These factors provide a few refinements on the importance of geographical closeness for UICs and explain the rationale underlying collaboration with universities located at larger geographical distances. By relying on the related literature on these factors, a more nuanced approach for treating the influence of geographical proximity on the MNEs' UIC patterns has been developed. This approach was tested with the help of the following sub-research questions:

- *Sub-research question 1:* Do MNEs collaborate more with universities located at larger geographical distances?
- *Sub-research question 2:* Do the subsidiaries of MNEs in other countries collaborate more with the local universities where they are established than with the universities in the country where they are headquartered?
- *Sub-research question 3:* Do the subsidiaries of MNEs collaborate with universities at various geographical scales in similar patterns?

One of the factors affecting the geographical reach of UICs is the size of the company. MNEs are much larger organizations than small and medium-sized enterprises (SMEs) and have abundant resources that they can invest in R&D activities. Simultaneously, the widespread adoption of the open innovation approach (Chesbrough, 2003) by MNEs has given rise to the emergence of the notion of 'global innovation networks', which refers to the international dispersion of their R&D activities and collaborative relations with international partners (Guimón & Salazar-Elena, 2015).

Studies in this area show that the likelihood of collaborating with universities is two to three times higher for larger firms (Dell'Anno & Del Giudice, 2015). Larger firms such as MNEs do not only have a tendency to collaborate more with universities, but also have the opportunity to interact more with universities located at larger geographical distances since they are less bounded by high interaction costs. Therefore, this paper asks the following sub-research question:

- *Sub-research question 1:* Do MNEs collaborate more with universities located at larger geographical distances?

On the other hand, MNEs opt for those regions to conduct their R&D activities where they can tap into the local knowledge and benefit from localized knowledge flows that are mainly generated by universities in these regions (Siedschlag, Smith, Turcu, & Zhang, 2013). Studies on innovation and R&D activities of MNEs (Belderbos, Van Roy, Leten, & Thijs, 2014) show that MNEs take into account the existence of excellent research universities as the primary reason when choosing where to locate their R&D subunits (Broström et al., 2009). Therefore, the geographical proximity to universities is much more critical for the subunits of MNEs in other countries. From this, another sub-research question is formulated:

- *Sub-research question 2:* Do the subsidiaries of MNEs in other countries collaborate more with the local universities where they are established than with the universities in the country where they are headquartered?

Lastly, the internal configuration and characteristics of MNEs, such as the level of absorptive capacity and the knowledge base of the company, also have an influence on the propensity to collaborate with external actors in their knowledge-access strategies. The level of absorptive capacity, which is defined as 'the ability of an organization to recognize the value of new, external information, assimilate it, and apply it to commercial ends' (Cohen & Levinthal, 1990, p. 128), are expected to be higher for MNEs with rich human capital. However, the level of absorptive capacity does not show much divergence within the branches of MNEs that have highly qualified engineers and researchers.

The knowledge base of firms is argued to exert an influence on firms in their geographical lookout for partners (Asheim, 2007). If the firm operates in an industrial branch that is dominated by an analytical (science-based) knowledge base, such as pharmaceuticals and biotechnology, the collaborations are expected to be less confined to localities mainly due to the codified nature of the knowledge being produced, shared, and exchanged. On the other hand, for firms operating in a synthetic (engineering-based) knowledge base, such as automotive and electronics, for which technical know-how and tacit knowledge is the key, the collaborating partners are located in close vicinity of the firms (Davids & Frenken, 2018). Moreover, the oil and gas sector, also, has a predominantly synthetic knowledge base, since learning-by-doing and engineering-based activities require the acknowledgment of environmental and geographical contexts. However, the knowledge base of the subsidiaries of MNEs remain unchanged if they operate in the same industry.

Combining these two aspects regarding internal similarities of MNEs, with regard to absorptive capacity and knowledge base, this paper raises the following sub-research question:

- *Sub-research question 3:* Do the subsidiaries of MNEs collaborate with universities at various geographical scales in similar patterns?

With the help of these sub-questions, the paper attempts to portray the geographical reach of UICs for MNEs, which is an important aspect in learning which universities MNEs collaborate with for their research and knowledge needs. Since MNEs are multisite actors with their

subsidiaries, if an adequate picture of spatiality of the UICs for MNEs can be depicted along with their subunits, something meaningful can be said about the influence of geographical proximity on UICs. It can be specified how and to what extent the effects of geographical proximity are at play in the choice of collaboration partners for MNEs.

CASE STUDY AND METHODOLOGY

This paper uses co-publications as a proxy for 'successful' UICs in line with a growing interest in using co-publications as an indicator of joint knowledge production (Marek, Titze, Fuhrmeister, & Blum, 2017). Co-publications provide a quantifiable output for UICs (Hoekman, Frenken, & van Oort, 2009). Moreover, since they are registered in journal databases, they constitute an important source for the analysis of UICs. Indeed, as Tijssen et al. (2016, p. 681) argue, they 'are currently the only available information source for large-scale and systematic quantitative analysis' to measure university–industry linkages.

In order to answer the research questions, the author created a co-publication architecture for a single MNE using bibliometric data, which enabled to depict how different the co-publication patterns are between the various branches of the MNE. The sub-research questions were analyzed in line with the data, with the expectation that they would enable a reflection on the structures of UICs within an MNE.

A firm-centric approach is preferred in this paper because it is actually the firms that require new knowledge, and/or the potential applications of new knowledge, generated in universities or co-created with them in order to remain competitive. As the active knowledge seekers in UICs, it is assumed that firms initiate interaction with universities and benefit from collaboration. Moreover, the involvement of corporate staff in co-publications reflects the exchange of knowledge and joint knowledge production by university and corporate researchers.

The case: Equinor

Specifically, this paper conducts a case study on the Norwegian company Equinor and the geographical distribution of its co-publication partnerships with universities. Equinor is a state-owned oil and gas company in Norway. Earlier known as 'Statoil', the company changed its name to 'Equinor' in 16 May 2018; however, this name change did not affect the study at hand. This particular company has been selected due to its capacity to represent the oil and gas industry, which constitutes the backbone of the Norwegian economy. In addition, Equinor is counted among the largest R&D-conducting companies in the Norwegian economy (Wicken, 2007). According to the statistics of the Norwegian Industrial Property Office, Equinor is one of the most innovative companies in the country, as it is the most active native patent applicant in the last 20 years.

Equinor is a good example of an MNE, as it has numerous offices both within Norway and in other countries globally. Its offices and R&D centres are scattered across Europe, the Middle East, China and the United States, which makes it suitable for cross-regional and cross-national comparison. Table 1 presents the various Equinor bases worldwide and the number of permanent employees by countries. As depicted, approximately 87% of Equinor employees work in Norway. The other large offices of Equinor are located in the United States, the UK, Denmark and Brazil, respectively, in terms of size. In this paper, all the addresses attributed to Equinor and its corresponding operation bases (23 addresses/offices in eight countries) that are used in the database (see below) are examined.

The data source: Web of Science

Thomson Reuters' Web of Science (WoS) database was used as the main source for data collection on publications. WoS collects and archives scientific publications electronically. The WoS database contains detailed information on publications, such the addresses of the authors, year

Table 1. Number of permanent employees per country for Equinor group, 2017.

Country	Employees	Country	Employees
Algeria	27	Libya	3
Angola	15	Mexico	5
Azerbaijan	11	Netherlands	8
Bahamas	54	Nigeria	12
Belgium	64	Norway	17,632
Brazil	323	Russian Federation	53
Canada	131	Singapore	29
China	6	Tanzania	21
Denmark	330	UK	476
Germany	14	United Arab Emirates	3
Indonesia	19	USA	984
Ireland	2	Venezuela	22
Kazakhstan	1	Total	20,245

Source: Statoil ASA (2018, p. 50).

of publication, related scientific disciplines and funding sources of the articles. This database was used because it contains over 10,000 journals in a wide range of disciplines and it is indicated as being one of the most comprehensive sources of information on scientific research activities by several authors (Lata, Scherngell, & Brenner, 2015; Hoekman et al., 2009). The database enables researchers to find the articles of their interest by conducting searches through certain criteria such as topic, title, language of the article, and journal, author name(s), city, job affiliation, type (article, book, book chapter, etc.), and time of publication.

The methodological steps

For the purposes of this paper, a search query was conducted in the database for 'Articles' published in 'English' for the '2008–2016' with the search terms '(OG = Statoil)'. The 'OG' (i.e., organization-enhanced) search code (field tag) denotes the name of the organization that published the article and includes all the related usages and variants of the search term, in this case 'Statoil'. The search was limited to 2008–16 because the addresses of authors were compiled in the database only beginning from 2008 onward.

The results of the search were eliminated by checking the co-publication status, thereby implying controlling whether the articles are written only by Equinor employees or in collaboration with others, either other private sector actors or universities. At the end of this process, only the articles published in collaboration with academics and those that contain a university name in the address section were forwarded to the next stage of classification.

The database search yielded 956 articles, out of which 739 were found suitable for examination with UICs. Three articles were excluded from the analysis, since they did not indicate any Equinor address, and 214 articles were excluded because they were published without any university collaboration. Therefore, the analysis was conducted on this reduced dataset of 739 articles and involved 996 collaborations of Equinor with 245 universities in 45 countries.

Thereafter, the articles were classified on the basis of the addresses of Equinor bases. It must be noted here that some addresses provided in the address section of the database point to the same unit of Equinor, specifically for the bases in Norway. For example, the Equinor addresses provided for Rotvoll, Ranheim and Trondheim all respond to the Equinor base in Trondheim. The same issue is also observed for the addresses provided as Sandsli and Bergen, corresponding to the Equinor unit in Bergen. Further, Equinor addresses for Fornebu and Oslo also indicate the Equinor Oslo office, while those for Harstad and Medkila denote the Equinor Harstad.

Moreover, some of the addresses that are located in the same province and close to each other are taken into account together. As such, Equinor addresses in Mongstad and Kollsnes are added to Equinor Bergen, and the Equinor address in Stjørdal is combined with Equinor Trondheim in the analysis. This is done for simplification and agglomeration purposes, under the assumption that the offices located in close proximity are part of the same local/regional innovation system and show similar collaboration patterns. The results of the agglomeration/simplification step can be summarized in the following manner:

Equinor addresses in:

- Bergen, Mongstad, Kollsnes and Sandsli are grouped under *Bergen*.
- Harstad and Medkila are grouped under *Harstad*.
- Trondheim, Ranheim, Rotvoll and Stjørdal are grouped under *Trondheim*.
- Fornebu and Oslo are grouped under *Oslo*.
- Stavanger and Porsgrunn are dealt with independently (Figure 1).

As the next step, all the co-authors from the universities were categorized on the basis of the addresses in the relevant section of the database. The accounts that are published by Equinor authors with university affiliations were also recognized as UICs. For those academic partners who have multiple university affiliations, each of the universities that they are affiliated with were considered as engaging in UICs with Equinor.

In order to detect the prevalence of collaborations realized in geographical proximity, the collaborations were divided into four geographical scales: local, national, continental and global. This division is organized in the following manner: The local scale implies the collaborations of Equinor bases with the closest university. The national scale denotes collaborations with universities realized in the same country of the Equinor subunit, except for the closest university. International collaborations are further divided into two scales, continental and global, with respect the ease of flight trips between distances. Therefore, the continental scale denotes the collaborations within the same continent, while the global scale encompasses collaborations with universities in other continents. In order to exemplify this classification, the collaboration of Equinor Trondheim is classified as local when it has collaborated with the nearest university – that is, the Norwegian University of Science and Technology (NTNU); as national when it has collaborated with the University of Stavanger (UiS); as continental when it has collaborated with a European university; and finally as global when it has collaborated with a university from the United States.

GEOGRAPHIES OF CO-PUBLICATION PARTNERSHIPS

Initially, the analysis examines the number of co-publication volumes by Equinor bases in order to detect the productivity of Equinor bases in terms of co-publications (Table 2). The results indicate Equinor bases in Trondheim, Stavanger and Bergen as the top three contributors, constituting approximately 77% of Equinor co-publications. When the offices in other parts of Norway (Porsgrunn, Oslo, Harstad, Mongstad, Medkila and Kollsnes) are included, the share of all Equinor bases in Norway rises to 90.7% of all co-authored papers. This indicates that the bases in Norway generate nine out of 10 co-publications of Equinor. Further, two Equinor offices in the United States (Austin and Houston) account for 6% of Equinor co-publications, while the UK offices (London and Aberdeen) produce 1.8% of Equinor's co-publications. The remainder of the co-publications (1.5%) was co-authored by Equinor employees in Canada (Calgary), China (Beijing), Germany, Sweden and Iran.

The location of university partners are then investigated to determine the geographical reach of Equinor co-publications (Table 3). In total, Equinor bases worldwide have collaborated with

Figure 1. Equinor addresses in Norway.
Note: The map indicates the Equinor addresses found in the database and used in the analysis and not all Equinor bases in Norway. Source: Author's own elaboration.

Table 2. Co-publication volumes by Equinor bases.

	n	%		*n*	%		*n*	%
Trondheim	354	35.5%	Oslo	37	3.7%	Calgary	3	0.3%
Stavanger	236	23.7%	Austin	36	3.6%	Germany	3	0.3%
Bergen	184	18.5%	Houston	24	2.4%	Sweden	3	0.3%
Porsgrunn	54	5.4%	London	17	1.7%	Aberdeen	1	0.1%
Harstad	38	3.8%	Beijing	5	0.5%	Iran	1	0.1%

universities in 45 different countries, which shows that Equinor has a global outreach and is embedded in global innovation networks in order to collect external knowledge. However, the results also signal that Norwegian universities have an overwhelming share in the distribution and their total share in all Equinor co-publications accounts for 41.4% of co-publications (412 collaborations). This is followed by the share of universities located in Europe (38.4% with 382 collaborations) and universities in the rest of the world[2] (20.3% with 202 collaborations).

Table 3 reveals that approximately 70% of the publications of Equinor are produced in collaboration with universities in Norway, the UK and the United States, where Equinor has the largest offices with maximum number of employees. This signals that geographical proximity may have some implications for UICs. Table 3 also indicates that geographical proximity is of significance, but only to a point. This becomes evident in the sense that Equinor has also collaborated with universities from countries where it has very little or no presence in the form of subsidiaries. However, it must be noted that most of these collaborations were realized in the form of co-affiliation of the academic authors with these universities. Another possible explanation for lower co-publication volumes (for most of the 1's in Table 3) is that they are the publications that received funding from the respective countries of the universities.

Further, the share of universities is also examined to determine the gravity centres in terms of Equinor's co-publication partnerships (Table 4). The NTNU is by far the most collaborated with university for Equinor. It alone constitutes 21.5% of the collaborations with Equinor bases. The leading partner at the European continental level for Equinor co-publications is the Imperial College London in the UK, while the leading global partner is the University of Texas, Austin in the United States.

Moreover, the locality of partnerships for all Equinor bases are examined by considering the location of the universities in accordance with the geographical scales. The results are presented in Table 5. Several distinctive features are evident. The first aspect relates to the high share of local university linkage in Trondheim. Equinor bases in Trondheim collaborate extensively with the local university, NTNU. The second striking aspect is the relatively low share of the local university, UiS, in co-publications of Equinor headquarters in Stavanger and higher rate of national collaborations and much higher rate for continental scale collaborations. The third aspect is that the Equinor unit in Bergen poses another picture. For Equinor Bergen, the collaborations at the continental scale – that is, with European universities – constitute the majority, and these collaborations have the highest value among all other Equinor bases. Lastly, the Equinor bases in the capital of Norway, Oslo, have no co-publication collaborations with the local universities in Oslo.

Briefly, this data section reveals the following aspects:

- Equinor bases in Norway produce the majority of co-authored papers with universities (Table 2).
- Equinor collaborates mainly with universities in Norway, the UK and the United States (Table 3).
- The co-publication partnerships of Equinor are concentrated in 13 universities, accounting for over 50% of all co-authored papers (Table 4).
- The shares of different geographical scales fluctuate and do not remain constant (or portray a similar pattern of distribution) for different Equinor bases (Table 5).

It can be inferred from these aspects that geographical proximity is of importance for UICs in the form of co-publications for the Equinor case. Although Equinor is a firm with a global reach, it mainly collaborates with universities in Norway, specifically with universities that are located in the close vicinity of Equinor bases that have a strong presence (with regard to employee numbers). Nevertheless, the share of co-publications with universities in geographical proximity is

Table 3. Co-publication volumes by countries of the universities[a].

Norway	412 (41.4)	China*	19 (1.9)	Iran*	5 (0.5)	Czech Republic	2 (0.2)	Israel*	1 (0.1)
UK	160 (16.1)	Spain	19 (1.9)	Turkey*	5 (0.5)	Ireland	2 (0.2)	Lithuania	1 (0.1)
USA*	112 (11.2)	Belgium	12 (1.2)	Ukraine*	5 (0.5)	Argentina *	1 (0.1)	Mexico*	1 (0.1)
Germany	32 (3.2)	Sweden	9 (0.9)	Oman*	4 (0.4)	Costa Rica*	1 (0.1)	New Zealand*	1 (0.1)
Italy	30 (3.0)	Finland	8 (0.8)	Russia*	4 (0.4)	Croatia	1 (0.1)	Romania	1 (0.1)
France	28 (2.8)	Switzerland	8 (0.8)	Brazil*	3 (0.3)	Estonia	1 (0.1)	Slovakia	1 (0.1)
Canada*	27 (2.7)	Australia*	7 (0.7)	Greece	3 (0.3)	India*	1 (0.1)	Taiwan*	1 (0.1)
Netherlands	25 (2,5)	Poland	6 (0.6)	South Africa*	3 (0.3)	Indonesia*	1 (0.1)	Thailand*	1 (0.1)
Denmark	22 (2.2)	Austria	6 (0.6)	Algeria*	2 (0.2)	Iraq*	1 (0.1)	Venezuela*	1 (0.1)

Notes: [a]Values in parentheses are percentages.
Universities marked with an '*' are considered to be located in the rest of the world.

Table 4. Volumes by leading universities (with over 10 co-publications).

University	Co-publications and shares	University	Co-publications and shares
NTNU	214 (21.5%)	Durham	16 (1.6%)
Bergen	81 (8.1%)	Technical University of Denmark	14 (1.4%)
Stavanger	38 (3.8%)	Texas Austin	12 (1.2%)
Oslo	35 (3.5%)	Delft University of Technology	12 (1.2%)
Imperial College London	31 (3.1%)	Leeds	11 (1.1%)
Manchester	17 (1.7%)	Aberdeen	11 (1.1%)
Tromsø	16 (1.6%)	Total	508 (50.9%)

Table 5. Geographical distribution of university partners for Equinor bases.

		Location of university partners (%)			
Equinor bases	Co-publications	Local	National	Continental	Global
Trondheim	354	42.1	12.1	27.4	18.4
Stavanger	236	11.4	29.7	42.8	16.1
Bergen	184	15.8	14.1	53.8	16.3
Porsgrunn	54	13.0	48.1	18.5	20.4
Harstad	38	18.4	31.6	39.5	10.9
Oslo	37	0.0	35.1	37.8	27.0
Austin	36	16.7	44.4	8.3	30.6
Houston	24	0.0	16.7	4.2	79.2
London	17	29.4	47.1	17.6	5.9
Beijing	5	40.0	20.0	0.0	40.0
Germany	3	0.0	0.0	33.3	66.7
Calgary	3	33.3	33.3	0.0	33.3
Sweden	3	0.0	66.7	33.3	0.0
Aberdeen	1	100.0	0.0	0.0	0.0
Iran	1	100.0	0.0	0.0	0.0
Total	996	23.6	22.3	34.6	19.5
Norway	903	24.3	21.0	37.2	17.5
Outside Norway	93	17.2	34.4	9.7	38.7

not evenly distributed for Equinor bases both in Norway and other countries. This aspect leads to the argument that geographical proximity is significant, but holds significance at different levels for different units of MNEs. The fluctuating percentages for geographical scales in Table 5 explicitly indicate the changing influence of geographical proximity from unit to unit.

GEOGRAPHICAL PROXIMITY, A COMMON DENOMINATOR FOR UICs?

The tendency of MNEs to collaborate with universities in other countries, the expectation of more local university collaboration for subsidiary units established in other countries, and the similarity of collaboration patterns among subsidiary units has been examined with the approach

developed in the second section in order to clarify the impact of geographical proximity in UICs of MNEs.

Our findings indicate that MNEs are more inclined to collaborate internationally. The share of international collaborations (continental and global scales combined) constitute the majority of co-publication collaborations of Equinor. For all subunits of Equinor combined, the majority of university partners are located in other countries, either at the continental scale (34.6%) or at the global scale (19.5%). However, when examined in detail, a few differences also come to the surface. For example, the co-publication collaborations with European universities for Equinor bases located in Norway and other European countries – that is, continental collaborations – have an overwhelming share (36.8%); on the other hand, for Equinor bases in the American continent (in the United States and Canada), collaborations on the global scale are dominant (49.2%).

Second, in partial opposition to the general wisdom that the overseas units of MNEs are expected to collaborate more with the local universities where they are located, our findings illustrate another picture. For all Equinor subsidiary units outside of Norway, the share of local collaborations remains at 17.2%. However, the total number of co-publication collaborations for such countries is very low. The analysis also illustrates another aspect regarding national-level collaborations. The bases across Norway are responsible for 409 collaborations out of 412 collaborations with Norwegian universities. This provides strong support for the argument regarding collaboration networks being confined within national boundaries (Lata et al., 2015; Ponds et al., 2007). Moreover, it shows that Equinor bases worldwide are less dependent on the universities in Norway, where the firm is headquartered. This can be interpreted as a sign that the subsidiaries of Equinor are doing well in terms of obtaining access to knowledge flows in the countries in which they are established, instead of turning back to Norwegian universities for knowledge demands.

