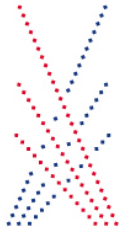

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Knowledge-intensive services in academic engagement and commercialisation

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BAM2019 Conference

3 - 5 September 2019

Aston University, Birmingham, UK

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Abstract

Drawing on data from an original survey and theories on proximities in inter-organisational learning and types of knowledge, we explore the nature of the relations between KIBS firms and academics in formal research collaboration and in academic spin-offs. We assess how different mechanisms are used to integrate knowledge in these relations. We confirm the importance of social proximity in inter-organisational relations and uncover the specific roles of cognitive proximity in research collaboration and organisational proximity in the setting up of academic spin-offs. The paper builds on and extends the debate on proximities and inter-organisational relations. We show that proximities differ in different types of inter-organisational relations and in different levels of knowledge integration.

Key words: KIBS, academic, inter-organisational relations, proximity

1. Introduction

Knowledge intensive business services (KIBS) firms are firms that process a high level of knowledge for their own growth and disseminate knowledge to other actors in the system of innovations (Gallouj, 2010). Examples of KIBS firms include firms providing ICT services, financial services, legal services, and management consultancy. There are some features of KIBS firms that make their roles in the systems of innovation particularly interesting. First, the service sector accounts for more than 70% of employment in most advanced economies, and this growth is particularly driven by KIBS firms (OECD, 2015). This is in line with the increasing organisational trend in externalising many activities and functions. Many firms seek professional services from organisations outside their organisational boundary to support their product development, R&D or procurement activities, IT operations, organisational re-structuring, human resources, and legal advice. Second, there is much evidence that there is a greater contribution of KIBS firms to other firms and sectors' innovation. Studies show that KIBS contribute to and co-create innovation in various types of firms and sectors, including small- and medium-sized firms (Muller and Zenker, 2001), the manufacturing sector (Ciriaci et al., 2015), and the public sector (Windrum, 2013).

At the same time, external engagement by university academics is increasingly encouraged by government and universities to seek legitimation for publicly subsidised research, foster economic growth, and raise funds for university (Perkmann et al., 2013). Attention has been paid to the relevance and the features of academic engagement and commercialisation of universities, involving attention to both inter-organisational collaborations to provide new ideas or solutions to firms, and to the setting up of academic spin-offs to exploit university inventions (Rothaermel et al., 2007; Thursby and Thursby 2002)

We know little, however, about the role of KIBS firms in the academic engagement and commercialisation of universities. Research has highlighted two prominent ways in which universities and KIBS interact for innovation collaboration. First, many R&D, engineering consultancy and IT services firms work closely with universities to access advanced technologies. In particular, financial services firms, which often innovate through the utilisation of new technologies developed in other sectors (Miozzo and Soete, 2001), are turning to academia for technological breakthroughs in data science, risk management, internet security, and artificial intelligence (The Royal Society, 2009). Second, many university academics setting up spin-offs with technologies ready for commercialisation lack resources in financing, intellectual property rights, human resources, business strategy, manufacturing, marketing, and sales. A string of literature has discussed the variety of KIBS firms, such as management consultancies, legal services and financial services, involved in the process of the commercialisation of university science (Howells, 2006, Wright et al., 2008). This suggests that KIBS firms could acts as both knowledge recipients in collaboration with universities and as knowledge suppliers for universities for academic spin-offs. Despite the increasing importance of KIBS in the systems of innovation and universities in economic growth, how KIBS firms and university academics interact with each other for innovation remains a black box.

Drawing on theories on proximities in inter-organisational learning (Boschma, 2005) and types of knowledge (Asheim and Coenen, 2005; Asheim and Gertler, 2005), we explore the nature of the relations between KIBS firms and academics in formal research collaboration and in the setting up of academic spin-offs. We assess how different mechanisms are used to integrate knowledge in these relations. Our assumptions are that different types of collaboration and

different types of knowledge integration mechanisms are associated with different types of knowledge generation and different levels of proximities.

We provide next the framework of our study. After that, we describe the data and methods. We then present the findings. A conclusion follows.

2. Theoretical framework

2.1. Inter-organisational relations and proximity

In order to understand how KIBS firms and academics interact with each other for innovation, we build on the literature that suggests that interaction with external partners is affected by "similarity" or "distance" among parties involved in the relationship. We draw on Boschma (2005) that propose a multi-dimensional framework of proximity that facilitates interactive learning and innovation collaboration in inter-organisational relations. We describe below the different types of "proximities" that have been researched and which are relevant for our analysis. These include cognitive proximity, social proximity and organisational proximity.