Lastly, our findings indicate that geographical proximity does not exert a similar influence on all branches of an MNE. Even though all the bases have more or less the same level of absorptive capacity and rely on the same knowledge base, their propensity to collaborate with local–regional universities shows a significant divergence. Table 5 illustrates this finding and reveals that there is a wide range of fluctuations in the shares of co-publication collaborations with local universities among Equinor bases. The share of local collaborations peaks for Equinor bases in Trondheim with NTNU collaborations. In Stavanger, an opposite trend is brought to light with the lowest share of local collaborations, except for Equinor bases that have no local collaborations at all, such as Oslo.

All these aspects illustrate the differentiated effect of geographical proximity on the collaboration patterns of MNEs. Although geographical proximity plays a role in facilitating the process of knowledge transfer between firms and universities, it does not have the same influence in every case. It is difficult to discuss geographical proximity as a common denominator for UICs of MNEs. MNEs enjoy the advantages of geographical proximity while they also shoulder the burdens of distant relationships if, and when, they need to access specific new knowledge. If the required new knowledge is to be found in universities in other regions or countries, MNEs attempt to establish collaborative linkages with them in order to sustain their innovativeness and competitiveness.

CONCLUSIONS

The arguments in favour of the significance of geographical proximity for easing the process of collaborations between universities and industry are well established. However, does geographical proximity equally influence the collaboration networks of MNEs with universities? This study suggests that geographical proximity exerts an influence, but a differentiated one, on the

collaboration patterns of MNEs. There is no 'one-size-fits-all' type influence of geographical proximity on UIC patterns of multisite actors. It is shown that among the geographically dispersed branches of a single MNE, geographical proximity has different effects. While a few subsidiary units collaborate more intensively with local universities, some of them are more commonly engaged in collaborations with international partners.

We find that the effect of geographical proximity appear to be lower for MNEs that, in principle, have richer resource bases for establishing and maintaining long-distance collaborations. This is illustrated by our case of Equinor, for which the share of international collaborations constitutes the majority of all co-publication partnerships.

In addition, we also find that the subunits of the examined MNE in other countries are not more likely to collaborate with local universities in the countries where they are established. This aspect challenges the arguments that MNEs locate their R&D activities in other countries in order to obtain access to local knowledge sources retained mostly in local/regional universities. Nevertheless, our findings also suggest that despite the low levels of collaboration with local/regional universities, the presence of MNEs subunits in a country increases the likelihood of national-scale collaborations. The share of national collaborations for subsidiaries in other countries are much higher than the national collaborations realized in the country where the case firm has its headquarters. In other words, the mere existence of MNE subsidiaries in a particular region of a country provides a gateway to reach other universities at the national layer in that country. While the main rationale for MNEs in establishing subsidiary units in other countries is to tap into local knowledge networks, the existence of these units has a spillover effect and also paves the way toward reaching national networks. Therefore, establishing subsidiaries in other countries appears to be a viable strategic choice for MNEs that are willing to broaden their knowledge acquisition efforts globally.

The findings of the paper also strengthen the most significant aspect of proximity literature – 'geographical proximity between organizations is neither a sufficient nor a necessary condition for learning and interactive innovation to take place' (Boschma, 2005, p. 62). Geographical proximity is a potential determinant of UICs, but its influence changes and does not remain constant for the collaborations of a single multisite firm. However, our data, its analysis, and findings do not reveal anything about why this is the case. The questions of why the geographical pattern of UICs differs among various bases of an MNE and why these subunits prefer to collaborate with universities located at longer distances require a broader research that takes into account several other factors, and from the perspective of proximity, the inclusion of non-geographical proximity dimensions. Therefore, in explaining the determinants of UICs, other dimensions of proximity must be included in examining the partner choice of MNEs.

Researches trying to combine proximity approach and UICs in the context of MNEs should take into account that both universities and MNEs are multisite actors and have presence in various locations as campuses or subsidiaries. UIC studies about MNEs taking the academic and industrial partners as unitary actors would result in flawed conclusions stemming from attributing, or aggregating, connections of different units to one central body, which may provide an unbalanced, and therefore inaccurate, representation of the existing partnership patterns. For more elaborate and accurate studies on the influence of geographical proximity in defining the scope of UICs for MNEs, the issue of which unit's proximity to which university must be approached with caution.

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NOTES

1. These categories are indicated as: (1) Capacity and resources; (2) Legal issues, institutional polices and contractual mechanisms; (3) Management and organizational issues; (4) Issues relating to the technology; (5) Political issues; (6) Social issues; and (7) Other issues (Ankrah & Al-Tabbaa, 2015, p. 395).
2. Universities marked with "*" are considered in this category.

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PAPER 2

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FULL ARTICLE

Proximity across the distant worlds of university–industry collaborations

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Abstract

This paper examines the extent to which firms perceive different dimensions of proximity to be important for the formation of their interactions with universities. Furthermore, it investigates whether the importance of the different types of proximities varies depending on the type of interaction—be it about knowledge exploration, knowledge exploitation, competence enhancement, advice-seeking or marketing. Using data from a survey of 1,200 Norwegian firms, we find that most managers believe cognitive, institutional, social and geographical proximity were important for their decision to collaborate with university partners and that the importance of proximity types varies depending on the contents of the interaction.

KEYWORDS
distance, Norway, proximity, survey, university-industry collaboration

JEL CLASSIFICATION
123; 125; O32

1 | INTRODUCTION

Universities and firms interact for multiple purposes, and their interactions therefore take many different forms. Firms collaborate with universities to explore new knowledge, for example, through contract research or joint research projects, and to exploit new knowledge through commercialization in the form of patents, licences or new spinoff firms. Firms also collaborate with universities to enhance their competence, for example, contributing to the

education of university students or participating in training for firm staff. They may consult academics to solve their technical problems or seek advice on their activities, often in informal ways. And they may simply want to brand or market themselves by, for example, sponsoring the university or organizing events.

However, university-industry interactions can be hard to realize. Universities and firms have been described as occupying different worlds (Bruneel, D'Este, & Salter, 2010), with differences in worldviews, organizational structures, values and cultures, goals and motivations acting as barriers to interaction. These distances are not the same across all university-firm relationships. Not all firms or all universities share the same values; have the same cognitive capacities; or operate under the same organizational principles (Sauermann & Stephan, 2013). They also do not matter equally for all types of collaboration but their importance will vary depending on the content and purpose of collaboration. Hence, university-industry interactions can play out differently in different cases, suggesting that different university–industry collaboration (UIC) types need to be tackled separately.

Proximity (in a geographical as well as non-geographical sense) is important for the formation of networks (Boschma, 2005). If firms and universities occupy different worlds, a pertinent question is which dimensions of proximity can enable UIC of different types. Nonetheless, the number of studies looking at the importance of proximity dimensions in UICs has been limited (Ponds, van Oort, & Frenken, 2007; Steinmo & Rasmussen, 2018) and these works have largely focused on specific UIC mechanisms, such as joint research, co-patenting and spin-offs (Hoekman, Frenken, & van Oort, 2009; Marek, Titze, Fuhrmeister, & Blum, 2017). More importantly, existing studies have seldom examined the relative importance of various proximity dimensions in facilitating different forms of UICs (D'Este, Guy, & Iammarino, 2013). However, the different characteristics of UICs depending on the purpose of interactions require a closer examination of the interplay between various proximity dimensions and various UIC channels. Furthermore, prior research has employed crude measures for proximity dimensions instead of collecting primary data on actors' perceptions of the importance of proximity for the formation of the relationships. This paper fills these gaps in the literature and provides a more comprehensive understanding of the significance of proximity dimensions for a wide set of UIC channels.

With the empirical analysis drawing on a customized survey of firms in Norway, conducted in 2018, this paper represents the first endeavour to analyze the role of various dimensions of proximity across different UIC channels. The results indicate that the majority of interactions occur with local and regional universities for all types of UICs. The analyses also indicate the importance of non-geographical proximity for UICs. However, the importance of proximity dimensions varies depending on the UIC type. We run a multinomial logit regression analysis to determine the relative significance of each proximity dimension for different UIC types. Compared to competence enhancement UICs, cognitive and institutional proximity matter more for knowledge exploration collaborations, while geographical proximity is less significant. Social proximity is perceived as more important by firms engaging in knowledge exploitation interactions. For advice-seeking interactions, organizational proximity is less important.

The remainder of the paper is structured as follows. First, we discuss previous literature on distance(s) in UICs and the role of proximity in bringing the "two worlds" closer, outlining how different dimensions of proximity matter for different UIC types (Section 2). Then, we describe the data and methodology in Section 3. In Section 4, we present the findings of the analysis. A discussion of the results concludes the paper (Section 5).

2 | THEORETICAL FRAMEWORK

2.1 | Proximity in UICs

The proximity framework provides a useful theoretical perspective on inter-organizational collaborations for knowledge exchange purposes (Nilsen & Lauvås, 2018). Proximity, defined as "being close to something measured on a certain dimension" (Knoben & Oerlemans, 2006, pp. 71–72), helps in overcoming co-ordination problems by facilitating communication and reducing uncertainty, and therefore, contributes to effective interaction in knowledge

transfer between the partners (Boschma, 2005). Some studies argue that geographical proximity, or the co-location of the partners, facilitates the interaction process by allowing face-to-face communication that enables thick knowledge exchange (Storper & Venables, 2004), making knowledge, especially tacit knowledge, easier to transfer (Maskell & Malmberg, 1999). However, co-location does not necessarily ensure the effectiveness of the knowledge exchange, as it does not in itself lead partners to interact (Broekel & Boschma, 2012). Moreover, actors who are not located in close proximity can still effectively exchange knowledge, in many cases building on non-geographical dimensions of proximity—including cognitive, organizational, institutional, and social proximity (Boschma, 2005).

Partners engaging in knowledge transfer need to be competent enough to understand each other—or in the proximity language, they must have cognitive proximity. Cognitive proximity depends on the similarity of the knowledge base of the agents (Boschma, 2005). For an effective knowledge transfer, the actors should be able to perceive, absorb, internalize and process the new knowledge coming from the other partner. This is easier if their knowledge base is similar. Organizational proximity denotes being subject to the same, or similar, control mechanisms and depends on the degree of formal arrangements governing the relationship between the actors (Fitjar, Huber, & Rodríguez-Pose, 2016). It reduces the chances for opportunistic behaviour of the partners in the knowledge exchange process by providing a control mechanism in the form of "checks-and-balances," especially when the arrangement is formalized. Institutional proximity facilitates knowledge transfer by ensuring that the interacting parties are governed by similar hard/formal (regulations, laws etc.) and soft/informal (values, culture, language etc.) institutions (Boschma, 2005). Social proximity captures the social relations mainly emanating from prior ties, repeated interactions, friendship or kinship between the individuals involved in the collaboration (Boschma, 2005). Social proximity provides a solid basis for trust (Fitjar et al., 2016; Innocenti, Capone, & Lazzeretti, 2020), which works as a safeguard against opportunistic behaviour and, thus, facilitates communication and knowledge sharing.

Notwithstanding the critical facilitative role of proximities in inter-organizational relationships, too much proximity can be detrimental to learning. Too much proximity may result in lock-in situations that can block the effectiveness of collaborations. If cognitive proximity is too high, the potential for learning becomes small. Excessive social proximity can be associated with nepotism, if actors choose to collaborate only with their personal friends. Too much organizational proximity can mean a highly bureaucratic framework with little room for maneouvre. Institutional proximity can work conservatively if established values and norms are not challenged. Hence, in innovation networks, the actors should be neither too close nor too far, but located at the right distance from each other to maximize the benefits from collaboration (Broekel & Boschma, 2012; Fitjar et al., 2016). While some distance is thus required for effective collaboration, several studies have shown that proximity increases the likelihood that a relationship is formed (Boschma & Frenken, 2010; Broekel & Boschma, 2012).

University-industry collaborations represent a puzzle from the proximity perspective. Following divergent institutional logics, academia and businesses are said to represent "two worlds" (Hall, 2003; Hewitt-Dundas, Gkypali, & Roper, 2019), suggesting irreconcilable distances between them. Universities and firms differ in their orientations—due to dissimilarities in worldviews and motivations—and encounter transactional difficulties, arising from the inflexibility of university administrations and conflicts regarding intellectual property (Bruneel et al., 2010). In this regard, UICs involve proximity structures that are characterized by distance rather than proximity.

Despite the distances, UICs are being formed between academic and industrial actors. This suggests that the distances can be bridged and barriers can be overcome in UICs. In order to achieve this, the social and relational characteristics of actors are of crucial importance in UICs (Al-Tabbaa & Ankrah, 2016, 2019). The proximity of the interacting partners presents pre-conditions that either hinder or facilitate the collaboration process in UICs (Rajalo & Vadi, 2017; Slavtchev, 2013; Steinmo & Rasmussen, 2018).

Against this backdrop, various studies have shown that individual dimensions of proximity affect the formation of UICs and the interaction process (Cao, Derudder, & Peng, 2019; Crescenzi, Filippetti, & Iammarino, 2017; D'Este et al., 2013). One strongly held argument in the literature is the prominence of geographical proximity in easing the collaborations, and thus the more prevalent realization of UICs between universities and firms located in close geographical proximity. Knowledge generated at universities spills over to geographically proximate industrial actors

more easily than to distant firms (Jaffe, Trajtenberg, & Henderson, 1993) and tends to remain in the localities where the universities are established (D'Este et al., 2013). Firms, especially in science-based sectors such as biotechnology and pharmaceuticals, tend to locate their R&D establishments in close vicinity of research universities. University spin-off firms primarily concentrate around universities and research institutes (Ponds, Oort, & Frenken, 2010). The firms around universities also benefit from access to graduates staying in the local area after their studies. Firms tend to initially approach nearby universities when looking for collaboration partners. The majority of UICs hence takes place in close geographic proximity (Fitjar & Gjelsvik, 2018).

Non-geographical dimensions of proximity further facilitate the formation and management of UICs. Cognitive proximity can make communication between universities and firms easier by building a shared understanding based on the similarities of knowledge bases of universities and firms. Organizational proximity in UICs can be achieved through common membership of the same organizational structures, such as research centres (Kuttim, 2016). Villani, Rasmussen, and Grimaldi (2017) argue that "intermediary organizations" such as technology transfer offices (TTOs) and collaborative research centres (CRCs) facilitate UICs by creating organizational proximity. Institutional proximity, conceptualized as the similarity of institutional arrangements (such as intellectual property rights regimes and common language) at the national level (Hoekman et al., 2009) or as the subordination of firms and universities to the same overarching institutional authorities (Hong & Su, 2013), has been found to facilitate UICs. Finally, social proximity in the form of having graduates from a specific university increases the likelihood of firms collaborating with that university in Denmark (Drejer & Østergaard, 2017), presumably in part due to their social connections to faculty. Crescenzi, Nathan, and Rodríguez-Pose (2016) show that social proximity plays a significant role in the co-patenting behaviour of researchers with firms in the UK. Previous collaborative experiences also positively influence the success of R&D-related UICs in Spain (Mora-Valentin, Montoro-Sanchez, & Guerras-Martin, 2004).

Even though the role of proximity dimensions in UICs has been examined, prior research lacks several perspectives that we attempt to address in this paper. First, existing studies often focus on a single proximity dimension, typically geographical proximity (D'Este & Iammarino, 2010; D'Este & Perkmann, 2011; Johnston & Huggins, 2017; Laursen, Reichstein, & Salter, 2011; Ponds et al., 2010; Tijssen, Klippe, & Yegros, 2020). Second, studies that include a broad proximity perspective typically use indirect measures of proximity, and rarely take the perspective of the firm. Finally, no previous studies have examined how important proximity is for different types of collaboration. Therefore, this paper asks: how important are the various dimensions of proximity in the emergence of UICs of different types?

2.2 | Which types of proximity for which types of interaction?

Firms establish collaborations with universities in various forms, ranging from formal R&D collaboration to graduate recruitment, from joint patenting to informal consultations (Fernández-Esquinas, Pinto, Yruela, & Pereira, 2016; Muscio, 2013). The organizational involvement of the actors, the degree of formalization of the relationship, the intensity and frequency of contact, and the thickness of knowledge exchange vary greatly across UIC types. The literature on UICs has developed different typologies for UIC channels. For instance, Ankrah and Al-Tabbaa's (2015) systematic review presents six categories for organizational forms of UICs, covering 41 distinct activities. Hughes and Kitson (2012) report four "pathways"—people-based activities, community-based activities, commercialization activities and problem-solving activities—through which academics and businesses interact. A report prepared for the European Commission identified 14 UIC activities in four different areas: education, research, valorization and management (Davey, Galan Muros, Meerman, Orazbayeva, & Baaken, 2018).

Many of these typologies classify UICs from the perspective of universities. In this study, we instead consider various rationales based on the needs and purposes of collaborations from the perspective of the firm. We distinguish between five broad categories of UICs: "knowledge exploration UICs" are mainly concerned with the generation of new knowledge that businesses lack internally. This can take the form of contract research or joint research

activities. The research activities may lead to commercial outputs such as new patents or the establishment of new ventures, which we refer to as "knowledge exploitation interactions." These interactions seek to commercially valorize the knowledge. "Competence enhancement interactions" address activities aiming to increase the internal capabilities of firms, such as education, training or the mobility of staff and students. Firms often seek out academics for advice on issues they face, resulting in UICs in the form of informal consultations, which we term "advice-seeking interactions." Finally, firms may collaborate with universities to gain public visibility and increase their image and reputation, for example, through sponsorships or the organization of events. We call these UICs "'marketing interactions."

The various channels of interaction between universities and firms have different characteristics (Gertner, Roberts, & Charles, 2011). The degree of actors' involvement, the type of knowledge concerned (tacit or codified) (Gertler, 2003), the intensity and frequency of contact (Storper & Venables, 2004), and the institutionalization of the interaction structure vary greatly by the type of UIC. In the light of these differences, we should not expect each and every UIC channel to follow the same interaction pattern (Ramos-Vielba, Fernández-Esquinas, & Espinosa-de-los-Monteros, 2010). Although various types of collaboration between universities and firms fall under the broad banner of UIC, the interaction channels require different types of proximity. This requires a closer examination of how proximities affect the UIC types individually. Therefore, this paper poses the following research question: does the importance of proximity depend on the type of UIC?

Based on the needs of each type of interaction, we expect the various proximity dimensions to be more or less important for the different types. For example, collaborative research activities can take place between actors situated far from each other, especially in science-based industries, due to the codified nature of the exchanged knowledge (Ponds et al., 2010). The need for face-to-face communication during the implementation of joint research projects may be satisfied through regular meetings. Therefore, for knowledge exploration interactions, geographical proximity is less important than for other types of interactions (Abramovsky & Simpson, 2011; Thune, 2011). Conversely, geographical proximity may be especially important for advice-seeking interactions, since these interactions often rely on face-to-face contact through purposeful or serendipitous encounters between academics and firm representatives (Azagra-Caro, Barberá-Tomás, Edwards-Schachter, & Tur, 2017). This has been highlighted as one of the reasons why firms in R&D-intensive industries often locate close to universities (Abramovsky & Simpson, 2011). For other types of UICs, geographical proximity also matters: UICs aimed at knowledge exploitation have been shown to occur in smaller geographical distances. Spin-offs or start-ups established from university research tend to locate close to the mother university (Breznitz & Feldman, 2012; Goldstein & Drucker, 2006). Patenting also represents a highly localized phenomenon despite its codified nature (Jaffe et al., 1993). Competence enhancement interactions rely on direct communication between the actors involved, such as students, graduates and businesses (Thune, 2011). For marketing interactions, geographical proximity is important, as philanthropy and other types of community initiatives are often oriented towards the local community (Fitjar & Gjelsvik, 2018; Glückler & Ries, 2012).

Cognitive proximity can play a decisive role particularly in research collaborations, since the partners must understand each other for the projects to succeed (Steinmo & Rasmussen, 2016). Therefore, cognitive proximity matters more for explorative UICs than any other type of interactions. Cognitive proximity is less important for marketing interactions as knowledge exchange is not the central aim of such collaborations. For other types of UICs, some cognitive proximity is also important: knowledge exploitation interactions can be claimed to represent later stages of innovation processes of which both sides are knowledgeable. Therefore, some cognitive proximity is required between partners in these interactions. In competence-enhancing interactions, the knowledge bases of firms and universities should be overlapping to meet the competence enhancement expectations of both sides properly. A certain level of cognitive proximity is also required for advice-seeking interactions, since a common understanding of the subject matter is necessary.

Without strong organizational commitments, knowledge exploitation interactions are hard to realize. Therefore, high organizational proximity is particularly important for the establishment of UICs aimed at

knowledge exploitation (Crescenzi et al., 2017). As advice-seeking interactions are mainly informal, organizational proximity is less relevant for this type of UICs. Organizational proximity is also typically not required for the formation of marketing type of links, but formal relationships such as strategic partnerships may provide the basis for marketing interactions. Organizational proximity may also help in the establishment of knowledge exploration interactions since new projects are often easier to generate in a shared organizational context. Organizational proximity is also fairly important for competence enhancement interactions since joint organizational structures will play the role of intermediaries.

The institutional flexibility of the university administration is especially important for knowledge exploitation interactions since it reduces the risk of transaction-oriented barriers, such as conflicts over intellectual property (Bruneel et al., 2010). Conversely, institutional proximity is less important for marketing interactions as these interactions can also take place at arm's length. Institutional proximity is somewhat important for knowledge exploration interactions, as universities need to be open for the involvement of firms in research projects for such interactions to materialize. Institutional proximity is salient with regards to the adoption of a business-friendly attitude by universities that can support the development of human capital in enterprises through competence enhancement interactions. Institutional proximity can also be influential in removing the barriers for the establishment of advice-seeking interactions between firms and universities, as they require a positive attitude by academics to spend their time providing advice to firms.

Social proximity in the form of prior linkages is less relevant for knowledge exploration interactions since research projects to explore new ground will often involve new partnerships. On the contrary, a high level of social proximity may facilitate knowledge exploitation activities. As this type of interactions requires a large element of trust given the intellectual property involved, personal contacts and previous collaboration experience plays a crucial role in the formation of such links. Social proximity can also play a role in initiating interactions with universities for competence enhancement purposes since they often emerge as a result of contacts between lecturers and firm staff. Personal and social networks also make it easier to reach out to academics for advice (Azagra-Caro et al., 2017). Social proximity is also important for marketing UICs, since it would be easier to establish this type of linkages when prior knowledge on the corresponding partner exists. For instance, prior studies on donations to universities have shown that personal contacts are important for this type of linkages (Glückler & Ries, 2012).

Table 1 summarizes the UIC categories for which we expect each dimension of proximity to be more and less important than for the other dimensions.

TABLE 1 Summary of the importance of proximity dimensions for UIC categories

UIC Type	Geographical proximity	Cognitive proximity	Organizational proximity	Institutional proximity	Social proximity
Knowledge exploration interactions	Less important	More important			Less important
Knowledge exploitation interactions			More important	More important	More important
Competence enhancement interactions					
Advice-seeking interactions	More important		Less important		
Marketing interactions		Less important		Less important	

3 | DATA & METHODOLOGY

3.1 | Description of data

In order to examine the role of proximity in UICs, we conducted a survey of 1,201 businesses in Norway. The survey covers firms located in regions that host universities: Oslo/Akershus, Agder, Hordaland, Nordland, Rogaland, Troms, and Trøndelag. These are all university regions that include the headquarters of a university. Furthermore, the distances between the regions, in particular their main cities and university campuses, are relatively large, which helps distinguish between regional and extra-regional interactions.

Norwegian firms attach more importance to innovation collaboration and interact more with external partners than firms in many other developed countries (Fagerberg, Mowery, & Verspagen, 2009). However, most of these interactions happen within supply-chain relationships, typically with suppliers and customers (Fitjar & Rodríguez-Pose, 2013). A small share of Norwegian firms (around 3%) value universities as the most critical source to obtain external knowledge for innovation (Fitjar & Rodríguez-Pose, 2017). Similarly, a report commissioned by OECD (2017) shows that the share of small and medium-sized enterprises (SMEs) collaborating with HEIs for innovation purposes is relatively low in Norway (around 16.7%), which is slightly above the OECD average of 13%.

Intensifying the interactions between universities and businesses has been a significant priority for Norwegian governments and various policies have been put into force, especially in the last 20 years (Gulbrandsen & Nerdrum, 2007). These policies have been geared towards increasing the contributions of Norwegian universities to regional development and national competitiveness by engaging with businesses in third mission activities, mainly through direct collaboration, commercialization of academic R&D results, and undertaking a more prominent role in the innovation system (Thune & Gulbrandsen, 2011). Firms also receive financial support for R&D projects in collaboration with universities and research institutes, from competitive programmes as well as rights-based schemes such as SkatteFUNN.

The survey was specifically designed to examine the interactions of Norwegian firms with universities. The sample of firms was compiled from the Norwegian Register of Business Enterprises (Brønnøysund Register Centre), which collects and stores information about all enterprises in Norway. The population comprised firms with more than five employees in mining, manufacturing, trade and knowledge-intensive service industries[1] in the aforementioned regions. In total, 10,117 companies were contacted, and 1,201 completed the survey, which corresponds to a response rate of 11.9%. A market research firm (Ipsos) carried out the survey through telephone interviews with firm representatives in December 2018. Table 2 presents the share of firms that were interviewed by county, sector and number of employees.

3.2 | University-industry collaborations

Firms were initially asked whether they had been involved in interactions with universities in the last three years. 232 firms stated that they had been involved in UICs (19.3%). This share is comparable to other studies from Norway (e.g., Fitjar & Rodríguez-Pose, 2013 with a share of 24.9%), and elsewhere, such as the UK (e.g., Laursen & Salter, 2004, 27% and Tether, 2002,16% of innovative firms). From then on, the survey continued separately for firms with and firms without UICs. The firms which had not interacted with universities (without UICs) received a shorter version of the questionnaire, while those who had interacted (with UICs) answered questions about the nature and content of these UICs. The longer version of the questionnaire was aimed at providing detailed accounts of UICs from the firms' perspective with a particular emphasis on the dimensions of proximity.

[1]This includes the NACE codes B, C, G (excluding sub-section 47), J, K, M and N.

TABLE 2 Distribution of firms in the sample by region, sector and firm size

	With UIC		Without UIC		All
Region	Frequency	Share (%)	Frequency	Share (%)	Frequency
Oslo/Akershus	91	18.3	407	81.7	498
Hordaland	28	17.5	132	82.5	160
Rogaland	29	14.8	167	85.2	196
Agder	19	19.6	78	80.4	97
Trøndelag	40	30.3	92	69.7	132
Nordland/Troms	25	21.2	93	78.8	118
Sector					
(B) Mining and quarrying	6	42.9	8	57.1	14
(C) Manufacturing	58	22.1	204	77.9	262
(G) Wholesale and retail trade	35	11.0	284	89.0	319
(J) Information and communication	38	30.2	88	69.8	126
(K) Financial and insurance activities	2	7.7	24	92.3	26
(M) Professional, scientific and technical activities	72	23.0	241	77.0	313
(N) Administrative and support service activities	21	14.9	120	85.1	141
No. of employees					
5–9	72	14.4	429	85.6	501
10–49	40	37.0	68	63.0	108
50–99	97	18.3	432	81.7	529
100+	23	36.5	40	63.5	63
N	232	19.3	969	80.7	1,201

Respondents with UICs were asked to indicate what types of interactions (among 17 predefined types, with the additional option of entering other types if the predefined categories did not fit) they were involved in with universities. The UIC types considered in the study were selected from Ankrah and Al-Tabbaa's (2015) systematic literature review on UIC. The selection was based on the most prevalent interaction types. In this regard, the typology resembles that of Muscio (2013) and Fernández-Esquinas et al. (2016). These UIC types were, then, grouped into five exclusive categories according to the purpose of interaction from the perspective of the firm: *knowledge exploration*; *knowledge exploitation*; *competence enhancement*; *advice-seeking; and marketing interactions*. This classification covers three common purposes of university-industry collaborations from the perspective of firms: (i) the generation of new knowledge through research activities (knowledge exploration); (ii) the transfer of knowledge from universities to businesses via mobility of students and university staff and the provision of training (competence enhancement); and (iii) the absorption and use of knowledge in innovation processes through valorization by patents and spin-offs (knowledge exploitation) (Thune, 2009). In addition, we include two categories of interaction which are often overlooked, but which are nonetheless important and common channels of interaction: the more informal advice-seeking interactions, as well as marketing interactions where firms want to increase their visibility and prestige in the eyes of the public.

3.3 | Operationalizing proximities

The survey included various questions related to firms' interactions with the university with which they had the most extensive collaboration. They were asked about the dominant type of UIC with that university. Furthermore, they were asked how important various factors were in their decision to interact with that university. These factors reflect five dimensions of proximity (cognitive, organizational, institutional, social and geographical), following the typology of Boschma (2005). We operationalized proximity dimensions building on Fitjar et al. (2016), who provide more direct measures of proximity than earlier studies by asking the actors about the importance of various proximity dimensions in their choice of collaboration partners. Previous studies of proximity in UICs have mainly relied on rather indirect indicators of proximity dimensions—such as the matching of academic fields and industrial sectors for cognitive proximity (Garcia, Araujo, Mascarini, Gomes Dos Santos, & Costa, 2018). This makes it impossible to capture the dynamics of proximity dimensions, which are subject to change over time. Furthermore, they are often unable to detect variation across universities and across firms. In addition, existing studies have measured various dimensions of proximity by looking at established collaborations and trying to figure out possible proximities between the actual collaborators. However, they do not account for how proximities were perceived by the actors and how proximity to the university influenced the decision to interact in the first place. Therefore, we prefer the direct questioning of proximity dimensions based on the subjective assessment of firms. This is the first study of UICs that examine proximities using such a direct approach, rather than relying on indirect indicators of proximity. Respondents were requested to rate the importance of each factor on a four-point Likert scale with 4 as 'very important', 3 as 'fairly important', 2 as 'not very important' and 1 as 'not at all important'.

For the operationalization of cognitive proximity, we rely on the original definition provided by Boschma (2005, p. 63): "with the notion of cognitive proximity, it is meant that people sharing the same knowledge base and expertise may learn from each other." Therefore, we asked firms about the importance of "sharing a common knowledge base and expertise with this university" in their decision to interact. Boschma (2005, p. 65) defines organizational proximity as "the extent to which relations are shared in an organizational arrangement, either within or between operations." Accordingly, we operationalize organizational proximity in terms of common membership of organizational structures, such as research centres or science parks. Institutional proximity encompasses "formal rules and cultural values at a macro level (Boschma, 2005, p. 68). Adapting this to the context of UIC, we operationalize it in terms of the adoption of a business-like mindset and attitude by universities. This reflects the perception by firms of whether or not the values and norms of the university are similar to those of the firm's institutional sphere. Social proximity is operationalized as "having previous/ongoing interaction with that university," following the definition that "social proximity refers to the extent to which agents share prior mutual relationships" (Balland, De

TABLE 3 Operationalization of proximity dimensions

Dimension of proximity	How important have the following reasons been in your decision to interact with this university?
Cognitive proximity	Sharing a common knowledge base and expertise with this university.
Organizational proximity	Being members of the same organizational network/structure (research centre, research consortium, association, cluster, science park etc.).
Institutional proximity	Feeling that the university/faculty/unit has a business-friendly, entrepreneurial mindset.
Social proximity	Having previous/ongoing interaction with that university.
Geographical proximity	Being geographically close to our company.

Vaan, & Boschma, 2013, p. 756). For geographical proximity, we include an operationalization that captures firms' subjective perception of closeness, asking for the importance of the university "being geographically close to our company." Table 3 reports the operationalization of proximity dimensions used in the analysis.

The operationalization of proximity variables based on the perception of the actors comes with some drawbacks. The statements may have resonated differently in the minds of the respondents. Furthermore, we are not able to distinguish between whether proximity is absent, or whether it is present but the respondents consider it unimportant for the decision to interact. For instance, firms may not have organizational proximity since they are not part of any joint organizational structures with universities. Or, they might be part of such structures, but deem organizational proximity unimportant. Overall, we consider this to be a benefit, as studies relying on objective measures draw conclusions about the role of proximity without knowing whether the partners consider these aspects to be important or not.

In order to address this limitation, we assess the extent to which partners that are proximate using objective criteria also consider proximity to be important for the formation of the relationship. Table A3 in the Appendix compares—for each dimension on which objective data are available—the share of proximate and distant firms that consider proximity to be important. For cognitive proximity, we distinguish between firms with above (cognitively proximate) and below (cognitively distant) average shares of staff with tertiary education. Social proximity was measured as the length of interactions. Firms who have collaborated with universities longer than three years have been categorized to have high social proximity, whereas more recent collaborators have low social proximity. Finally, we distinguish between regional and extra-regional interactions in order to account for geographical proximity. For institutional and organizational proximity, no data was available to measure the proximity between partners using objective criteria. The results show that 83% of geographically proximate partners consider geographical proximity to be important for the decision to interact, compared to 27% of geographically distant partners. Similarly, 80% of socially proximate partners consider social proximity to be important, compared to 35% of socially distant partners. These differences are statistically significant. For cognitive proximity, 81% of proximate partners consider proximity to be important, compared to 72% of distant partners. This difference is not statistically significant.

4 | RESULTS

Table 4 describes the total number of interactions and the share of firms using each UIC type. Competence enhancement interactions are the most frequently used. More than 90% of firms that interact with universities use at least one type of competence enhancement interaction. Student projects are the most common interaction type in this category. Two of three firms (64.66%) have engaged with universities through student projects. As an individual channel, informal consultations are the most widely used channel between Norwegian firms and universities. Almost three out of four enterprises that interact with universities (72.84%) use informal consultations. Despite the focus on patents and spin-offs in UIC research and policy, these two channels are the least realized interactions, with 7.33% and 10.78% of firms involved, respectively.

If we look exclusively at the interaction considered most important by the firm, competence enhancement interactions remain the most frequent type. They are followed by knowledge exploration interactions (Table 4). However, when we look at individual channels within each type, joint research projects lead the list. They represent approximately 20% of the interactions considered most important. Knowledge exploitation interactions are rarely the most important type of UIC. Only nine firms have indicated that commercial exploitation of knowledge represents the core of their interaction with universities. Most of the interactions in this category occur via the use of university infrastructures.

Table 5 presents an overview of the universities with which firms interact. The Norwegian University of Science and Technology (NTNU) is, by far, the most frequent university partner for Norwegian firms. Almost 30% of firms

TABLE 4 Total number of interactions and percentage of firms using each UIC type

Type of interaction	All interactions (multiple answers allowed)		Most important interaction (one answer only)	
	Number of firms	Share of firms (%)	Number of firms	Share of firms (%)
Knowledge exploration interactions	216	52.59	58	
Consultancy/Contract research	62	22.84	15	6.79
Joint research projects	154	46.55	43	19.46
Knowledge exploitation interactions	164	37.50	9	
Purchase of university patent, license or other IPR	18	7.33	1	0.45
Use of universities' facilities, laboratories, equipment etc.	82	28.88	6	2.71
Creation/funding of Research Centres/Incubators/ Research, Science and Technology Parks	33	13.36	1	0.45
Creation of new ventures/firms (Spin-offs, start-ups)	31	10.78	1	0.45
Competence enhancement interactions	741	90.52	105	
Joint PhD supervision/Industrial PhDs	62	25.00	4	1.81
Temporary staff exchanges for research purposes	30	12.50	1	0.45
Training of firm staff/employees	87	31.03	9	4.07
Student internships/apprenticeships	121	46.98	18	8.14
Student projects	174	64.66	39	17.65
Guest lecturing at universities	131	44.83	15	6.79
Recruitment of graduates based on a contract/referral	87	33.19	13	5.88
Co-development and co-delivery of curriculum	49	19.83	6	2.71
Advice-seeking interactions	215	71.55	17	
Informal consultations	215	72.84	17	7.69
Marketing interactions	176	59.05	32	
Sponsorship, scholarships, fellowships provided to university	55	20.69	2	0.90
Joint organization of events	92	33.19	4	1.81
Other interactions	29	34.91	26	11.76

have identified NTNU as their most significant university partner. The dominance of NTNU is not surprising when its position in the Norwegian university landscape is considered. The university has a long history of interaction with industry (Gulbrandsen & Langfeldt, 2004) given its leadership in technology-related fields (Gulbrandsen & Nerdrum, 2007). The majority of interactions with NTNU occur in the form of joint or contract research projects, while slightly fewer are related to competence enhancement. Norwegian firms collaborate heavily with NTNU for knowledge exploration, which illustrates that NTNU acts as a magnet that attracts the attention of Norwegian firms for research collaboration. More than 40% of knowledge exploration interactions of Norwegian firms happen with NTNU. The Norwegian University of Life Sciences (NMBU) in Akershus and the University of Agder follow NTNU in terms of the number of interactions. The other regional universities in Bergen, Stavanger, Tromsø, Bodø (Nord) and Oslo follow closely, along with BI and HVL, all with 10–15 interactions. Foreign universities are rarely the most crucial partners for Norwegian firms. Only six firms have identified their most significant university partner as located in another country.

TABLE 5 The most interacted universities by UIC category

	Total	Knowledge exploration interactions	Knowledge exploitation interactions	Competence enhancement interactions	Advice-seeking interactions	Marketing interactions
Norw Univ of Science and Technology	64	41.4	44.4	21.9	29.4	25.0
Norwegian University of Life Sciences	18	8.6	22.2	6.7	17.6	3.1
University of Agder	18	1.7	22.2	8.6	11.8	12.5
University of Bergen	15	8.6	0.0	5.7	5.9	9.4
University of Stavanger	15	3.4	0.0	7.6	11.8	9.4
University of Tromsø	14	6.9	11.1	4.8	0.0	12.5
Nord University	13	6.9	0.0	5.7	0.0	9.4
BI Norwegian Business School	10	5.2	0.0	6.7	0.0	0.0
Western Norway Univ Applied Sciences	10	0.0	0.0	9.5	0.0	0.0
University of Oslo	10	5.2	0.0	2.9	11.8	6.3
Foreign universities	6	5.2	0.0	1.9	5.9	0.0
Other universities	28	6.9	0.0	18.1	5.9	12.5
Total	221	58	9	105	17	32

4.1 | Geographical distribution of UICs

In order to measure the spatial distribution of UICs in terms of the location of university partners, the firms were asked to list all the possible types of UICs they have utilized across four geographical scales, namely *regional*, *national*, *European* and *outside Europe*. As very few firms reported collaboration with universities outside Europe, we combined these answers with the *European* category and labelled them as *international* at the analysis stage. Figure 1 reports the university partners' location for all UICs. Most of the interactions, regardless of the UIC type, occur with universities in the region where the firm is located. Alongside the dominance of regional collaborations for all kinds of interaction types, the distribution across different geographical scales remains more or less the same for many of the interaction categories. The exception is knowledge exploration interactions, which have a different profile. The share of international collaborations for knowledge exploration purposes is much higher than for any other UIC category. Exploratory interactions with foreign universities account for more than 25% of the total interactions in this category, while the share is less than 10% for all other UIC types.

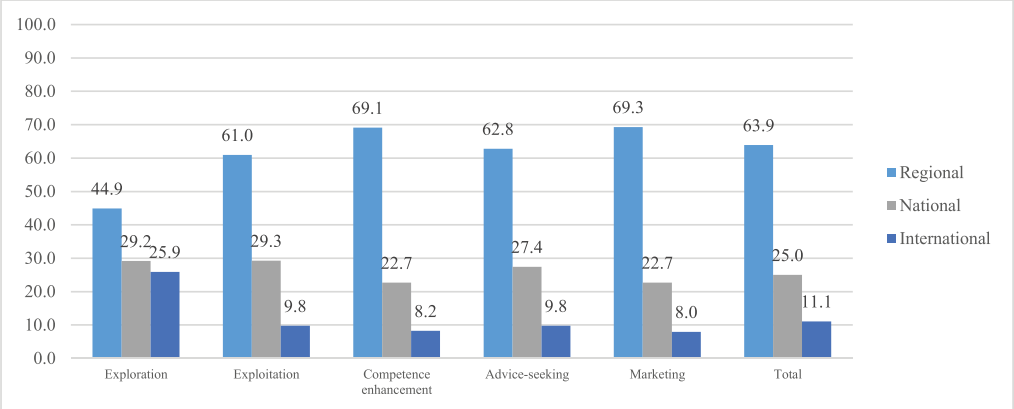

FIGURE 1 Distribution of all UICs across geographical scales

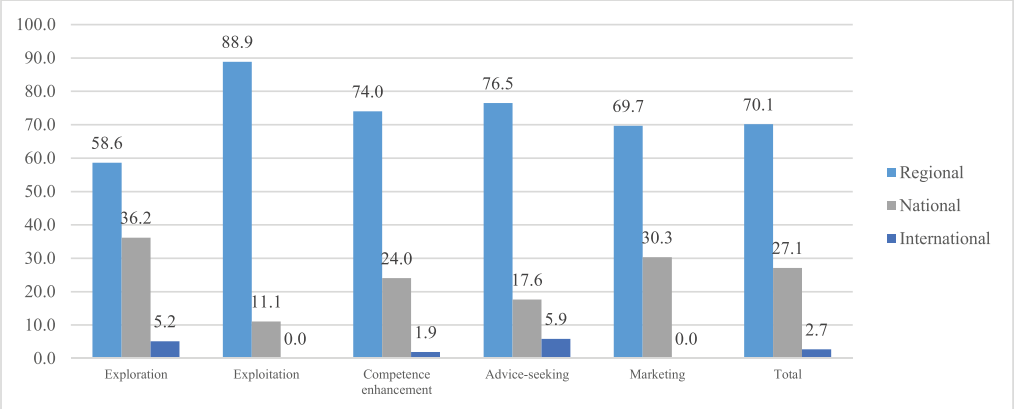

FIGURE 2 Distribution of most important UICs across geographical scales

In Figure 2, firms were asked which university they consider to be their most important partner, and what was the most important type of interaction with this university. The interactions with regional universities have the largest share once again. For all UIC categories, the regional level represents the modal scale. Seven out of ten interactions arise between universities and firms in the same region. Interactions at the international scale are less visible in this classification. None of the businesses that were dominantly involved in knowledge exploitation and marketing interactions indicated that their most significant university partner is foreign.

4.2 | Importance of proximity dimensions

As the previous section illustrates, most of the interactions between universities and firms occur in close geographical proximity. But how important do firms consider different dimensions of proximity to be when initiating interactions with universities? This question is addressed in Table 6, which shows the mean responses for each

TABLE 6 Mean values of proximity dimensions and share of firms by UIC categories

UIC Category		Cognitive proximity	Organizational proximity	Institutional proximity	Social proximity	Geographical proximity
All interactions	Mean	3.09	1.89	2.97	2.81	2.84
	Important (%)	77.3	27.6	73.8	67.0	66.8
Knowledge exploration interactions	Mean	3.32	2.00	3.20	2.93	2.72
	Important (%)	80.6	30.5	83.1	70.5	62.3
Knowledge exploitation interactions	Mean	2.89	2.11	2.75	3.33	3.33
	Important (%)	77.8	33.3	50.0	77.8	77.8
Competence enhancement interactions	Mean	3.00	1.95	2.91	2.77	2.90
	Important (%)	76.0	31.8	73.4	68.1	70.4
Advice-seeking interactions	Mean	3.07	1.21	2.40	2.33	3.07
	Important (%)	71.4	0.0	53.3	46.7	73.3
Marketing interactions	Mean	2.85	1.80	2.96	2.81	2.63
	Important (%)	73.1	24.0	73.1	65.4	59.3

Note: Important (%) denotes share of firms considering proximity to be very or fairly important in the decision to collaborate with this university.

proximity dimension by the UIC categories. Table 6 also includes the share of firms which indicated that these dimensions were either very or fairly important in their decision to interact with their most significant university partner.