First, cognitive proximity refers to the extent to which collaborative actors share the same knowledge (e.g., scientific discipline, or technological capacity). The idea of sharing similar knowledge has been operationalised in various ways, including technological knowledge in specific industrial fields (e.g., patent industry classification) (Makri et al., 2010; Miozzo et al., 2016) and skill profile of employees (e.g., official occupational classification, or formal qualifications) (Porter, 1987; Farjoun, 1998). The ability to identify, access, absorb, assimilate and integrate relevant internal and external knowledge is one of the most important factors for renewing organisational competences (Cohen and Levinthal, 1990). Similarity in knowledge base among actors reduce barriers to learning and create synergies in knowledge production (Nonaka, 1994; Zara and George, 2002). In the context of collaboration in scientific research, cognitive proximity is particularly important. This is because scientific knowledge is highly specific and thus requires a high level of shared understanding of particular scientific laws or theories among collaborators. Studies indicate positive associations between cognitive proximity and research collaboration, emphasising the greater importance of innovation collaboration with universities for science-based industries, such as chemicals, biomedicine, and computer sciences, in comparison to other industries (e.g. Meyer-Krahmer and Schmoch, 1998; Schartinger et al., 2002).

Second, social proximity measures the degree of interpersonal relations between collaborative partners. Examples include the closeness of personal relationship built through education, employment, or other social occasions. Existing research highlights the importance of social proximity in alliances. Trust and prior relationships are important in cross-border alliances (Bleeke and Ernst, 1991). Collaborations are also more likely to last longer in alliances in which organisations have collaborated previously (Pangarkar, 2003). The underlying assumption about the role of social proximity in inter-organisational collaborations is that acquaintance and positive working relationships in the past build trust between partners which otherwise may be sceptical towards entering or sustaining a new collaboration.

Finally, organisational proximity refers to the extent to which organisations share organisational arrangements, such as degree of autonomy or extent of organisational control (Boschma, 2005). Organisational proximity provides organisational templates, rules and norms for actors from different units to follow. Hence coordination cost resulting from the need to monitor behaviour and actions of collaborative partners to avoid opportunism may be reduced.

Indeed, such templates or arrangements are found to be beneficial to the transfer of complex knowledge between organisational units (Argote and Ingram, 2000; Hansen, 1999; Miozzo et al., 2012). Organisational proximity has been conceptualised in several ways. The progressive re-arrangement of units, departments or subsidiaries after a merger or acquisition is regarded as facilitating organisational evidence of proximity by promoting integration and knowledge flows (Balland et al., 2015). Fitjar et al. (2016) operationalise the concept by looking into whether the relation between collaborators is organised through formal arrangements.

Empirical evidence shows that there is a positive association between cognitive proximity and innovation (Heringa et al., 2014). Similarly, there is also a positive association between social proximity and innovation (Heringa et al., 2014; Huber, 2012). The evidence on the relation between organisational proximity and innovation, however, is inconclusive. On the one hand, some find a negative effect of organisational proximity on innovation performance and no effect on knowledge sharing (Heringa et al., 2014). On the other, organisational proximity is regarded as important at the stage of development of the innovation (rather than the stages of research or marketing) (Davids and Frenken, 2018).

Some studies, rather than see the association between proximities and collaboration as a linear relationship, highlight that it is the level of proximity between collaborators that matters. For instance, although social proximity in a network can be positive for firm survival, Uzzi (1996) reveals that firms depending too much on inter-personal relationships in the network lower their survival rate. The reasons given for this are, first, networks relying too much on social proximity may result over time in reduced diversity, and, second, firms may overlook potentially negative economic impacts of loyalty to friendship. Similarly, Nooteboom et al. (2007) find an invert U-shaped relationship between cognitive proximity and innovation performance in technological alliances. The reason for is that very high cognitive proximity reduces knowledge diversity thus precluding new learning from partners. Assessing multiple dimensions of proximity at the same time, Fitjar et al. (2016) report that innovation collaboration with a medium level of proximity improve the output.

2.2. **Inter-organisational relations and types of knowledge**

A main objective of inter-organisational relations for learning is knowledge generation and transfer. Different types of relations are likely to involve the generation and transfer of different types of knowledge. Conversely, the generation and transfer of different types of knowledge requires different types of inter-organisational relations. To identify different type of knowledge, we build on the distinction between analytical and synthetic knowledge (Asheim and Coenen, 2005; Asheim and Gertler, 2005).