In overall terms, proximity is considered to be important for UICs from the perspective of firms. For four of the five dimensions, more than two-thirds of the firms find proximity to be important for their decision to interact. The exception is organizational proximity. Only 27.6% of the firms report that organizational proximity was important in their choice of the most important university partner. This reflects that a low percentage of firms were collaborating with universities through formal organizational structures. Conversely, the highest share of firms (77.3%) report that cognitive proximity was important for their decision to interact with their most important university partner. Almost three out of four firms (73.8%) report that institutional proximity was influential in their decision. Social proximity and geographical proximity also play a decisive role in the UICs for two-thirds of the firms (67.0% and 66.8% respectively).

Despite the overall tendency to rate proximities important, some nuances can be found across the different UIC categories. The weight attached to proximity dimensions by firms varies by UIC types. Cognitive proximity is most important for knowledge exploration interactions (mean of 3.32) and least important for marketing interactions (2.85), in line with the predictions in Table 1. Organizational proximity is most important for knowledge exploitation (2.11) and least important for advice-seeking interactions (1.21), also in line with Table 1. However, even for knowledge exploitation, the share of firms reporting that organizational proximity is important is only 33.3%. Institutional proximity is considered most important by firms involved in knowledge exploration interactions (3.20), and least important for advice-seeking (2.40). Social proximity is most important for knowledge exploitation (3.33) and least important for advice-seeking (2.33). Geographical proximity is also most important for knowledge exploitation (3.33), and least important for marketing interactions (2.63).

TABLE 7 Multinomial logit model results for proximity

	Knowledge exploration	Knowledge exploitation	Advice-seeking	Marketing
Cognitive proximity	0.458** (0.221)	−0.393 (0.394)	0.185 (0.322)	−0.104 (0.243)
Organizational proximity	−0.104 (0.176)	0.387 (0.398)	−0.915** (0.441)	−0.134 (0.239)
Institutional proximity	0.359* (0.191)	−0.220 (0.368)	−0.351 (0.259)	0.224 (0.237)
Social proximity	0.188 (0.180)	0.780* (0.461)	−0.422 (0.282)	0.308 (0.231)
Geographical proximity	−0.269* (0.159)	0.297 (0.399)	0.367 (0.277)	−0.314 (0.205)
Log of no. of employees	0.049 (0.135)	−1.033** (0.433)	−0.068 (0.242)	−0.217 (0.179)
Log % of tertiary education	−0.190 (0.172)	−0.142 (0.330)	−0.150 (0.244)	−0.492*** (0.182)
Constant	−2.072* (1.165)	−1.649 (2.168)	0.811 (1.728)	1.079 (1.249)
Pseudo R2	0.0899			
Log likelihood	−262.55456			
Observations (N)	220			

Notes:
*p < 0.10, **p < 0.05, ***p < 0.01; Standard errors in parentheses.

We further test more formally whether the perceived significance of proximity dimensions for the decision to interact varies across UIC types using a multinomial logit regression model. The model takes the following form:

$$\Pr(UIC_i = k) = \alpha_k + \beta_{1,k}\boldsymbol{Proximity}_i + \beta_{2,k}\boldsymbol{Controls}_i + \varepsilon_i. \quad (1)$$

In the model, *k* refers to the different types of UIC: *knowledge exploration*; *knowledge exploitation*; *competence enhancement*; *advice-seeking*; and *marketing*. The reference category for the model is *competence enhancement* interactions.

The independent variables of interest are the five dimensions of proximity, that is, cognitive, organizational, institutional, social and geographical proximity. We used mean substitution for missing values and don't knows in order to avoid bias from listwise deletion. As a robustness check, we have also estimated the models using multiple imputation, and with listwise deletion (see Appendix, Tables A1 and A2). Both approaches give results consistent with those reported here.

We also include a vector of control variables. These include the log number of full-time employees and the log share of employees holding a university degree.[2]

Table 7 shows the results for the estimation. While the explained variance of the model is relatively low, there are some notable differences in the importance of proximities across UIC types. Firms that engage in knowledge exploration interactions attribute more importance to cognitive proximity than firms interacting for competence enhancement or for knowledge exploitation purposes. This is the only category with a significant positive coefficient for cognitive proximity, although the coefficient is also positive, but not significant for advice-seeking interactions. Firms asking for informal advice from universities rely less on organizational proximity compared to firms with competence enhancement or knowledge exploitation interactions. Institutional proximity is more important for

[2]We have tried introducing additional control variables, such as industry and regional fixed effects, and R&D expenditure. However, the limited degrees of freedom reduce the number of additional variables that can be introduced without rendering the model subject to multicollinearity. We therefore prefer to keep the model simple with a few key control variables. For R&D expenditure, several units have missing values and the correlation with the two other control variables is fairly high. However, we ran the multiple imputation model with R&D expenditures as an additional control and the results were consistent with the main findings.

TABLE 8 Confirmation of relative importance of proximity dimensions for UIC categories

UIC Type	Geographical proximity	Cognitive proximity	Organizational proximity	Institutional proximity	Social proximity
Knowledge exploration interactions	Less important CONFIRMED	More important CONFIRMED		POSITIVE	Less important
Knowledge exploitation interactions			More important	More important	More important CONFIRMED
Competence enhancement interactions	BASELINE	BASELINE	BASELINE	BASELINE	BASELINE
Advice-seeking interactions	More important		Less important CONFIRMED		
Marketing interactions		Less important		Less important	

knowledge exploration interactions than for any other types of UIC (except for marketing interactions, where the difference is not significant). Social proximity is more important for knowledge exploitation than for competence enhancement or advice-seeking UICs. The only statistically significant coefficient for geographical proximity is for knowledge exploration interactions. Firms engaging in joint knowledge exploration collaborations attribute less importance to geographical proximity than firms in any other category (except for marketing interactions). For the control variables, firm size has a significant and negative coefficient for knowledge exploitation interactions, implying that firms engaged in this category of UICs tend to be smaller than firms with competence enhancement interactions. The other control variable—the share of employees with a higher education degree—has a negative and significant coefficient for marketing interactions, meaning that in comparison to firms with competence enhancement interactions, these firms tend to have a lower share of university graduates in their workforce.

These results indicate that proximity dimensions matter differently for various types of UICs. In Table 8, we compare these results to predictions derived from Table 1, where we indicated the expected importance of proximity dimensions for each UIC category. The results confirm the lower importance of geographical proximity and the higher importance of cognitive proximity for knowledge exploration interactions. Institutional proximity is also more important for knowledge exploration interactions. The results also confirm that organizational proximity is less important for advice-seeking interactions compared to knowledge exploitation interactions. In addition, the results confirm that social proximity is more important for knowledge exploitation interactions than for competence enhancement interactions.

5 | DISCUSSION AND CONCLUSIONS

This paper has examined the geographical distribution of the interactions between firms and universities and the influence of five proximity dimensions in shaping the decisions of firms to collaborate with universities in different types of UICs. The empirical data was gathered through a survey of firms' interaction with universities with a focus on their perception of the importance of proximity for the decision to interact with their most important university partner. The study examines how the importance of different types of proximity varies across UIC categories.

The contributions of the study are threefold. The first contribution is to provide large-scale empirical evidence on the use of a multitude of UIC types. The findings indicate that around 20% of the surveyed Norwegian firms interact with universities across different UIC types. Competence enhancement, knowledge exploration and advice-seeking interactions constitute the most prevalent channels of UICs in Norway. Conversely, knowledge exploitation

UICs are not very common among Norwegian firms and universities. The paper also considers the geography of different types of UICs. Regional interactions outweigh interactions at other geographical scales for all UICs, although their share fluctuates by UIC categories. Hence, geographical proximity is important for UIC formation.

However, non-geographical dimensions of proximity also matter. The second contribution of the paper is therefore to assess the importance of proximity for UICs from the perspective of industrial actors by directly asking how important proximity to their university partners was for the decision to interact. While previous studies have used remote proxies to account for proximity dimensions (Garcia et al., 2018; Petruzzelli, 2011), this study considers that how proximity is perceived and handled by the actors themselves is important for the decision-making process (Fitjar et al., 2016). With this approach, we assess the importance of proximity dimensions for the decision to interact with the most important university partner from the firms' perspective. The results illustrate the importance of several proximity dimensions for UICs. A large share of firms considers cognitive, institutional, social and geographical proximity as important for their decisions to interact with a university. However, organizational proximity, that is being part of the same organizational arrangements with universities, is considered less important. This does not mean that the influence of proximity is pre-determined, static and fixed. On the contrary, several studies have begun to assert that the actors may become more proximate in various dimensions in the course of interactions suggesting that proximities involve dynamic and evolutionary characteristics (Balland, Boschma, & Frenken, 2015; Broekel, 2015; Menzel, 2015). Specifically, the collaboration process can help in the development of proximity dimensions. For instance, UICs may lead to higher social proximity indicated by increased trust between collaborating partners (Hewitt-Dundas et al., 2019). This dynamic relationship between proximity dimensions and interaction processes creates possible endogeneity or circularity issues that need to be considered in future studies.

The third and most important contribution of the study is to extend the understanding of proximity dimensions for UICs by comparing their importance for different types of UICs. Although earlier studies have pointed out that proximity facilitates interactions between firms and universities (D'Este et al., 2013; Ponds et al., 2010), they have treated UICs as a homogenous group of activities, largely ignoring their different targets and characteristics (Gertner et al., 2011; Ramos-Vielba et al., 2010). This study, however, shows that the importance of proximity dimensions varies across different UIC channels. Although proximity facilitates UICs in overall terms, the impact of proximity dimensions differs by the type of interaction. Knowledge exploration collaborations tend to occur with universities at further spatial distances. Conversely, cognitive and institutional proximity are more important in these types of interactions. Social proximity—that is having previous interactions with a particular university—is particularly important when forming knowledge exploitation interactions. This finding reflects the ease of co-ordination between partners who know and trust each other, which is particularly important for the commercial exploitation of knowledge. Finally, firms consider organizational proximity less important when they seek informal advice from universities.

Several policy and managerial implications can be derived from this study. First, we show that UICs comprise a large range of activities. The majority of interactions occurs in the form of competence enhancement interactions, whereas knowledge exploitation is less prevalent. Therefore, policy-makers aiming to increase the levels of interaction between firms and universities should develop overarching and inclusive policies that take into account the variety of UIC channels. Second, the results illustrate the dominance of regional UICs. In this regard, universities, especially university managers and individual academics, should be aware of the breadth of ways in which they can contribute to the growth and development of firms in their regions and attempt to deepen their expertise aligned with the priorities of the industries around them. Third, we show that several distances exist between firms and universities. Policies for the mitigation of these distances should be developed that can support effective knowledge transfer in UICs. For example, firms need absorptive capacity to understand and utilize knowledge stemming from universities, which would increase cognitive proximity. This can be achieved by more effective mobility schemes that would allow short term staff exchanges between organizations. Institutional proximity may be increased by taking policy measures that would allow some flexibility in the regulations and norms that govern the institutional spheres of universities and firms. Social proximity can be enhanced by programmes and schemes for small-scale projects that would create the initial contact and provide the impetus for the initiation of interactions between firms and universities.

Finally, the findings indicate that various dimensions of proximity affect UICs differently depending on the purpose of the interactions. Thus, universities need to prioritize the development of proximities that are important for the type of UICs that they want to develop. Similarly, firms that would like to engage in UICs need to develop specific capabilities with regards to proximity dimensions. For instance, firms that are eager to collaborate with universities for knowledge exploration purposes can invest in increasing their cognitive capacities. The need for higher social proximity, proxied by previous collaborations, for knowledge exploitation UICs means that firms need to be patient to invest in their relationships and have longer time horizons when forming this type of relationships. The firms that seek informal advice from universities do not need to invest in developing their organizational proximity to universities by creating joint organizational structures, but can deploy their resources elsewhere such as creating linkages at the personal level.

The findings carry some limitations that need to be acknowledged. First, we only have data on objective proximity for some dimensions. Thus, we do not know whether negative answers mean that the collaboration involves distant partners or whether this reflects a proximate relationship for which proximity is not perceived as important. Future studies could combine objective measures for proximity with perceptional measures to address this. The second limitation of the study is the potential for non-response. Since the analysis uses data of firms who collaborated with universities, we furthermore do not have data on non-collaborators. Therefore, a study that includes the perception of firms that do not have any collaborations with universities can provide valuable insights about the importance of proximity in eliminating distance barriers in UICs. Third, since various dimensions of proximity are interdependent and interrelated, geographical and non-geographical dimensions of proximity may either overlap or substitute each other (Hansen, 2015; Huber, 2012). Hence, future studies may want to look at the interrelationship between different types of proximity. Finally, we investigated the role of proximity for the formation of UICs rather than for the functioning of UICs. However, proximity not only facilitates the establishment of linkages between actors in the first place, but also contributes to effective interactions. Further research on the significance of proximity dimensions in overcoming operational problems in UICs would enlighten the discussions on this topic.

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APPENDIX: ROBUSTNESS CHECK RESULTS A

TABLE A1 Multinomial logit results without mean replacement

	Knowledge exploration	Knowledge exploitation	Advice-seeking	Marketing
Cognitive proximity	0.536** (0.232)	−0.342 (0.413)	0.508 (0.375)	−0.016 (0.271)
Organizational proximity	−0.130 (0.186)	0.572 (0.423)	−0.991** (0.550)	−0.011 (0.250)
Institutional proximity	0.282* (0.202)	−0.232 (0.386)	−0.644** (0.302)	0.057 (0.253)
Social proximity	0.050 (0.192)	1.378** (0.689)	−0.546 (0.338)	0.183 (0.256)
Geographical proximity	−0.286* (0.170)	0.043 (0.397)	0.307 (0.310)	−0.353 (0.223)
Log of no. of employees	0.073 (0.151)	−1.033** (0.498)	0.071 (0.290)	−0.157 (0.200)
Log % of tertiary education	−0.026 (0.184)	−0.272 (0.378)	−0.005 (0.282)	−0.239 (0.204)
Constant	−2.175* (1.219)	−2.920 (2.470)	0.116 (1.994)	0.390 (1.319)
Pseudo R2	0.1014			
Log likelihood	−211.2423			
Observations (N)	179			

Notes:
*p < 0.10, **p < 0.05, ***p < 0.01; Standard errors in parentheses.

TABLE A2 Multinomial logit results with multiple imputation method (proximities are imputed)

	Knowledge exploration	Knowledge exploitation	Advice-seeking	Marketing
Cognitive proximity	0.431** (0.218)	−0.406 (0.388)	0.139 (0.361)	−0.106 (0.248)
Organizational proximity	−0.100 (0.174)	0.363 (0.389)	−0.696 (0.430)	−0.176 (0.244)
Institutional proximity	0.369* (0.192)	−0.155 (0.386)	−0.308 (0.274)	0.178 (0.230)
Social proximity	0.159 (0.179)	0.703 (0.439)	−0.423 (0.302)	0.188 (0.240)
Geographical proximity	−0.272* (0.157)	0.261 (0.386)	0.369 (0.311)	−0.283 (0.203)
Log of no. of employees	0.044 (0.139)	−1.023** (0.429)	−0.093 (0.247)	−0.202 (0.182)
Log % of tertiary education	−0.185 (0.174)	−0.147 (0.331)	−0.126 (0.249)	−0.466** (0.183)
Constant	−1.955* (1.166)	−1.403 (2.116)	0.430 (1.810)	1.397 (1.243)
Imputations	20			
Observations (N)	220			

Notes:
*p < 0.10, **p < 0.05, ***p < 0.01; Standard errors in parentheses.

TABLE A3 Share of firms that find different dimensions of proximity important based on objective measurement of proximities

	Firms with high human capital	Firms with low human capital	All firms
Cognitive proximity	81.4%	72.4%	77.3%
	Previous collaborators	New collaborators	All firms
Social proximity***	80.0%	34.8%	73.8%
	Regional collaborators	Extra-regional collaborators	All firms
Geographical proximity***	83.1%	26.7%	66.8%

Note:
***Significant at 1%.

PAPER 3

Alpaydın, U. A. R. & Fitjar, R.D. (2020). What Are University-Industry Collaborations Good For? Tangible and Intangible Outcomes of Collaboration Types, In Review in *Science & Public Policy*

What Are University-Industry Collaborations Good For? Tangible and Intangible Outcomes of Collaboration Types

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Abstract

This paper explores which benefits firms perceive from university-industry collaborations (UICs), building on survey data from 1200 Norwegian firms. We find that firms report not only to obtain tangible outputs such as innovation and commercialization, but also intangible benefits in the form of closer relationships to universities that can improve future collaboration. We compare the reported outputs from various types of collaboration, finding that firms engaging mainly in research and education-oriented interactions report more tangible outcomes than those engaging in more informal collaborations. Such outcomes include innovation, commercialization and human resource development. However, informal collaborations are equally important for building closer relationships. They enable the development of cognitive, organizational, institutional and social proximities between firms and universities.

Keywords: University-industry collaboration, innovation, tangible and intangible outcomes, proximity.

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1. Introduction

A rich literature examines how collaboration with universities contribute to firms' innovativeness and competitiveness. Universities provide qualified human capital in the form of graduates (Leten et al., 2014), they complement internal R&D capabilities of industry by engaging in collaborative projects (Steinmo&Rasmussen, 2016), and they provide solution-oriented consultancy services (Freitas et al., 2014). In turn, firms develop capabilities through such collaborations to innovate new products and processes, and to reach other types of outputs such as patents or spin-offs.

Alongside the direct contributions to innovation, university-industry collaborations (UICs) also contributes to the development of several other capabilities in firms and universities (Perkmann et al., 2011). Through collaboration, firms and universities build closer relationships that help them to collaborate more effectively in the future. They enhance their abilities to manage such interactions and their cognitive capabilities to learn from each other (Hewitt-Dundas et al., 2019). They learn how to better align their expectations to the competences of their partners, how to coordinate activities and how to behave in accordance with the expectations and systems of their partners. The accumulation of such experiences increases the likelihood of partners to collaborate again on new projects. Despite the increasing evidence of learning effects from prior collaborations, the micro-processes leading to this have seldom been studied.

Instead, the impact of collaboration between universities and firms have mainly been scrutinized through economic lenses (Hou et al., 2019). Policy-makers and practitioners have called for tangible returns to investments in UICs, or more broadly in academic and scientific research, in the face of increasing public pressure to provide value for money spent (Perkmann&Walsh, 2007). While patents or spin-offs provide readily available indicators (Hou et al., 2019), other benefits of UICs are more difficult to observe. This is certainly the case for relational

outcomes, such as learning to collaborate better (Heringa et al., 2014). Yet, UICs are often a long game which can take years to deliver results, but with potentially very large results at the end of the process. Consequently, we believe that these intangible outputs of UICs have not received enough policy and scholarly attention (Vick&Robertson, 2018). Therefore, this paper asks the following research question: What benefits do firms experience from UICs?

Furthermore, the scientific literature on UICs has concentrated on a narrow range of UIC mechanisms, mainly reflecting research and innovation collaboration. The overemphasis on certain types of UICs provides somewhat a distorted representation of the UIC phenomenon in two broad senses: First, UICs do not occur through a limited set of interaction mechanisms, but cover a diverse array of activities ranging from research to education, from professional training to inter-sectoral mobility of researchers and so on (Perkmann et al., 2013). Second, there is limited understanding of the influence of less formal interaction channels on the outputs emerging from UICs. We know relatively little about which benefits firms get from informal UICs and from non-research-oriented ones. Hence, the second research question of the study is: Do the perceived benefits vary across different types of UICs?

In order to address these questions, this study investigates a wide range of potential outcomes of UICs, including tangible as well as intangible outcomes, as perceived by the firm. Furthermore, it investigates a variety of collaboration types, including research-oriented, education-oriented and informal interactions. We explore the relationship between UIC types and perceived outputs. The analysis makes use of a tailor-made survey on university-industry interactions conducted among 1,201 firms in Norway. The findings indicate that UICs generate different types of outputs, depending on the nature and objectives of the interaction. A large share of firms report tangible outputs in the form of innovation, commercialization and the development of human resources. Benefits for innovation are mainly the

result of research-oriented interactions, while education-oriented interactions are more beneficial for human resource development. Informal interactions provide fewer tangible benefits but are equally important in building closer relationships between firms and universities. These intangible outputs support the development of several types of proximities between the partners, which might be crucial for the persistence of UICs over time.

2. University-Industry Collaborations

2.1. Collaboration types and outputs

Schartinger et al. (2002) define university-industry interactions as "all types of direct and indirect, personal and non-personal interactions between organizations and/or individuals from the firm side and the university side, directed at the exchange of knowledge within innovation processes" (p.304). This definition reflects the economic rationale underpinning UICs, with the expected utility from UICs specified as innovation. The widespread adoption of this or similar definitions, which champion the innovation-oriented understanding of UICs, has resulted in an extensive focus on certain outputs of UICs, such as patenting, spin-offs and licensing (Marek et al., 2016; Hoekman et al., 2009; Carvalho de Mello et al., 2016). The easy availability of data for these outputs also contributes to the prevalence of studies examining these UIC outputs. The existence of large data sets providing detailed information on commercialization outputs enables researchers to conduct comprehensive analyses on specific UIC relationships.

Indeed, many studies equate outputs with UIC channels and analyze UICs by looking at the outputs (Fritsch et al. 2019). This provides a somewhat misleading comprehension of UICs that leaves out the ongoing interaction processes and the learning effects they bring about. The extensively studied tangible outputs of UICs represent only one side of the coin, as UICs also provide a range of learning benefits that are intangible in nature. On this matter, Ankrah et al. (2013) state that the majority of UIC benefits are less tangible. Summarizing

recommendations from previous literature, Ramos-Vielba et al. (2010) call for the study of a broader set of UIC outputs that would extend beyond the narrow focus on commercialization and Intellectual Property Rights (IPRs). Vick and Robertson (2018) conclude their systematic literature review on UICs by suggesting to describe intangible benefits of UICs more clearly.

Some studies do consider various types of UICs and UIC outputs (Perkmann et al., 2013; D'Este&Patel, 2007). The common finding of these studies is that the overwhelmingly studied UIC types represent just the tip-of-the-iceberg (Norn, 2016) and hence vastly underestimate the extent of collaboration between universities and firms. Therefore, there is a need to expand the scope of studies examining UICs to include the 'hidden majority', such as education-related mechanisms – guest lecturing, student projects, traineeships, internships – and informal consultations (Ramos-Vielba&Fernández-Esquinas, 2012; Capone&Lazzeretti, 2018). Indeed, there is evidence that businesses attach more value to these understudied UIC mechanisms through which university knowledge flows to industry than to the more pervasive ones (Foray&Lissoni, 2010; Thursby&Thursby, 2011). For instance, firms often regard open channels, such as conferences, publications, informal exchange and consulting, as more salient sources to access university research. They could be complemented by more formal collaboration types – that are licensing of patents and the establishment of cooperative ventures – rather than replacing them altogether (Cohen et al. 2002).

Following the latter strand of studies, we expand the focus from research-oriented interactions to also include education-oriented and informal interactions. Research-oriented interactions include the types of UICs that are widely analyzed in the literature, such as research projects or joint research centres, contract research and commercialization. Education-oriented interactions cover education and training activities for firms and universities, especially concerning students. Informal interactions involve ad-hoc exchanges aimed at the generation or

exchange of knowledge, such as informal consultations, sponsorships and the organization of joint seminars. The typology of UICs presented above covers the three common purposes of UICs suggested by Thune (2009), which are (1) the generation of new knowledge, (2) the transfer of knowledge and (3) the absorption and use of knowledge in innovation processes. In this study, research-oriented interactions relate to the exploration of new knowledge and its commercial exploitation, while education-oriented and informal interactions are mainly concerned with the reciprocal transfer of knowledge between collaborating firms and universities. These types of interactions have different rationales and purposes, which shape their governance modes, in terms of e.g. the formalization of the relationship (Bodas Freitas et al., 2012; 2014).

Research-oriented interactions have been heavily emphasized in scientific and policy circles alike. Since they target specific tangible outputs at the end of collaboration (Perkmann and Walsh, 2007), they are considered to have direct effects on firm competitiveness, job creation and regional or national economic growth. However, the impact of education-oriented and informal collaborations on the economy is less visible and more indirect (Fabiano et al., 2020). These types of interactions also involve a time lag, especially in the case of education-oriented interactions such as graduate recruitment, which may provide fruitful and tangible results for firms only in the long term. Therefore, different characteristics of UIC types may vary in their propensity to generate tangible outputs. Research-oriented interactions are expected to deliver more innovation and commercial types of outputs, while education-oriented interaction target other outputs, such as human resource development.

However, previous studies of UICs do not provide a comprehensive analysis of the relationship between different types of UICs and different types of outputs (Perkmann&Walsh, 2007). This paper addresses this gap by examining the outputs resulting from different types of collaboration.

2.2. Development of proximities

The outputs of UICs are not limited to tangible ones, but the interaction process generates some intangible outcomes as well. The relational aspect of UICs involving social interaction of different partners suggests that UICs lead to several learning effects that are hard to observe and assess. Specifically, interaction processes develop collaborative ability of firms and universities by helping them build relational capabilities (Steinmo&Rasmussen, 2018). By engaging in UICs, firms and universities become familiar with each other's working principles and they gain experience on how to foster a successful interaction process. Interactions may expand to different UIC categories and result in the deepening of the involvement of actors by developing cognitive competences of firms and ensuring a sense of trust between the collaborating partners (Hemmert et al. 2014; Johnston&Huggins, 2018). The learning effects, or intangible outcomes, play a bridging role that reduces the distances between collaborators in different aspects. They help overcome several barriers of UICs by creating proximity between the worlds of academia and industry (Bruneel et al., 2010).

The existence or development of proximity between partners is crucial for the success of collaboration, as it shapes the ability to learn from the partner. Proximity – with its multiple dimensions, including geographical, cognitive, organizational, institutional and social proximity – facilitates collaboration and enhances the effectiveness of interactions by reducing the risks and uncertainties associated with the knowledge exchange process (Boschma, 2005; Balland et al., 2015). However, too much proximity can reduce the potential for learning as it limits the scope for new ideas to emerge. For UICs, the problem is likely to be too little, rather than too much, proximity, as firms and universities are often said to live in different worlds (Bruneel et al., 2010; Hewitt-Dundas et al., 2019) with considerable distances between them.

Proximity is not a static concept. Through the interaction process, partners tend to become closer as they learn to understand each other,

develop social bonds and create organizational structures to govern the relationship (Leszczyńska&Khachlouf, 2018). By adapting a dynamic perspective on proximity, several studies on knowledge networks among firms have asserted that the actors may become more proximate in various dimensions through interactive learning processes (Balland et al., 2015; Broekel, 2015; Menzel, 2015). Interactions thus provide learning effects, which enable the partners to collaborate more effectively in the future. These learning effects rarely take place in a tangible form, but are mostly realized as intangible outcomes of collaboration process that can be linked to various proximity dimensions.

Cognitive proximity between actors may increase since each partner learns more about the capabilities of the other by sharing the knowledge they have. Through interaction, the partners' knowledge bases will become more similar as they learn from each other. In the case of UICs, firms can increase their cognitive capabilities and get to know more about the competences of the universities as a result of the interaction process. This is closely related to the notion of absorptive capacity, i.e. that firms must be able to understand and apply the knowledge from universities for collaboration to be useful (Cohen&Levinthal, 1990). Meanwhile, universities learn about firms' needs and can adapt their activities accordingly. Therefore, UICs can lead to an increased reciprocal understanding of the competences of the partners (Steinmo&Rasmussen, 2018), which indicates an increase in the cognitive proximity.

The interaction process may also lead to a reconfiguration of the coordination rules of the interaction, which can increase organizational proximity between the partners. Through the establishment of shared organizational routines and practices, or the creation of joint organizational structures, the partners can become more organizationally proximate. Over time, the partners may feel encouraged to increase their commitment, which can lead to deepening and broadening of the interactions with more and different types of interactions. The partners

can enlarge their portfolio of interaction channels by adding collaboration types they have not practiced before, or what in network analysis is often referred to as multiconnectivity (Powell et al. 2005). Less formal and looser linkages may be turned into formalized commitments as a result of successful interaction experiences, implying higher organizational proximity between the firm and the university. Informal consultations may turn into research projects with formal contracts governing the collaboration, and research projects may become long-term research centres or strategic partnerships, with joint organizational structures that help to bring partners together in an organizational sense.

Similarly, the interaction process helps the partners grasp more easily the values and norms that shape their counterparts, which leads to a higher level of institutional proximity. They learn the rules of the game that govern the interactive sphere and adapt to them reciprocally. The partners also familiarize themselves with each other's operational principles and norms. This is especially important when the divergent institutional logics that govern academia and industry are considered. In this manner, the interaction process helps in easing the problems created by the "two-worlds paradox" (Hall, 2003), for instance through an enhanced recognition of the academic principles, norms and values by the firm, and an increased understanding of the firm's market and commercial considerations by the university. The universities and firms find a middle way to converge their interests, motivations and incentives in line with what is acceptable to both sides. They learn each other's working culture by being exposed to close interaction over the course of the UIC. This results in the enhancement of institutional proximity between universities and firms.

Finally, the interactions can enhance social proximity between partners. The complexity and uncertainty inherent in UICs make trust, a key element of social proximity, crucial for the success of the collaboration (Gertner et al., 2011). Since the knowledge transfer and

interaction process generally involves sensitive information, it requires high levels of trust between the partners, which can be built up during the process of interaction (Broekel, 2015; Nilsson, 2019). The interacting partners develop a sense of trust in each other that can lead to more dense relationships through eliminating uncertainties and preventing free-riding.

Hence, the interactions between firms and universities provide several learning effects that assist in shrinking the non-geographical distances in cognitive, organizational, institutional and social terms. We expect all types of UICs to provide these types of outputs. These can be regarded as "intangible outputs" of UICs, which help to build a closer relationship that makes future collaboration more effective. Through interacting, both firms and universities learn to collaborate, which may indeed be crucial for the continuation and success of UIC processes. Yet, there might be differences in the generation of intangible outputs depending on the collaboration channel. For instance, research-oriented interactions may be expected to strengthen cognitive proximity more compared to other collaboration types. In some instances, joint research projects may lead to the establishment of new organizational structures, implying an increase in the organizational proximity. Education-oriented interactions and informal collaborations, on the other hand, may help in the development of institutional proximity and social proximity through making partners familiar with each other's working principles and ensuring a sense of trust between them without strong commitments.

3. Data and methods

The study examines the different tangible and intangible outputs that firms experience from UICs, using data from a survey on UICs among firms in Norway. The Norwegian innovation system relies on close collaboration between firms to secure knowledge transfer, but it faces challenges in developing a more science-based approach to innovation. Norwegian governments have therefore prioritized intensifying the interactions between universities and businesses through various policies

that have been initiated in the last 20 years (Gulbrandsen&Nerdrum, 2007). These policies have been geared towards increasing the contributions of Norwegian universities to regional development and national competitiveness by stimulating them to engage in third mission activities with businesses, mainly through direct collaboration and commercialization of academic R&D results, and undertaking a more prominent role in the innovation system (Thune&Gulbrandsen, 2011). A recent report published by Nordic Institute for Studies in Innovation, Research and Education (NIFU) indicates that around one quarter of the members of the Confederation of Norwegian Enterprise (NHO) has collaborated with universities over the last five years (Rørstad&Børing, 2019). Although empirical evidence shows that slightly more than 20% of Norwegian firms collaborate with universities (Fitjar&Gjelsvik, 2018), only a small share of firms (around 3%) rate universities as the most critical source of external knowledge for their innovation processes (Fitjar&Rodríguez-Pose, 2017). Norway therefore offers an interesting case to study whether UICs actually provide benefits to firms in a context where innovation is mainly experience-based and universities are not valued very highly as sources of knowledge for innovation.

The study draws on data from a tailor-made survey of 1,201 Norwegian firms located in regions with universities. The firms were sampled from the Norwegian Register of Business Enterprises, where all firms have to register. They were stratified by region, sector and firm size. We focus on firms located in university regions (Oslo/Akershus, Agder, Hordaland, Nordland, Rogaland, Troms, and Trøndelag), as these can more easily collaborate with universities. Collectively, these regions host around 70% of private firms in Norway. Furthermore, we focus on firms operating in mining, manufacturing and knowledge-intensive services[4], and on firms with more than five employees. The

[4] NACE sectoral codes included: (B) Mining and quarrying, (C) Manufacturing, (G) Wholesale and retail trade; repair of motor vehicles and motorcycles (excluding 47: Retail trade, except of motor vehicles and motorcycles), (J) Information and communication, (K) Financial and

implementation of the survey was carried out by a professional market research company (IPSOS), who executed the survey by interviewing firm representatives on the phone during December 2018. The survey had a response rate of 12 percent. Around 47 percent of the original sample could not be reached over the phone (implying response rate of 23 percent among those who were contacted), while 30 percent refused to participate. A non-response analysis by firm size, region and industry shows a somewhat lower response rate for firms with more than 100 employees (8 percent) and in mining and financial services (both 9 percent), and a higher response rate in professional, scientific and technical services (15 percent).

Drawing on similar prior surveys, e.g. one conducted in the UK (Hughes&Kitson, 2013) and a European-wide study for the European Commission (Davey et el., 2018), the survey focused on the extent, content and outcomes of the interaction of firms with universities. Initially, the survey asked whether firms had interacted with universities during the last three years. In total, 232 firms, or 19.3 percent, indicated that they had such interaction. These firms answered a more extensive set of questions, including about the type of interaction and the outputs from these interactions. The paper therefore uses this limited sample of firms that do interact with universities to examine the perceived outputs from such interactions.

3.1. Variables

The analysis uses two sets of dependent variables: First, tangible outputs of UICs, encompassing innovation-related, commercial and human resources benefits. Second, intangible outputs, understood as the contribution of UICs to the development of proximities between firms. Table 1 shows the UIC outputs that we address.

insurance activities, (M) Professional, scientific and technical activities, (N) Administrative and support service activities.
http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NACE_REV

Table 1. UIC outputs addressed in the study

	Outputs
Tangible outputs	
Innovation	New or significantly improved products/services New or significantly improved processes New organizational methods in business practices, workplace organization or external relations New marketing concept or strategy
Commercialization	Patents, licenses or other IPR at least partly belonging to the company Spin-off / Start-up company (in which your enterprise has a share)
Human resources	Recruitment of graduates/transfer of university staff to your enterprise
Other outputs	Other outputs (open-ended) Joint publications (in which your enterprise's employees/staff are co-authors)
Intangible outputs	
Cognitive Proximity	We have got a better understanding of the competences of the university.
Organizational Proximity	We have started a more organized/formal interaction with university.
Institutional Proximity	We have got a better understanding of the values/culture/institutional environment of the university.
Social Proximity	We have developed a higher level of trust in the university.

The survey asked firms to indicate the results/outputs that have emerged from their interaction with universities. The respondents were provided with a list of eight different types of outputs, from which they could select multiple options. They could also include other types of outputs as an open-ended answer if the predefined categories did not fit. We classify the outputs into four categories of tangible outputs: *Innovation*, *Commercialization*, *Human Resources* and *Others*. *Innovation* outputs refer to the development of new products, services,

processes, organizational methods and marketing, as defined in the Community Innovation Surveys. *Commercialization* outputs denote valorization results in terms of intellectual property and/or the creation of new ventures. *Human resources* outputs are directly linked with the acquisition of highly qualified personnel from universities, either as new graduates or established academic researchers. *Other outputs* include scientific outputs such as joint publications, and other outputs that are not classified elsewhere.

For the development of proximities, we focus on the relationship to the university with which the firm had the most extensive interaction. We developed indicators reflecting the four different dimensions of Boschma's (2005) proximity construct, i.e. cognitive, organizational, institutional and social proximity. We presented firms with a statement pertaining to each dimension and asked for their level of agreement on a five-point Likert scale ranging from completely disagree (1) to completely agree (5). The statements account for the extent that the interaction process contributed to firms' developing a closer relationship with universities in different dimensions. While we would ideally have wanted to measure the development of proximities using multiple indicators, the need to keep the survey to a manageable length implied that we could only include one indicator for each dimension of proximity. We are not aware of earlier studies or other sources of data on the development of the relationship between universities and firms across all four proximity dimensions for a large sample of firms. Therefore, we nonetheless consider this a step forward in the empirical study of this phenomenon. For the operationalizations themselves, we formulated questions that captured the essence of each proximity dimension in a clear language comprehensible to respondents.

For *cognitive proximity*, firms were asked whether they "have got a better understanding of the competences of the university". This captures the core idea of the cognitive proximity concept that the firm needs to understand the knowledge communicated from the university in order to

be able to use it. For *organizational proximity*, we asked whether the firm has "started a more organized or formal interaction with the university". This reflects the idea that organizational arrangements assist the exchange of knowledge. For *institutional proximity*, the statement was "we have got a better understanding of the values, culture and institutional environment of the university". An understanding of the institutions governing the partner is a prerequisite for good communication and collaboration. Finally, for *social proximity*, we asked whether the firm "developed a higher level of trust in the university", building on the definition that "[r]elations between actors are socially embedded when they involve trust based on friendship, kinship and experiences" (Boschma, 2005:66).

The independent variables relate to the different types of UICs. Focusing once more on the university with which the firm had the most extensive interaction, the firms were asked about what this collaboration was mainly about. They could select among 17 different areas of collaboration. We classify these as *research-oriented UICs*, *education-oriented UICs*, and *informal UICs*, in line with previous studies. The UIC channels included are also informed by previous literature, such as the systematic literature review by Ankrah&Al-Tabbaa (2015) and a study by Fernández-Esquinas et al. (2016). The typology used to classify UIC channels corresponds to a great extent with Davey et al.'s (2018) University-Business Cooperation study, conducted for the European Commission. Table 2 shows the categories that firms could indicate and their classification into UIC types.

Table 2. Categorization of UICs

Research-oriented interactions	Education-oriented interactions	Informal interactions
- Consultancy / Contract research - Joint research projects - Purchase of university patent, license or other IPRs - Use of universities' facilities, laboratories, equipment etc. - Creation/funding of research centers, incubation centers, or research, science and technology parks - Creation of new ventures/firms (Spin-offs, start-ups)	- Joint PhD supervision, Industrial PhDs - Temporary staff exchanges for research purposes - Training of firm staff/employees - Student internships, apprenticeships - Student projects - Guest lecturing at universities - Recruitment of graduates based on a contract/referral - Co-development and co-delivery of curriculum	- Informal consultations - Sponsorships, scholarships, fellowships provided to university - Joint organization of events - Other interactions

We further control for characteristics of the UIC and of the firm. *Regional* takes the value of 1 if the collaboration occurs between firms and universities located in the same region, and 0 otherwise. *UIC length* is the log number of years that collaboration has been ongoing with this university. *External funding* is a dummy variable which takes the value of 1 if the collaboration expenses receive external financial support. Additionally, dummy variables for different types of universities account for university-level differences, with three different categories: *Olduni* refers to the four classic research universities in Norway, namely the Norwegian University of Science and Technology (NTNU), University of Bergen (UiB), University of Oslo (UiO) and University of Tromsø – the Arctic University of Norway (UiT), which have better government funding and a stronger focus on basic research. *Newuni* refers to universities that were awarded university status more recently (between

2004 and 2011). These include the University of Stavanger (UiS), University of Agder (UiA), Norwegian University of Life Sciences (NMBU), and Nord University. Other universities and university colleges are labelled as *otheruni*.

On the firm side, we control for *firm size* (log number of employees), the percentage of firm employees with university or tertiary education degrees (*unidegshare*), the share of the budget spent on R&D expenditures (*rdshare*) and the age of the firm (*firm age).* The *sector* of the firm is introduced as dummy variable that distinguishes between manufacturing and service industries. Finally, we control for the location of firms, distinguishing between *Eastern Norway* encompassing firms in Oslo and Akershus; *Southwestern Norway* including firms from the regions of Hordaland, Rogaland and Agder; and *Central and Northern Norway* encapsulating firms operating in Trøndelag, Nordland and Troms. Table 3 and Table 4 provide the descriptive statistics and the correlation matrix, respectively, for the variables included in the empirical analysis.

Table 3. Descriptive statistics

Variable	Explanation	Mean	SE	Min	Max
Research-oriented UICs	UIC mainly about research	0.310	0.030	0	1
Education-oriented UICs	UIC mainly about education	0.457	0.033	0	1
Informal UICs	UIC mainly about informal interaction	0.203	0.026	0	1
Firm size	Log no. of employees	3.045	1.359	0	8.412
Unidegshare	Log % employees with tertiary education	3.729	1.074	0	4.615
		1.701	1.221	0	4.615
RDshare	Log share of budget for R&D expenditures	2.600	0.944	0	5.198
		0.75	0.434	0	1
Firmage	Log firm age				
Services	Dummy. Baseline: Manufacturing.				
Ext fund	External funding for UIC	0.267	0.443	0	1
UIC length	Log years collaborated	1.918	0.812	0	3.714
Type of university					
Old university	Classic research universities	0.466	0.500	0	1
New university	New universities (2004-2011)	0.290	0.455	0	1
Other university	University colleges and new universities since 2011	0.244	0.431	0	1
Region					
Eastern Norway	Oslo/Akershus	0.392	0.489	0	1
Southwestern NO	Hordaland, Rogaland or	0.328	0.470	0	1
Central/Northern NO	Agder	0.280	0.450	0	1
Regional interaction	Trøndelag, Nordland or Troms	0.701	0.459	0	1
	University located in same county				
Tangible outputs					
Innovation	Any type of innovation output	0.409	0.493	0	1
Commercialization	Any type of	0.147	0.354	0	1
Human Resources	commercialization output	0.323	0.469	0	1
	Any type of human resources output				
		3.947	1.129	1	5
Intangible outputs	UIC lead to greater …	3.051	1.523	1	5
Cognitive proximity	Cognitive proximity	3.548	1.312	1	5
Organizational proximity	Organizational proximity	3.852	1.159	1	5
Institutional proximity	Institutional proximity				
Social proximity	Social proximity				

Table 4. Correlation matrix of variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1.Research-oriented UICs	1.00																					
2.Education-oriented UICs	-0.62*	1.00																				
3.Informal UICs	-0.34*	-0.46*	1.00																			
4.Innovation	0.28*	-0.15*	-0.11	1.00																		
5.Commercialization	0.25*	-0.09	-0.15*	0.15*	1.00																	
6.Human Resources	-0.11	0.29*	-0.23*	-0.09	0.08	1.00																
7.Cognitive Proximity	0.13	-0.08	-0.08	0.15*	0.08	0.01	1.00															
8.Organizational Proximity	0.20*	-0.14*	-0.06	0.18*	0.25*	0.02	0.37*	1.00														
9.Institutional Proximity	0.05	-0.05	0.00	0.04	0.08	0.04	0.49*	0.40*	1.00													
10.Social Proximity	0.11	-0.09	-0.02	0.08	0.12	0.04	0.55*	0.33*	0.56*	1.00												
11.Firm size (log)	0.02	0.04	-0.10	0.07	-0.09	0.28*	0.11	0.14*	0.10	0.15*	1.00											
12.RDshare (log)	0.18*	-0.08	-0.13*	0.14*	0.24*	0.01	0.13*	0.15*	0.12	0.06	-0.14*	1.00										
13.Unidegshare (log)	0.00	0.10	-0.15*	-0.10	0.06	0.22*	0.05	0.04	-0.01	-0.03	-0.12	0.16*	1.00									
14.Firm age (log)	0.03	-0.02	-0.04	0.09	-0.01	0.06	0.12	-0.01	0.15*	0.12	0.29*	-0.08	-0.04	1.00								
15.UIC length (log)	0.04	0.02	-0.11	0.07	0.17*	0.21*	0.01	0.16*	0.12	0.11	0.28*	0.12	0.06	0.42*	1.00							
16.External funding	0.33*	-0.30*	-0.03	0.17*	0.19*	-0.14*	0.18*	0.25*	0.05	0.03	0.01	0.10	-0.08	0.09	0.01	1.00						
17.Services	-0.22*	0.13*	0.07	-0.25*	-0.10	0.08	-0.04	-0.16*	-0.03	-0.09	-0.19*	0.04	0.37*	-0.22*	-0.08	-0.12	1.00					
18.Regional interaction	-0.11	0.08	0.02	-0.04	-0.05	0.08	0.03	0.01	0.03	0.02	-0.02	-0.10	-0.06	0.06	0.02	-0.05	-0.07	1.00				
19.Southwestern Norway	-0.11	0.13*	-0.05	0.09	-0.06	-0.05	0.00	0.00	-0.01	-0.14*	0.00	0.07	0.01	-0.09	-0.07	-0.04	0.02	0.06	1.00			
20.Northern Norway	0.12	-0.05	-0.08	0.03	0.09	0.02	0.08	0.03*	0.03	0.06	-0.09	0.06	-0.09	0.09	0.07	0.11	-0.19*	0.14*	-0.44*	1.00		
21.Old university	0.19*	-0.21*	0.01	0.07	0.33*	0.04	-0.02	0.21*	0.10	0.03	0.07	0.13*	-0.02	0.10	0.26*	0.14*	-0.18*	-0.26*	-0.17*	0.28*	1.00	
22.New university	-0.07	0.00	0.09	-0.02	-0.19*	-0.09	0.05	-0.15*	0.03	-0.01	-0.05	-0.06	-0.07	0.01	-0.13*	-0.04	0.08	0.29*	0.19*	-0.04	-0.60*	1.00

Note: *p<0.05

3.2. Model and estimation procedures

The characteristics of the dependent variables selected for this study justify the employment of a series of binary logit models for tangible outputs and OLS regression models for the intangible outputs of UICs. Therefore, we run two different models for the econometric analysis.

The model for tangible outputs takes the following form:

$$\text{logit [Pr } (TangOutput_i)] = \alpha + \beta_1 \boldsymbol{UICtype}_i + \beta_2 \boldsymbol{Controls}_i + \varepsilon_i \quad (1)$$

We run this model separately for each of the different types of tangible UIC outputs: *innovation*; *commercialization*; and *human resources*.

The model for intangible outputs takes the following form:

$$Proximity_i = \alpha + \beta_1 \boldsymbol{UICtype}_i + \beta_2 \boldsymbol{Controls}_i + \varepsilon_i \quad (2)$$

We run this model separately for each of the different dimensions of proximity: *cognitive*, *organizational*, *institutional*, and *social*.

4. Which outputs do firms perceive from UICs?

4.1. Perceived outputs of UICs

We first examine which tangible results firms perceive from UICs by simply calculating the share of firms reporting each type of UIC output. The results show that the majority of perceived UIC outputs occur in the form of innovations and graduate recruitment, rather than patents or spin-offs (Table 3). Almost half of collaborating firms report that UICs

directly contribute to their innovation outputs. 28% of the firms indicate that their interaction with universities resulted in product innovation, and 15% that it resulted in process innovation. Organizational and marketing innovation are reported by 7.8% and 12.9% of firms, respectively. The mobility of graduates and university staff to firms is the second most frequent output, reported by around 1/3 of collaborating firms. While policy-makers often expect UICs to result in the commercialization of research, only around 15% of firms report such outputs. Patents or similar kinds of IPRs are reported by 11% of firms, while 5% established a new venture, spin-off or start-up. Almost 20% of firms report that the UIC did not provide any tangible outputs for them. Table 5 shows the share of firms that reported each type of output.

Table 5. Tangible UIC outputs

Outputs	Share of firms (%)	SE
Tangible outputs		
Innovation	*41.0*	*0.493*
New or significantly improved products/services	28.0	0.450
New or significantly improved processes	14.7	0.354
New organizational methods in business practices, workplace organization or external relations	7.8	0.268
New marketing concept or strategy	12.9	0.336
Commercialization	*14.7*	*0.354*
Patents, licenses or other IPR at least partly belonging to the company	11.2	0.316
Spin-off / Start-up company (in which your enterprise has a share)	4.7	0.213
Human resources	*32.3*	*0.469*
Recruitment of graduates/transfer of university staff to your enterprise	32.3	0.469
Others	*31.9*	*0.467*
Other outputs (open-ended)	19.0	0.393
Joint publications (in which your enterprise's employees/staff are co-authors)	15.1	0.359
No output	*18.8*	*0.391*

Next, we examine potential intangible outputs from UICs by looking at the mean levels of agreement with the statements about the development of proximities as a result of the collaboration. Around three-quarters of firms partly or fully agree that they have got a better understanding of the competences of the university as a result of the interaction (*cognitive proximity*). Less than half of the firms (46.8%) report that the interaction has resulted in a more organized or formal interaction with the university (*organizational proximity*). Nearly two-thirds of the firms (63.6%) report that they got a better understanding of academic environment as a result of their interaction (*institutional proximity*). Finally, 70% indicate that their trust in the university has increased due to the interaction (*social proximity*). Table 6 shows the share of firms that partly or fully agree with each statement and the mean values for each dimension.

Table 6. Operationalization of non-geographical proximity dimensions

Dimension of proximity	***To what extent has the interaction with the university contributed to strengthening your relationship with the university?***	***Share of firms that Agree (%)***	***Mean / (SD)***	***N***
Cognitive Proximity	We have got a better understanding of the competences of the university.	73.3	3.95 / (1.13)	225
Organizational Proximity	We have started a more organized/formal interaction with university.	46.8	3.05 / (1.52)	216
Institutional Proximity	We have got a better understanding of the values/culture/institutional environment of the university.	63.6	3.55 / (1.31)	217
Social Proximity	We have developed a higher level of trust in the university.	70.0	3.85 / (1.16)	223

4.2. UIC types and outputs

Second, we examine the frequency of each output for UICs of different types (Table 7). Firms which report that the UIC is mainly research- or education-oriented interactions tend to perceive tangible outputs much more frequently than those who engage mainly in informal UICs. For those engaging mainly in research-oriented UICs, innovation is the most frequent output. More than 60% of firms engaging in research-oriented

UICs perceive innovation-related outputs. The shares of firms engaging mainly in education-oriented and informal UICs that report innovation outputs are much lower – in both cases, around a third of collaborating firms report innovation as a result of the interaction. A similar picture is also visible for commercialization outputs. The share of firms with mainly research-oriented interactions reporting commercialization outputs outweighs that of firms with mainly education-oriented and informal UICs. While more than one quarter of firms with mainly research-oriented UICs perceive benefits in terms of commercialization, the ratios drop to 1/10 for those with mainly education-oriented and 1/20 for firms with mainly informal UICs. However, in the case of outputs related to human resource development, these are reported more frequently by firms engaging mainly in education-oriented interactions compared to the other two categories. Nearly 50% of firms engaging mainly in education-oriented interaction perceive the development of human resources as an output of the interaction. One quarter of firms engaging mainly in research-oriented UIC report human resource outputs, while the share of firms with mainly informal interactions perceiving human resources development is slightly above 10%[5].

Table 7. The share of tangible UIC outputs by the most important UIC type (%)

	Research-oriented UICs	Education-oriented UICs	Informal UICs
Innovation	61.1	33.0	29.8
Commercialization	27.8	11.3	4.3
Human Resources	25.0	47.2	10.6

[5] Many firms engage in several types of interaction besides the most important type. For instance, 89% of the firms which indicated research-oriented interactions and 72% of firms which indicated informal collaborations as the main channel of collaboration with their main university partner reported that they were also involved in at least one type of education-related UIC with all universities. This can to some extent account for the human resource related outputs for research-oriented and informal interaction categories, and the innovation and commercialization outputs for education-oriented ones.

Additionally, we examine the extent to which different types of UICs are conducive to the development of proximities by calculating the mean value on each dimension for firms reporting each type of UIC to be most important. In this case, the results vary less across UIC types (Table 8). For all UIC types, the mean response tends towards agreement for cognitive, institutional and social proximity. Although firms engaging mainly in research-oriented UICs tend to perceive the highest improvement in all dimensions of proximity, the differences are fairly small. The exception is organizational proximity, where there is a marked higher level of agreement for firms engaging mainly in research-oriented UICs. For firms engaging mainly in education-oriented and informal UICs, the mean response for organizational proximity leans more towards disagreement.

Table 8. Development of non-geographical proximity dimensions by UIC category, mean

UIC Type / Contribution to	Research-oriented UICs	Education-oriented UICs	Informal UICs
Cognitive proximity	4.15	3.85	3.77
Organizational proximity	3.49	2.82	2.86
Institutional proximity	3.63	3.48	3.54
Social proximity	4.04	3.74	3.81

5. Do firms engaging in different UIC types perceive different outputs?

Finally, we move on to the question of whether different types of UICs lead to different outputs, by examining the factors associated with each output in regression analyses. The first set of regression analyses relates to the different tangible outputs of UICs. The results are presented in Table 9. Collaborating with universities in mainly research-oriented UICs is associated with a higher probability of innovating and of reaching commercialization outputs compared to informal UICs, but not with a higher probability of human resource outputs. Mainly education-oriented UICs are positively associated with the probability of

commercialization and human resources outputs, compared to informal UICs, but not with a higher probability of innovation outputs. Overall, the results indicate that informal UICs are less likely to lead to tangible outputs than more formal types of UIC. Meanwhile, research- and education-oriented UICs target different types of outputs, being oriented towards innovation and human resource outputs, respectively. However, both research- and education-oriented UICs are more likely to lead to commercialization outputs than informal UICs. This implies that firms engaging in education-oriented interactions do not only benefit in terms of skill acquisition, but also experience benefits in terms of commercialization, such as patents or new firms.

Among the control variables, firm size is positively associated with human resources and negatively with commercialization outputs. The share of university degree graduates in the workforce of a firm positively influences its likelihood of experiencing human resource benefits. Firms in the services industry are less likely to perceive innovation-related outputs as a result of their collaboration with universities compared to manufacturing firms. Firms in Southwestern Norway are also more likely to develop innovations from UICs compared to firms in Eastern Norway. In terms of UIC features, UICs that are externally funded and that have lasted for a long time are more likely to create commercialization outputs. Regional UICs result more frequently in the recruitment of graduates than extra-regional collaborations. Finally, firms collaborating with older universities in Norway have a much higher likelihood of developing patents or spin-offs than the firms collaborating with other universities. However, there are no differences for other types of output.

Table 9: Logit regression results for tangible outputs of UICs

		Innovation	Commercialization	Human Resources
UIC type	Research-oriented UICs	0.997**	2.668**	1.046
		(0.464)	(1.132)	(0.662)
	Education-oriented UICs	0.137	2.235*	1.921***
		(0.431)	(1.152)	(0.609)
	Informal UICs	Baseline	Baseline	Baseline
Firm characteristics	Firm size (Log of no. of employees)	0.040	-0.413*	0.558***
		(0.119)	(0.212)	(0.147)
	Unidegshare (Log % of employees with tertiary education)	-0.165	0.038	0.644***
		(0.155)	(0.236)	(0.246)
	RDshare ((Log % of R&D expenditures)	0.171	0.282	0.008
		(0.133)	(0.211)	(0.150)
	Firm age (Log of firm age)	0.024	-0.232	-0.083
		(0.192)	(0.320)	(0.223)
	Services	-0.819**	-0.405	0.350
		(0.403)	(0.610)	(0.484)
	Manufacturing	Baseline	Baseline	Baseline
	Southwestern Norway	0.704*	-0.185	-0.344
		(0.377)	(0.594)	(0.426)
	Northern Norway	0.108	-0.693	-0.077
		(0.425)	(0.661)	(0.493)
	Eastern Norway	Baseline	Baseline	Baseline
UIC features	Regional interaction	-0.229	0.642	0.705*
		(0.363)	(0.576)	(0.429)
	External funding	0.408	1.011**	-0.606
		(0.360)	(0.496)	(0.456)
	UIC length	0.157	0.601*	0.207
		(0.221)	(0.322)	(0.264)
	Old university	-0.133	2.515***	0.289
		(0.430)	(0.867)	(0.493)
	New university	-0.124	0.289	-0.170
		(0.439)	(0.995)	(0.494)
	Other university	Baseline	Baseline	Baseline
	Constant	-0.420	-5.941***	-7.145***
		(0.935)	(1.812)	(1.422)
	Pseudo R2	0.1081	0.3031	0.2269
	Log likelihood	-128.47907	-62.803479	-103.70408
	Observations (N)	213	213	213

Regarding the intangible outputs of UICs, the results of the regression analyses are presented in Table 10. There are no significant differences across different types of UICs for the development of proximities. Hence, informal UICs are equally important as more formal types in giving firms experience with university collaboration and in developing a closer relationship to universities.

Among the control variables, firm size positively influences the development of all non-geographical proximity dimensions, except institutional proximity. The effect size is the biggest for organizational proximity, implying that bigger firms tend more often to develop formal structures to govern the collaborations when building a closer relationship to the university. Firm R&D intensity positively influences the development of institutional proximity, suggesting that firms with higher shares of R&D expenditures develop a better understanding of academic culture, and hence more cognitive proximity, as a result of their interaction with universities. This suggests that prior absorptive capacity supports the development of cognitive proximity. Firm age has a negative relationship with organizational proximity, meaning that younger firms more frequently enter into formal organizational arrangements with universities as a result of UICs. The interaction process has a smaller impact for the development of firms' trust in universities in Southwestern Norway compared to Eastern Norway, as indicated by the negative coefficient for social proximity. External funding augments the possibilities of engaging in more formal interactions with universities – suggested by the significant and positive coefficient for organizational proximity – but does not impact the development of the relationship in other dimensions. Finally, the length of the relationship is positively associated with the development of organizational proximity.

Table 10. OLS regression results for intangible outputs of UICs

		Cognitive Proximity	Organizational Proximity	Institutional Proximity	Social Proximity
UIC type	Research-oriented	0.160	0.166	0.004	0.099
	UICs	(0.245)	(0.317)	(0.297)	(0.254)
	Education-oriented	-0.022	-0.053	-0.004	-0.162
	UICs	(0.223)	(0.289)	(0.274)	(0.232)
	Informal UICs	Baseline	Baseline	Baseline	Baseline
Firm characteristics	Firm size (Log of no. of employees)	0.118*	0.137*	0.083	0.110*
		(0.063)	(0.082)	(0.076)	(0.066)
	Unidegshare (Log % of employees with tertiary education)	0.063	0.126	-0.036	-0.025
		(0.081)	(0.105)	(0.097)	(0.084)
	RDshare (Log % of R&D expenditures)	0.125*	0.098	0.148*	0.105
		(0.070)	(0.090)	(0.085)	(0.072)
	Firm age (Log of firm age)	0.144	-0.258**	0.162	0.098
		(0.099)	(0.130)	(0.119)	(0.104)
	Services	0.047	-0.431	0.139	-0.106
		(0.217)	(0.278)	(0.260)	(0.226)
	Manufacturing	Baseline	Baseline	Baseline	Baseline
	Southwestern Norway	0.031	0.035	-0.024	-0.389*
		(0.195)	(0.253)	(0.238)	(0.204)
	Northern Norway	0.230	-0.059	-0.057	-0.010
		(0.220)	(0.286)	(0.264)	(0.229)
	Eastern Norway	Baseline	Baseline	Baseline	Baseline
UIC features	Regional interaction	0.060	0.274	0.141	0.060
		(0.188)	(0.246)	(0.227)	(0.196)
	External funding	0.355	0.740***	0.057	-0.024
		(0.193)	(0.249)	(0.232)	(0.201)
	UIC length	-0.155	0.306**	0.018	0.036
		(0.116)	(0.151)	(0.140)	(0.121)
	Old university	-0.149	0.369	0.395	-0.106
		(0.227)	(0.291)	(0.273)	(0.236)
	New university	0.042	-0.142	0.329	0.009
		(0.231)	(0.301)	(0.280)	(0.239)
	Other university	Baseline	Baseline	Baseline	Baseline
	Constant	2.810***	1.819***	2.252***	3.375***
		(0.492)	(0.644)	(0.598)	(0.512)
	Observations (N)	210	201	213	208

6. Discussion and Conclusions

This paper has examined the various outputs which firms perceive from university-industry collaborations, including both tangible outputs in the form of innovation, commercialization and the development of human resources, and intangible outputs in the form of developing a closer relationship to the university. The paper has also analyzed how the likelihood of different outputs vary across different UIC types.

The analysis has two main results that provide new insights into the discussions on UICs and their outputs. First, we show that the output types most frequently emphasized by policy-makers and studied in the literature, such as patents and spin-offs, are not perceived by most firms as the main outputs from UICs. More often, university-firm linkages generate generic outputs, such as the recruitment of graduates. Moreover, the direct influence of UICs on firm innovation is also highly visible, especially in terms of product innovation. Furthermore, we show that firms perceive not only tangible outputs from UICs, but very often also intangible outcomes in the form of a closer relationship to the university.

Second, we show that more formal UIC types are more likely to generate tangible outputs than informal UICs. Engaging in research-oriented and education-oriented collaborations significantly increase the likelihood of firms perceiving tangible outputs compared to informal types of collaboration. Furthermore, different UIC types result in different types of outputs: Research-oriented UICs tend more frequently to produce innovation, while education-oriented UICs more often lead to human resource outputs. Meanwhile, both research- and education-oriented UICs lead equally to commercialization outputs. We find that there are no differences across UIC types when it comes to the development of a closer relationship between firms and universities. Hence, despite their lower impact on tangible outputs, informal UICs are still important insofar as they help bring universities and firms closer together, which can result in the development of more tangible outputs in the long run.

Overall, this indicates that specific tangible outputs such as innovation and commercialization are much more likely if firms and universities formalize collaborations. Therefore, current policies advocating the formalization of UICs for better results (Thune&Gulbrandsen, 2011) should be fostered. However, firms and universities should also acknowledge the value of the interaction process itself. Various types of UICs are helpful in teaching the partners how to interact with each other, with positive repercussions for future collaboration. Therefore, firms and universities should be encouraged and supported to initiate the interaction process. The establishment of informal networks and forums with the involvement of academic and industrial actors can be a catalyst for long-term relationships. Finally, when evaluating UICs, academics and policy-makers should consider the broader learning effects of interaction processes on the relationship between the collaborating partners. In addition to emphasizing tangible outputs, the intangible effects of UICs should be made a central component of the evaluation criteria for UICs. Key Performance Indicators for UICs should go beyond measuring the level of satisfaction (Mora-Valentin et al., 2004) and include more detailed measures that also capture intangible outputs. Indeed, the inclusion of intangible outputs or benefits of UICs would provide a more accurate representation of the UIC phenomena and their impact. This would indicate how programs and policies to support collaboration can be designed better, which consequently would improve the success and effectiveness of future UIC support mechanisms.

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PAPER 4

Alpaydın, U. A. R., What drives the spatiality of university-industry collaborations: Proximity or motivations? *In progress.*

What drives the spatiality of university-industry collaborations: Proximity or motivations?

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Abstract

Firms have two broad options from a geographical perspective to decide on with which university to collaborate: either with a local university or a distant one. Research has frequently addressed this challenging choice by pointing out to the proximity of actors, both in geographical and non-geographical terms. However, studies have been inadequate in that firms are motivated by different factors in interacting with universities. The different purposes of collaboration influence firms' decisions on choosing their university partners, consequently determining the spatial reach of collaboration. However, the influence of the motivations has not been studied in detail. This paper, therefore, explores the influence of dimensions of proximity and collaboration motivations on the spatial patterns of university-industry collaborations (UICs). Drawing on survey data from 1200 Norwegian firms, the paper investigates to what extent different non-geographical proximity dimensions and motivations affect the tendency of firms to collaborate with regional or extra-regional universities. The findings indicate that UICs motivated by capacity development and relying on cognitive proximity are less sensitive to distance, while geographical proximity matters more for firms intending to create societal impact and building their collaboration on institutional and social proximity. The study highlights that motivations need to be taken into account in studies employing proximity framework to UICs.

Keywords: Proximity dynamics, university-industry collaboration, motivation, geographical proximity

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1. Introduction

The spatial aspect of university-industry collaborations has been a widely discussed issue in the geography of innovation literature. The reasons leading to the establishment of interactions between the firms and universities at various geographical scales, be they regional or extra-regional – including national and international scales – has been questioned from different viewpoints (Hewitt-Dundas, 2013; Broström 2012; Muscio, 2013). Investigating the factors that define the spatiality of the collaborations and that make firms establish linkages with close or distant university partners is important for explaining the effectiveness of external knowledge sourcing activities of actors, which may have different influence on the innovative behavior of firms. Exploring the underlying rationale of the UIC's spatial profiles will also enhance our understanding on the contributions of universities to regional economic development in their territories and their involvement in national or global innovation systems.

The general wisdom suggests that the majority of the interactions occur between the firms and universities located in the same region (Fitjar and Gjelsvik, 2018). However, UICs also take place beyond the regional level. In some cases, the interactions between firms and universities transcend the regional borders resulting in the establishment of collaborative linkages at further distances notably at national (Hoekman et al., 2009) and international (Chen et al., 2019) scales.

Previous studies on the spatial scope of UICs generally refer to the ease of communication that is facilitated by geographical proximity in explaining the dominance of collaborations at the regional level. However, more recent approaches on inter-organizational collaborations emphasize the relational attributes of the interacting partners – that is non-geographical dimensions of proximity (Slavtchev, 2010). Additionally, this perspective helps in explaining the rationale underlying the interactions between universities and firms located at a

distance. The existence of cognitive, organizational, institutional and/or social proximity between the interacting firms and universities is said to compensate for the lack of geographical proximity in long-distance UICs. Sharing a common knowledge base – indicative of cognitive proximity – can facilitate the establishment of UICs at larger distances. Firms and universities bounded by similar organizational commitments can exchange knowledge successfully even from a distance. The similarity of institutional values and principles may enable a smooth interaction between firms and universities even though they are not located in the same geographical area. Strong social bonds, which emanate from prior knowledge or other relational links, such as friendship and kinship, may also overcome the problems created by geographical distance and facilitate the UICs between distant partners. Still however, the influence of non-geographical dimensions of proximity on the spatiality of UICs is not clear. There is a lack of empirical analyses on how different forms of non-geographical proximity play out in UICs occurring at different geographical scales.

However, existing studies have implicitly assumed that UICs are driven by the same motivations and have seldom paid attention to the different motivations of the firms in choosing their university partners (Hansen, 2014). Firms are motivated by different reasons to engage in UICs and the motivations strongly influence firms' decision on which universities to collaborate with. Consequently, motivations play a definitive role in the spatiality of UICs. While for some motivations – such as in the case of getting access to R&D facilities of universities – the partners need to be in close proximity, the necessity for geographical proximity decreases and can be compensated with proximity in non-geographical terms for some motivations like accessing new knowledge especially when knowledge being sought is located at further distances. Yet, there is little known about the influence of such differing motivations on the spatiality of UICs. Even the proximities literature has been criticized for not recognizing that firms have different reasons for engaging in

interorganizational collaborations (Hansen, 2014). Furthermore, we do not know whether it is the differences in motivations or in non-geographical dimensions of proximity that lead firms to develop regional or extra-regional UICs.

This paper attempts to fill these gaps in the literature by examining to what extent different non-geographical proximity dimensions and motivations influence the likelihood of firms to collaborate with regional or extra-regional university partners. First, the paper analyzes the significance of non-geographical proximity dimensions – cognitive, organizational, institutional and social – for regional and extra-regional UICs. Second, it evaluates the effect of different motivations – capacity development, getting access to external resources and creating societal impact – of the firms that engage in UICs at various geographical scales. These issues are empirically examined drawing on an original survey that sketches out the status of UICs in Norway, which was conducted with the participation of 1201 Norwegian businesses. The survey provides rich information and valuable insights on why and how Norwegian enterprises collaborate with universities.

The results provide valuable clarifications on the effect of motivations and non-geographical proximity dimensions on firms' choice to collaborate with universities in either their own region or somewhere else. The results indicate that firms that attach more value to institutional and social proximity are more likely to establish UICs at the regional scale, while firms emphasizing cognitive proximity have a higher likelihood to establish UICs at larger distances. These findings suggest that there is an interplay between geographical and non-geographical forms of proximity. While institutional and social proximity overlap with the geographical dimension, cognitive proximity can substitute for it, which highlights that several dimensions of proximity should be considered together in addressing the spatiality of interorganizational collaborations. Regarding the impact of motivations, the results suggest that the firms whose main motivation is to develop their capacities are

less likely to be bounded by geographical proximity to their university partners, while the firms that thrive to create societal impact are more likely to choose the universities in their region as partners. Moreover, the results indicate that motivations alter the influence of non-geographical dimensions of proximity suggested by the disappearance of the effect of cognitive proximity when considered in combination with motivations. This illustrates that motivations need to be taken into account when controlling for the proximity dimensions in the studies examining the geography of collaborations.

The remainder of the paper is structured as follows: Section 2 outlines some key aspects of the literature on the geography of university-industry interactions by focusing on proximity literature and motivations. Section 3 outlines the data and methods used in the paper. Section 4 reports the main results of the study and Section 5 concludes the paper with a discussion of the findings highlighting the contributions of the study together with several policy implications and some avenues for further research.

2. Geography of UICs and links with proximity dimensions and motivations

The collaborations between universities and industry are largely realized in the local/regional sphere, leading to the dominance of local interactions in UICs. Several studies show that businesses principally collaborate with local universities (D'Este and Iammarino, 2010; Fitjar and Gjelsvik, 2018; Slavtchev, 2013). The imminent effect of technology transfer, or knowledge spillovers, is much more visible in the locality around the universities (Jaffe, 1989). Academic spin-offs concentrate around universities (Ponds et al., 2010). In OECD countries, a 30 km distance have been found between co-patenting partners for half of the applications (OECD, 2019). The tendency of firms to collaborate with universities in geographical proximity has been attributed to the ease of communication and coordination. The personal connections between firm and university employees or the networking effects – such as the

possibility of unintended confrontations – also help the establishment of local UICs.

Despite the higher frequency of UICs realized at the local scale, businesses also develop interactive relationships with universities in greater distances, be they in other regions or in other countries. When doing so, one of the tendencies of the firms is to connect to leading research-intensive universities (Laursen et al., 2011). The existence of star scientists or highly capable well-known research groups can drive the long-distance UICs. Several firm characteristics – such as firm size, age, human capital and R&D intensity – also have been found to enable the establishment of interactive relations between firms and universities (Broström, 2012). More importantly, the existence of proximity in non-geographical dimensions between the collaborating firms and universities has been advocated to account for distant UICs (Slavtchev, 2010). The similarity of firms and universities in non-geographical aspects of proximity may drive the establishment of UICs between geographically distant partners. Yet, the influence of non-geographical forms of proximity on the spatiality of UICs is not straightforward. For instance, cognitive and organizational proximity may enable long-distance UICs by enabling the transfer of knowledge between actors sharing similar cognitive frameworks and organizational routines (Steinmo&Rasmussen, 2016). On the other hand, proximity in social and institutional terms may facilitate the establishment of UICs in close geographical proximity by providing a common platform for the development of trust between the collaborating actors (Ponds et al., 2007).

However, the spatial aspect of UICs can also be explained through other mechanisms. One possible explanation includes the motivations of firms, which plays a fundamental role in determining the right university partners for collaboration. Firms have different motives to interact with universities and these motives may strongly shape their orientation to potential university partners distributed across various geographies

(Hansen, 2014). The expertise and knowledge that firms seek may not necessarily be found in nearby universities, and thus, the search for knowledge may push firms to collaborate with universities at further distances. The motivations related to external funding may emerge in the form of a requirement of a funding call that necessitate the establishment of collaborations with universities located at some particular locations. For instance, several joint R&D programs initiated by the European Union require partners to be located in European countries, thereby limiting the establishment of collaborations with overseas universities. Alternatively, firms might be interested in developing the capacity of universities in their regions with the expectation to benefit from them in the long run (Fitjar&Gjelsvik, 2018). Consequently, firms base their decision on choosing the university not by looking at their size, R&D intensity, age, but by purposefully relying on their internal motivations in collaborating to fulfill their needs. However, the effect of diverse motivations on the geography of UICs has not been explored in detail.

2.1. Non-geographical dimensions of proximity as determinants of spatial reach of UICs

It is often argued that geographical proximity facilitates inter-organizational collaboration and knowledge exchange (Huber, 2012). Owing to the ease of communication and face-to-face contact, actors located in close proximity interact effectively, which leads to successful collaborations. The prevalent focus on geographical dimension in the proximity literature has been expanded by more recent approaches favoring the multidimensionality of the concept. These approaches mainly posit that non-geographical dimensions of proximity, including cognitive, organizational, institutional or social proximity, are beneficial for collaborations between organizations (Boschma, 2005). Albeit the facilitative role played by several dimensions of proximity in inter-organizational relationships, their effect may not be always positive. The recent approaches also caution about excessive proximity potentially also being harmful for collaboration. Excessive proximity may lead to

lock-in situations where partners are so similar to each other that they have less to learn from the other side, and thus, partners should be in optimal proximity for learning effects to take place (Fitjar et al., 2016).

The literature mainly deals with four dimensions of non-geographical proximity (Boschma, 2005; Broekel and Boschma, 2016). Cognitive proximity relates to the similarity of knowledge bases. The sharing of the same knowledge base and having similar frames of reference can enable the partners to communicate effectively. Second, organizational proximity enables the members of the same organizational structure to share knowledge. The close linkages between headquarters and subsidiaries of multinational enterprises is illustrative of organizational proximity. Third, institutional proximity denotes the similarity of soft and hard institutions. Actors who have similar norms, values and cultures (soft institutions) and abide by same laws, rules and regulations (hard institutions) can exchange knowledge more effectively than others can. Last, social proximity positively influences the interactive relationships by facilitating the establishment of trust between the partners primarily emerging from prior linkages, or other types of social ties – such as kinship, friendship.

In proximity literature, two opposing perspectives have been developed to explain how geographical and non-geographical dimensions of proximity are inter-related (Hansen, 2015; Fitjar et al., 2016). On the one hand, it is argued that there is an overlap mechanism, which suggests that geographical proximity facilitates the development of non-geographical forms of proximity. In this view, geographical proximity is regarded as a fundamental condition which allows the creation or development of proximity in non-geographical dimensions. With the help of geographical closeness, non-geographical dimensions of proximity find a suitable environment to grow. For instance, Storper and Venables (2004) stipulated that geographical proximity helps in the promotion of trust, an indicator of social proximity, through frequent face-to-face communications. Gertler (2003) argued that the influence of

geographical proximity on knowledge transfer, specifically on transfer of tacit knowledge, fundamentally lies in the shared norms, values emanating from the common institutional frameworks embedded in a local area. The alternative perspective favors a substitution mechanism, where non-geographical dimensions of proximity can compensate geographical distance, or – in other words – substitute the need for geographical proximity (Menzel, 2015). According to this perspective, proximity in non-geographical terms enable fruitful collaborative relationships in the case of geographical distance. Additionally, Huber (2012) shows that the substitution mechanism also works the other way around, implying that distances in non-geographical dimensions can be compensated by geographical proximity.

Nevertheless, the empirical studies that combine proximity literature – especially the non-geographical dimensions – with the geographical aspects of UICs are scarce. Prior research is mainly concerned with inter-firm linkages and the number of studies dealing with proximity issue in UICs is rather limited. Moreover, existing research on UICs deals with proximity dimensions separately rather than examining their interaction. The overlap/substitution issue has not been discussed very widely in UICs. There are several studies supporting the substitution mechanism in the literature. For example, Hewitt-Dundas (2013) finds that, in university-industry linkages, as cognitive proximity between the partners increases, the need for them to be co-located decreases. Ponds et al. (2007) iterate that research collaborations involving firms and universities tend to rely on geographical closeness mainly due to the institutional distance between the participating actors. Drejer and Østergaard (2017) show that social proximity based on a shared past – such as graduated from a specific university – may eradicate the need for geographical proximity in UICs, and thus enable the establishment of long-distance university-firm relationships. Their main weakness is that they apply a singular perspective considering the effect of a single dimension of non-geographical proximity in relation to geographical

one. However, a broader perspective considering several dimensions of geographical proximity simultaneously can enlighten the previous discussions on overlap vs. substitution mechanisms and develop our understanding on the interplay between geographical and non-geographical dimensions of proximity.

2.2. Firm motivations in UICs

Even though it is commonly assumed that firms collaborate with academic institutions mostly to access new knowledge produced through research activities (Bodas Freitas and Verspagen, 2017), the literature points out that firms are stimulated by a variety of motivations in engaging in UICs. Accessing knowledge does not motivate all the interactions between firms and universities and collaborations are largely driven by many different reasons than mere knowledge transfer. Firms may interact with universities in order to compensate for their lack of internal research capabilities. In this sense, the resource scarcity of firms acts a driving force in university-industry linkages (Lai & Lu, 2016). Accessing highly qualified human capital at universities in the form of both students, graduates and academics forms another strong motivation for firms in UICs (Lawton-Smith and Bagchi-Sen, 2006). However, firm motivations are not strictly limited to tangible expectations. Firms may also interact with universities in order to enhance their image and reputation (Ankrah et al., 2013). In order to be seen as responsible and caring actors, firms engage in university activities by providing various kinds of support to universities. Therefore, the motivations of firms engaging in UICs cannot be seen as unitary, but instead need to be examined as a multifaceted phenomenon. It should be considered that divergent motivations can lead to manifestation of UICs in various forms and at various geographical scales.

However, the literature on the geography of university-industry interactions is scarce on the role of motivations of firms in engaging with universities in close or distant proximity. Although the motivations of

different actors involved in UICs – firms, universities, university management and individual academics – have been frequently addressed (D'Este and Perkmann, 2011; Ankrah et al., 2013; Franco and Haase, 2015), little is known about whether different motivations lead to the selection of partners from various geographical locations. The study conducted by Bodas Freitas et al. (2014) can be noted as one of the few works on this subject matter. They distinguish UICs in terms of the activities involved and compare different types of UICs in relation to the geographical location of the partners in Italian region of Piedmont. They find that business-consulting activities generally involve firms and universities located in the same region, while firms collaborating for R&D and testing purposes are less likely to collaborate with universities in their own region. One major drawback of this study is that it takes the form of collaboration as the motivation of firms. However, the channels in which firms and universities interact may not necessarily equate with the motivations driving the collaboration, even though they are strongly associated. Motivations reflect a deeper goal which may also strongly affect the channel of interaction.

The motivations of firms concerning UICs illustrate what firms attempt to achieve by interacting with universities. In this sense, it is commonly argued that one of the most pressing and common motivation of firms in UICs is to get access to knowledge (Ankrah et al., 2013). Universities are seen as knowledge factories or generators (Uyarra, 2010) and firms want to capitalize on new knowledge created by universities in order to gain competitive advantage over their rivals by establishing collaborative relationships. The knowledge sought by firms may not necessarily be found in the closest university, which pushes firms to search potential university partners at greater distances. Therefore, we expect that UICs motivated by knowledge purposes are less bounded by the geographical proximity.

Another motivation of firms to engage in UICs is to complement internal capabilities with external resources (Ankrah&Al-Tabbaa, 2015). Firms

that do not have in-house R&D facilities may reach out to universities in order to gain access to these infrastructures, such as laboratories, testing machinery and equipment. In these circumstances, geographical proximity between firms and universities facilitate the establishment and operation of UICs. Additionally, external resources that firms aspire to get in UICs may concern financial support. Firms may want to share the financial risks associated with risky and unpredictable investments inherent in UICs. Therefore, they collaborate with universities to obtain additional financial support in the form of external funding. However, external funding can be provided by numerous organizations dispersed across various geographical levels. They can be sourced by local authorities, national R&D funding schemes, and, supranational funding bodies, such as Horizon 2020 programmes in the case of Europe. Therefore, we may expect a neutral effect of the motivations relating to accessing external resources on the spatiality of UICs.

Alongside these motivations, firms may also uphold societal concerns and engage in UICs in order to better respond to the societal challenges and to have a more positive image and reputation (Ankrah et al., 2013). Firms may want to increase their social status through engaging in purposeful UICs that can be stimulated by philanthropic reasons. While doing so, they collaborate mainly with local universities. Fitjar & Gjelsvik (2018) explains this through 'local communitarian model' of UICs, where firms consider collaborations with local universities as a part of their responsibility to contribute the development of local community with which they are embedded in. Similarly, they may strive for providing practical solutions to the challenges faced at the local sphere by collaborating universities in their vicinity. Therefore, when such societal concerns are at stake, we may expect that UICs occur mainly at the regional level, between the firms and universities located in the same region.

As discussions above suggest, motivations play a significant role in the search for possible partners, and hence, are strong determinants of the

geography of UICs. Yet, proximity literature has largely missed to incorporate motivations into their discussions and previous studies on the spatiality of UICs have failed to consider the differences in motivations of the firms. Therefore, the proximity perspective needs to be enlarged to include various and divergent motivations of the firms to engage in UICs while attempting to account for the geography of these interactions.

3. Data and Methodology

3.1. UIC survey in Norway

In order to examine the factors that affect the spatiality of the UICs, this paper draws on a large-scale survey of Norwegian businesses. The survey accounts for UICs in Norway and, in specific, the perspectives of Norwegian businesses on their interactions with universities. The survey was conducted with 1,201 Norwegian firms (out of 10,117 firms that were contacted with a response rate of 11,9%) with more than five employees in Oslo, Akershus, Aust and Vest Agder, Rogaland, Hordaland, Trøndelag, Nordland and Troms in mining, manufacturing and services sectors[7]. The survey was held through telephone interviews with the firm representatives (such as CEOs, R&D managers or HR managers) by a market research company in December 2018.

Firms were initially asked whether they had been involved in interactions with universities in the last three years. Out of 1,201 businesses, 232 of them reported to have UICs, corresponding to a rate of 19.3%. The paper draws on this subset of the sample involving the firms with UICs. The respondents with UICs were then asked why they had decided to interact

[7] NACE sectoral codes included: (B) Mining and quarrying, (C) Manufacturing, (G) Wholesale and retail trade; repair of motor vehicles and motorcycles, excluding 47: Retail trade, except of motor vehicles and motorcycles), (J) Information and communication, (K) Financial and insurance activities, (M) Professional, scientific and technical activities, (N) Administrative and support service activities. http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NACE_REV

with universities. They were provided seven statements accounting for the reasons – or 'motivations' – of their decision to collaborate with universities and asked to indicate their level of agreement to these statements on a 5-point Likert scale.

The results indicate that UICs are not solely motivated by one factor, but by a multitude of factors. The motivation with the highest mean value in the establishment of UICs is to gain access to human resources of the universities, both in the form of students and staff. More than 85% of the firms stated their agreement with this reason. Against the widespread belief that getting access to knowledge drives UICs, it is not considered as the lead motivation. Instead, it has been reported to be the second most important motivation of firms. Three-quarters of the firms say that they either fully of partly agree with the statement that "We want access to new knowledge" as their reason to collaborate with universities. The share of the firms, which indicated that they collaborated with universities in order to improve the skills of their employees, is also high (slightly above than 65%). The motivations concerning external resources, such as obtaining funds/financial assistance through UICs and accessing R&D facilities of universities, do not seem to motivate firms as much as other motivations. The access to R&D facilities of universities and external funding through UICs is regarded less important by firms. The share of firms that indicated their agreement is the lowest for the funding motive (32%) and the second lowest for R&D access (46%). Societal impact aspect of motivations is also regarded highly important by firms. Nearly 75% of the firms indicated that they collaborate with universities in order to provide societal benefits by addressing the societal challenges better. Another strong motivation for firms to collaborate with universities is to enhance their prestige and reputation in the society, indicated by 70% of the firms.

The results show that firms that have extra-regional university linkages report 'access to new knowledge', 'human resource improvement' and 'the obtaining of funding' as a stronger motivation than firms with

local/regional university partners. On the other hand, firms that cooperate with local universities indicate higher importance for 'access to R&D facilities', 'access to human resources (students and staff) at the university', 'to address societal challenges better' and 'to increase their image, prestige and reputation'. However, none of these differences carry statistical significance.

Table 1. Motivations in UICs by geographical scale of the most important collaboration

Why did you decide to interact with universities?	Regional		Extra-regional		Total	
	Obs	Mean	Obs	Mean	Obs	Mean
We want access to new knowledge.	154	3.94	66	4.21	220	4.02
We want to improve the skills of our employees/develop human resource capacities.	151	3.55	66	3.71	217	3.60
We want access to R&D facilities.	148	3.03	64	2.97	212	3.01
We want access to human resources (students and staff) at the university.	153	4.36	66	4.33	219	4.35
We want to obtain funding/financial resources.	149	2.38	64	2.73	213	2.49
We want to address societal challenges better.	153	3.97	65	3.92	218	3.96
We want to increase our image, prestige and reputation.	155	3.85	66	3.70	221	3.80

The firms were also asked to indicate the university partner with which they had interacted the most. They were provided a list of 20 Norwegian universities and university colleges. The firms were also allowed to name their most important university partner in case it was not covered in the predefined list. Based on the answers to this question, the geographical scales of the UICs were identified. The collaborations that involve firms and universities located in the same region, corresponding to administrative regions (counties) in Norwegian system, were defined as 'regional', while all other collaborations that occur between firms and universities situated in different regions of Norway and even in other countries are labelled as 'extra-regional'.

The survey, then, continued with various questions on the details of these interactions. Specifically, the firms were asked to indicate the importance of various proximity dimensions in their decision to collaborate with the university that they consider their most crucial partner. We asked several questions about firms' relationship to the university and the significance of several factors, which are intended to reflect different dimensions of proximity, were questioned. Cognitive proximity is operationalized as 'sharing a common knowledge base and expertise with this university.' The statement of 'being members of the same organizational network/structure (research center, research consortium, association, cluster, science park etc.)' is used to refer to organizational proximity. Reflecting the similarities in the working principles of firms and universities, I use the explanation 'feeling that the university/faculty/unit has a business-friendly, entrepreneurial mindset' as indicative of institutional proximity. Social proximity has been described as 'having previous/ongoing interaction with that university'. Last, the statement 'being geographically close to our company' has been used to denote geographical proximity. Table 2 reports the average of the responses based on a 4-point Likert scale (from 1: not at all important to 4: very important).

The most important driver in the establishment of UICs is a common knowledge base, that is cognitive proximity. Nearly 40% of the firms find it very important. Proximity at the institutional level characterized by the adoption of a business-friendly and entrepreneurial mindset of the university partner is the second most important driver with 38% of the firms saying that it is very important. Additionally, social proximity referring to the existence of prior or ongoing interactions with the universities is seen as very important by the one-third of the firms (33%). The results also indicate that the geographical proximity of universities to firms is a strong driver of UICs. Slightly more than 41% of the firms say that the spatial closeness between the firm and their most significant university partner has been a very important reason in their choice.

Organizational proximity specified as common membership into same organizational networks or structures do not play a significant role in the decision of most firms. Only 10% of the firms find it very important.

The differences in the importance attached to different proximity dimensions do not show statistical significance between the regional and extra-regional UICs except for the geographical dimension. Even though there are some variations in the mean importance for non-geographical forms of proximity, geographical proximity is the only dimension where there is a statistically significant difference. The co-location of firms and university partners is given as a reason significantly more often when the interaction is local compared to extra-regional collaborations.

Table 2. Mean values for proximity dimensions by geographical scale of the most important collaboration

	Regional		**Extra-regional**		**Total**	
	Mean	**Obs**	**Mean**	**Obs**	**Mean**	**Obs**
Cognitive Proximity	3.06	145	3.20	59	3.10	204
Organizational Proximity	1.87	136	1.93	56	1.89	192
Institutional Proximity	3.00	142	2.84	58	2.96	200
Social Proximity	2.87	143	2.64	59	2.81	202
Geographical Proximity* **	3.27	148	1.78	60	2.84	208

*** Significant at 1%

Additional information on various firm characteristics – such as firm size, age, share of R&D expenditures, etc. – and detailed accounts of the interactions were also collected with the survey questions.

3.2. Variables and model

Since the objective of the paper is to examine to what extent different motivations and significance of non-geographical dimensions are influential in determining the spatiality of the UICs, the association between these factors are investigated further.

The dependent variable 'geographical scale' is a binary variable that takes the value of one if a firm collaborated with a university located in the same region, and zero if the university is located somewhere else.

The study involves two sets of independent variables. The first category of explanatory variables is the non-geographical proximity dimensions. 'Cognitive proximity', 'organizational proximity', 'institutional proximity' and 'social proximity' are included in the analysis as ordinal measures and they measure the importance of the similarity of the knowledge bases, organizational structures, institutional mindsets and prior social relationships between firms and universities respectively.

Motivations represent the second set of explanatory variables, determined through a factor analysis of the reasons of collaborations, using principal factor analysis with Varimax rotation. Even though the questionnaire included seven initial motivations, the motivation 'access to human resources (students and staff) at the university' has been omitted from the analysis, since it does not have any strong loadings on any of the factors (both unrotated and rotated factor loadings are lower than 0.5 (Hair et al., 2014)). Moreover, since most of the respondents indicated their agreement with this motivation, there is limited variation on the variable, which resulted in its omission from the further analysis. Therefore, the factor analysis was repeated on remaining six motivations. While the eigenvalue rule lends support for one-factor solution, the parallel analysis and scree test indicate a three-factor solution (Figure A.1 in the Appendix). Consequently, the factor analysis identifies three major factors out of six initial reasons of collaborations (Table 3). The three factors were used as indexes created based on the constituting items and treated as ordinal variables.

The first factor is named 'capacity development' as it relates to the desires of firms to get access to new knowledge and to improve their internal capabilities. The second factor identified, termed as 'external resources', is closely associated with getting access to the resources

residing at universities in the form of infrastructure (R&D facilities) and with reaching additional, specifically governmental, funding. The last factor emerging from the analysis is labelled as 'societal impact' given its relation to the reasons of collaborating in order to provide better solutions to societal problems and to create a more positive image in the eyes of the society.

Table 3. Factor analysis of UIC motivations

	Rotated factor pattern (factor loadings)			
Motivation	Capacity Development	External Resources	Societal Impact	Uniqueness
We want access to new knowledge.	**0.42**	0.32	0.39	0.57
We want to improve the skills of our employees/develop human resource capacities.	**0.42**	0.38	0.29	0.59
We want access to R&D facilities.	0.26	**0.53**	0.26	0.59
We want to obtain funding/financial resources.	0.21	**0.51**	0.25	0.64
We want to address societal challenges better.	0.22	0.30	**0.53**	0.58
We want to increase our image, prestige and reputation.	0.22	0.21	**0.51**	0.65
Number of observations	216			
Variance explained by each factor	0.91	0.91	0.56	
Proportion explained by each factor	0.49	0.49	0.30	
Cronbach's alpha	0.65	0.63	0.63	

The analysis also includes a number of control variables that are referred in the literature to have an impact on the geography of UICs. The control variables mainly capture various firm characteristics and features of UICs. Firm size denotes the log of the number of full-time employees. The share of university degree graduates in the workforce of the firm is

also log transformed and included as a control variable in order to account for the internal capability of the firms. The share of R&D expenditures in the budget of the firm is additionally included in the analysis. It reflects the R&D intensity of the firms, since R&D intensive firms are shown to be more likely to collaborate with universities at larger distances. Another control variable included in the analysis is the firm age measured in the logarithmic form. Last, the sector in which the firm operates is classified based on the NACE codes by differentiating between the manufacturing and services industries, taking the value of one if the firm belongs to the services industry.

The regions of the firms are also included into the analysis as dummy variables to be representative of regional differences of UIC constellations. The existence of external funding and the length of the collaborations in terms of log number of years since the collaboration started are the additional control variables relating to the distinctive features of UICs.

Given the nature of the dependent variable 'regional', I run a logistic regression model with the inclusion of both non-geographical proximity dimensions and motivations as explanatory variables.

The model takes the following form:

$$\text{logit}\,[\Pr(Regional_i)] = \alpha + \beta_1 \boldsymbol{Motivation}_i + \beta_2 \boldsymbol{NongeogProx}_i + \beta_3 \boldsymbol{Controls}_i + \varepsilon_i$$

Table 4. Descriptive statistics

Variables		Obs	Mean	S.D.	Min	Max
Geographical scale	Regional	221	0.701	0.459	0	1
Motivations	Capacity Development	231	3.816	1.202	1	5
	External Resources	227	2.782	1.412	1	5
	Societal Impact	232	3.888	1.145	1	5
Non-geographical proximity dimensions	Cognitive proximity	232	3.090	0.876	1	4
	Organizational proximity	232	1.894	0.960	1	4
	Institutional proximity	232	2.966	0.995	1	4
	Social proximity	232	2.809	1.041	1	4
Firm characteristics	Firm size (Log of no. of employees)	232	3.045	1.359	0	8.412
	Unidegshare (Log % of employees with tertiary education)	232	3.729	1.074	0	4.615
	RDshare (Log % of R&D expenditures)	232	1.701	1.221	0	4.615
	Firm age (Log of firm age)	232	2.600	0.944	0	5.198
	Services	232	0.750	0.434	0	1
Region	Hordaland	232	0.121	0.326	0	1
	Rogaland	232	0.125	0.331	0	1
	Agder	232	0.082	0.275	0	1
	Troms	232	0.039	0.194	0	1
	Trøndelag	232	0.172	0.379	0	1
	Nordland	232	0.069	0.254	0	1
UIC features	External funding	225	0.267	0.443	0	1
	UIC length	232	1.918	0.812	0	3.714

Table 5. Correlation matrix of variables

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Regional	1.00																				
2.Capacity Development	-0.08	1.00																			
3.External Resources	-0.06	0.51*	1.00																		
4.Societal Impact	0.04	0.48*	0.43*	1.00																	
5.Cognitive proximity	-0.07	0.25*	0.21*	0.16*	1.00																
6.Organizational proximity	-0.03	0.09	0.22*	0.16*	0.18*	1.00															
7.Institutional proximity	0.06	0.17*	0.20*	0.14*	0.13	0.21*	1.00														
8.Social proximity	0.09	0.04	0.11	0.03	0.20*	0.10	0.03	1.00													
9.Firm size (log)	-0.02	0.12	0.06	-0.01	-0.08	0.10	0.10	0.15*	1.00												
10.Unidegshare (log)	-0.06	-0.01	-0.07	0.02	0.15*	0.02	-0.01	0.15*	-0.12	1.00											
11.RDshare (log)	-0.10	0.04	0.30*	0.17*	0.06	0.05	0.11	0.06	-0.14*	0.16*	1.00										
12.Firm age (log)	0.06	0.06	0.13	0.02	0.07	0.05	-0.05	0.13	0.29*	-0.04	-0.08	1.00									
13.Services	-0.07	-0.12	-0.23*	0.00	-0.06	-0.07	-0.20*	-0.05	-0.19*	0.37*	0.04	-0.22*	1.00								
14.Hordaland	0.08	-0.08	0.00	-0.02	0.03	-0.01	-0.06	0.06	0.04	0.04	0.07	-0.06	0.03	1.00							
15.Rogaland	-0.05	0.05	-0.02	-0.09	-0.08	-0.07	-0.05	-0.12	-0.01	0.04	0.00	-0.05	0.07	-0.14*	1.00						
16.Agder	0.06	0.10	0.06	0.02	0.06	0.05	0.06	-0.04	-0.03	-0.08	0.05	-0.03	-0.08	-0.11	-0.11	1.00					
17.Troms	0.08	-0.01	0.02	0.05	0.08	0.11	0.03	-0.09	0.03	0.01	0.02	0.05	0.01	-0.07	-0.08	-0.06	1.00				
18.Trøndelag	0.20*	0.10	0.08	0.00	0.07	-0.03	0.01	0.04	-0.08	-0.10	-0.04	0.10	-0.24*	-0.17*	-0.17*	-0.14*	-0.09	1.00			
19.Nordland	-0.11	-0.03	0.07	0.10	-0.07	0.12	0.13	0.00	-0.06	-0.02	0.14*	-0.01	0.00	-0.10	-0.10	-0.08	-0.05	-0.12	1.00		
20.External funding	-0.05	0.21*	0.34*	0.16*	0.19*	0.08	0.04	0.10	0.01	-0.08	0.10	0.09	-0.12	-0.01	-0.08	0.03	0.03	0.10	0.03	1.00	
21.UIC length	0.02	-0.09	0.06	0.00	0.12	0.12	-0.06	0.41*	0.28*	0.06	0.12	0.42*	-0.08	0.02	-0.09	-0.03	0.05	0.04	0.02	0.01	1.00

Note: *p<0.05

4. Results

Table 6 reports the results of logistic regression analysis of the geography of collaborations between firms and universities. Through a step-wise approach, I run the model for each of the two main vectors separately – using non-geographical proximity dimensions (Model 1) and, motivations (Model 2) – before conducting the main model (Model 3) where both vectors are included as explanatory variables. The results indicate a consistent pattern concerning the influence of independent variables on the geography of collaborations between firms and universities, with minor exceptions.

Regarding the effect of non-geographical dimensions of proximity on the spatiality of UICs, the results indicate that firms that attach a higher value to cognitive proximity – that is the existence of a common knowledge base and expertise with their most significant university partner – are less likely to collaborate with universities in their region. This suggests a substitution mechanism between cognitive and geographical proximity, implying that firms are more willing to shoulder the burdens of a long-distance relationship with universities with which they think to have same or similar knowledge. However, this result is valid only when the non-geographical proximity dimensions are considered (Model 1). The effect of cognitive proximity vanishes at the combined model (Model 3) where the motivations are also taken into account. If the firms base their decision in choosing their most significant university partners in line with the institutional proximity and social proximity, they are also more likely to go for UICs with the regional universities, indicating that an overlap mechanism is at play between social and institutional proximity and geographical proximity. When firms attribute higher importance to the business-like mindset of the universities and to prior interactions, the likelihood of forging collaborations with universities at the regional scale increases.

Firms whose main motivation relate to capacity development are less likely to collaborate with the universities in their region, whereas firms that collaborate with universities in order to create societal impact are more likely to establish partnerships with the universities in their localities. This indicates that firms that thrive to access the knowledge produced by universities are more likely to accept larger distances. Similarly, UICs in which firms want to develop their internal human resource capacities are less likely to be confined by geographical proximity. On the other hand, the likelihood of collaborating with universities in the same region is higher for firms that interact with universities with the intention to provide solutions to societal challenges or to build a more positive reputation in society. They tend not to look beyond the borders of their regions when they would like to collaborate with universities and tend to form UICs with the universities in their region.

The results also indicate some differences among the Norwegian regions in the geographical patterns of UICs. Overall, Norwegian firms located in other parts of Norway than Oslo/Akershus – the capital region – are more likely to collaborate with regional universities. The coefficients are positive and statistically significant for four regions (Hordaland, Agder, Troms and Trøndelag) and positive but not significant for one region (Rogaland). This suggests that firms in Hordaland, Agder, Troms and Trøndelag are more likely to collaborate with the universities located in their regions – University of Bergen (UiB), University of Agder (UiA), University of Tromsø (UiT) and Norwegian University of Science and Technology (NTNU) respectively – in comparison to firms in the capital area. The results show consistency in all models, except for the insignificant co-efficient for Troms in Model 2. The only region with a negative, and insignificant, coefficient is Nordland.

No firm-related controls and variables related to UIC features matter for the spatiality of UICs with the exception of R&D share. Among all control variables included in the analysis, it is only the R&D share that

shows a statistically significant and negative effect (Model 3). The higher the share of R&D expenditures in the budget of a firm, the higher its likelihood to establish an extra-regional UIC. It suggests that firms with a more generous budget for R&D activities are less sensitive to distance and can build UICs in larger distances.

Table 6. Logistic regression analyses of the geography of UICs

		Model 1	Model 2	Model 3
Non-geographical Proximity dimensions	Cognitive proximity	-0.342*		-0.311
		(0.203)		(0.218)
	Organizational proximity	-0.144		-0.226
		(0.175)		(0.186)
	Institutional proximity	0.325*		0.358*
		(0.176)		(0.185)
	Social proximity	0.323*		0.328*
		(0.175)		(0.182)
Motivations	Capacity Development		-0.365**	-0.409**
			(0.184)	(0.197)
	External Resources		-0.028	-0.007
			(0.153)	(0.160)
	Societal Impact		0.403**	0.456**
			(0.175)	(0.183)
Firm characteristics	Firm size (Log of no. of employees)	-0.148	-0.038	-0.109
		(0.129)	(0.127)	(0.133)
	Unidegshare (Log % of employees with tertiary education)	-0.076	-0.040	-0.071
		(0.176)	(0.169)	(0.181)
	RDshare (Log % of R&D expenditures)	-0.230	-0.231	-0.272*
		(0.145)	(0.151)	(0.157)
	Firm age (Log of firm age)	0.163	0.160	0.214
		(0.203)	(0.202)	(0.213)
	Services	0.180	0.038	0.191
		(0.464)	(0.459)	(0.483)
	Manufacturing	Baseline	Baseline	Baseline
Region	Hordaland	1.183**	1.192**	1.325**
		(0.573)	(0.577)	(0.599)
	Rogaland	0.277	0.549	0.647
		(0.481)	(0.498)	(0.514)
	Agder	1.145*	1.277**	1.453**
		(0.646)	(0.648)	(0.653)
	Troms	2.164*	1.480	2.047*
		(1.124)	(1.109)	(1.170)
	Trøndelag	1.845***	2.047***	2.224***
		(0.618)	(0.622)	(0.647)
	Nordland	-0.472	-0.396	-0.530
		(0.636)	(0.622)	(0.663)
	Oslo/Akershus	Baseline	Baseline	Baseline
UIC features	External funding	-0.359	-0.360	-0.336
		(0.381)	(0.390)	(0.407)
	UIC length	0.005	0.013	-0.012
		(0.255)	(0.242)	(0.272)
	Constant	0.504	0.508	-0.029
		(1.158)	(1.083)	(1.267)
	Pseudo R2	0.1211	0.1161	0.1529
	Log likelihood	-115.67722	-114.01896	-109.26268
	Observations (N)	217	212	212

* p<0.10, ** p<0.05, *** p<0.01

Standard errors in parentheses.

5. Discussion

This paper has examined the spatiality of university-industry collaborations from the lenses of a distinction between regional and extra-regional interactions, which is shaped or influenced by collaboration motives and proximity dimensions between the interacting partners. More precisely, the extent to which different motivations of firms and the significance of non-geographical dimensions of proximity influence the geographical scale of UICs has been investigated. This issue has been addressed empirically by drawing on a tailor-made survey attempting to explore the status and features of UICs in Norway conducted with 1,201 businesses.

The existing literature on the geography of UICs suggests that the local and/or regional collaborations – that are between the firms and universities located in the same region – are more common. The data presented in this paper corroborates these earlier studies and shows that the majority of the UICs (70%) happen at the regional level. However, there remains 30% of UICs occurring between firms and universities in different regions, which needs to be explained. Therefore, focusing on the regional collaborations means ignoring the UICs established between distant partners. Although some earlier studies have studied this phenomenon largely by drawing on the proximity literature, they have not explored the interplay between the geographical and non-geographical dimensions. Furthermore, the proximity literature has not paid attention to the examination of the underlying motivations or reasons to collaborate with universities at different geographies. However, this study, being the first to ask firms about their motivations in engaging in UICs and assessing how these motivations affect the geography of collaborations, shows that both categories of factors – non-geographical proximity dimensions and motivations– are significant determinants of the geographical pattern of UICs.

The study highlights that proximity acts as a facilitator but the importance of various dimensions of proximity varies for regional and extra-regional interactions. The analysis shows that firms relying on cognitive proximity in UICs are more likely to transcend the regional boundaries. This suggests that for firms that sharing a common knowledge base with universities is a higher priority in establishing partnerships, the geographical distance poses a relatively weaker barrier. Firms acknowledge the fact that benefits of having a university partner with a similar knowledge outweigh the costs associated with forging a long-distance collaboration. However, this relationship disappears when controlled for motivations. Therefore, we cannot conclude that a substitution mechanism operates between cognitive and geographical proximity, where cognitive proximity compensates the geographical distance. This contradicts with earlier studies suggesting that some sort of non-geographical proximity is required in the case of geographical distance (Huber, 2012; Fitjar et al., 2016). Furthermore, this finding adds to the discussions on substitution effect between cognitive and geographical proximity (Hansen, 2015) by indicating that this relationship is indeed contingent on the collaboration motives (Hansen, 2014).

On the other hand, businesses that lean on institutional and social proximity with their university partners favor regional UICs. This indicates that the sharing of similar institutional values and socially embedded relationships reinforce the establishment of UICs in geographical proximity. Hence, it suggests that institutional and social dimensions of proximity overlap with geographical proximity. Overall, this study extends the discussions on overlap/substitution mechanisms between geographical proximity and several non-geographical dimensions of proximity by suggesting that this relationship is not straightforward (Hansen, 2015). It illustrates that the overlap/substitution issue depends on the type of proximities considered, implying that proximity dimensions need be considered with an encompassing

approach that examines their effect simultaneously rather than studying them in isolation.

Differences in motivations of firms portray themselves in the tendency of collaborating with either regional or extra-regional universities. Motivations related to capacity development aspiration make firms less perceptive about the geographical limitations and establish extra-regional university partnerships. This suggests that knowledge stock is what matters for UICs with this motivation and that firms accept to engage in UICs at larger distances in order to fulfill their knowledge needs beyond their regions. From the perspective of firms, this result can also be explained by their preference for quality over geographical proximity. Corroborating the findings of Laursen et al. (2011), firms aspiring for capacity development are more likely to emphasize university quality in their selection of university partners and thus less bounded by geographical proximity resulting in the higher likelihood of establishing extra-regional UICs. On the other hand, firms with the motivations oriented towards building a more positive image are more likely to interact with the universities in their localities. By collaborating with the local universities, firms may want to enhance the universities competence and to be seen as caring actors within the regional societies (Fitjar and Gjelsvik, 2018). Since firms' desire to create societal impact and take responsibility are inherently more place-based and locally-oriented, suggesting that it is confined to the geographical proximity of actors, the establishment of regional UICs are more likely for this type of firms.

The findings also illustrate a clear manifestation of geography of UICs in Norway. The firms that are not located in the capital region of Oslo/Akershus have a higher likelihood to collaborate with the universities in their region. Compared to the firms in the capital area of the Norway, the firms located in the majority of other regions have an apparent tendency to interact more intensively with the universities found in their own regions. This may suggest that the choices of firms

differ between capital region and more peripheral regions. Corroborating the findings of Drejer&Østergaard (2017), geographical proximity to universities tends to have a lesser importance for firms located in the capital region, while its influence is higher for firms in more peripheral regions. The results are also in conformity with the studies of Fitjar&Rodríguez-Pose (2019) and Herstad (2018), who found that Norwegian firms in the capital region are less likely to collaborate with other organizations in the same region as well.

Several policy implications can be formulated in the context of these findings and results. First, the differences in motivations of firms in establishing UICs should be acknowledged in designing policy mechanisms so that both regional and extra-regional UICs can be nurtured simultaneously. For instance, the extra-regional collaborations are driven by capacity development motivations of firms, while societal impact is a stronger motivation in driving regional UICs. Therefore, firms' endeavors to forge UICs needs to be supported in line with their motives, instead of only incentivizing regional level collaborations. In this regard, financial support organizations or intermediary organizations that thrive to increase the levels of UICs, such as research councils may differentiate their support mechanisms by conducting a priori 'needs assessment' of firms and devise individualized and more targeted interventions. Second, the regional development policies targeting the stimulation of UICs should pay attention to the proximity dimensions other than solely the geographical one. Instead of assuming that pure geographical proximity will foster collaborations between firms and universities in the same region, policies should invest in developing the non-geographical proximities. Especially the distances between the firms and universities in the same region at the cognitive dimension that make firms to look outside of their region for potential university collaborators should be targeted by regional policy-makers. However, these policies should also bear in mind that the positive influence of

proximity is not limitless and too much proximity can also be detrimental.

This study is bounded by several limitations. First, it embraces a static approach on proximity dimensions. The collaborations may lead to changes in the configuration of proximity dimensions, especially for non-geographical forms, between the actors resulting in the co-evolution of proximities. However, the dynamic aspect of proximity has not been taken into account in this research. A longitudinal study may address this shortcoming. Second, the study concerns firms' collaboration with universities that they consider as the most important partner. However, firms may engage in a multitude of interactions motivated by a number of different purposes with universities at different locations. It is beyond the scope of this paper to examine all UICs of the firms and search for the influence of a variety of proximity dimensions and underlying motivations for every UIC. Further research with an in-depth case study approach can provide additional insights in this regard. Last, the use of direct questioning in the survey – the main data source utilized for the study – creates the issue of reliance on self-reporting. The respondents provided answers within the scope of their knowledge, which makes it very hard to triangulate data used in the analysis.

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7. Appendix

Figure A.1. Scree plot for factor analysis on motivations