Analytical knowledge refers to highly formalised scientific knowledge. It is produced through a deductive methodology following scientific principles. Analytical knowledge emphasises the substantive dimension of knowledge, i.e. knowing what and why, and is more readily codifiable, although tacit knowledge remains a necessary component (Asheim and Coenen, 2005; Jenson et al., 2007). It is highly important in science-based industries such as the chemical, pharmaceutical, biotechnology and information and communication technology industries (Asheim and Coenen, 2005). The transfer of such knowledge requires not only shared understanding of highly formalised scientific knowledge among actors involved in knowledge production, but also organisational practices that facilitate the production and integration of such knowledge. The production and dissemination of analytical knowledge are associated with innovation activities such as the recruitment of highly qualified science and engineering professionals, research collaboration with universities, formal internal R&D

activities, and research alliances with other external science-based organisations (Asheim and Gertler).

In contrast, synthetic knowledge concerns the application, combination and implementation of existing knowledge and is problem-driven (Asheim and Coenen, 2005). The knowledge is not universal but context specific. This may involve knowledge that is based on trial and errors, experience, experimentation, clinical problem-solving for social-economic phenomena (in contract to universal solutions according to the laws of nature sciences). Knowing how and who, rather than knowing what and why, contribute more to the production of synthetic knowledge. Synthetic knowledge is produced with a high level of reliance on tacit knowledge (Nonaka, 1994). Interactive learning and learning by doing that foster effective coordination among innovation actors and the mobilisation of cognitive skills to respond to fast-changing market conditions are particularly relevant to the production of such knowledge (Jenson et al., 2007). In industrial settings, innovation activities related to the production of synthetic knowledge include solutions for specific problems in interaction between suppliers, consultants and clients (Asheim and Gertler, 2005) and knowledge involved at the development stage of research commercialisation (Davids and Frenken, 2018) and other non-R&D related activities (Marzucchi and Montresor, 2017). In innovation collaboration, strategic interactions between actors in the value chain are seem as features of the production of synthetic knowledge, while joint formal R&D activities can be regarded as analytical knowledge production (Marek and Blažek, 2016).

2.3. **Hypotheses**

The paper explores the role of KIBS firms in academic engagement and commercialisation of universities. We build on the literature on the role of proximities in inter-organisational learning, which argues that the level of proximity matters. Literature on knowledge types uncovers the relation between different innovation activities and different types of knowledge. We draw on these concepts to analyse the various types of relations between KIBS firms and academics.

There can be many different types of relations between KIBS firms and academics. A report from the Royal Society in the UK (The Royal Society, 2009) indicates that KIBS firms account for as many as 37% of firms engaged directly in research projects funded by the Engineering and Physical Sciences Research Council (EPSRC)[1]. The majority of these relations are for joint research, contract research, and researcher placement. The same report shows that these KIBS firms interact with universities to access state-of-the-art science and technology, obtain solutions for specific problems, and access research networks and R&D facilities. We propose that when the nature of relations between KIBS firms and academics is for scientific research collaboration, the primary knowledge co-created is more likely to be the analytical knowledge. A high level of scientific expertise shared among academics and the KIBS partners, that is, cognitive proximity, is likely to play a central role in these relations to facilitate the production and transfer of analytical knowledge effectively. We thus expect that, overall, there is a positive association between cognitive proximity and research collaboration.

Furthermore, from the services innovation literature we know that KIBS firms can play the role of knowledge producers and suppliers in the systems of innovation. They can act as "bridges for innovation" (Czarnitzki and Spielkamp, 2003). They assist firms/organisations in various industries and sectors to innovate (Ciriaci et al., 2015; Muller and Zenker, 2001; Windrum, 2013). Howells (2006) shows that KIBS firms perform various intermediary functions from

[1] EPSRC is the main UK funding agency for fundamental research in engineering and physical sciences.

offering intelligence at the early stage of start-ups, to formulating IP and commercialisation strategies for their clients, and to assisting clients' diversification or entry into new markets. Indeed, academics who developed spin-offs interact with consultants for various aspects of the setting up of the firms (Wright et al., 2008). This is not surprising, as the process of setting up academic spin-ups involves intermediaries for the licensing of technology, networking and peer mentoring, advice on IP and business strategy, early-stage funding, and benchmarked financing (Clayton et al., 2018). The relations between KIBS firms and universities for academic start-ups focuses on the development and implementation of business strategies, where working solutions for specific problems need to be achieved. These solutions are more likely to be based on consultants' past experiences, problem-solving capabilities, ability to combine existing knowledge and networks of external contacts. In other words, synthetic knowledge may play an important role in such relations. Davids and Frenken (2018) find that synthetic knowledge is associated with the development stage of research commercialisation and organisational proximity. They argue that this is because at this stage, prototypes must be translated into well-functioning products. This process requires effective collaborations among actors from different functional tasks including R&D, production, planning and marketing, and thus organisational proximity is crucial in this process. Similarly, academic start-ups involve intermediaries to support the different organisational functions. As the process of setting up academic spin-offs requires many aspects of knowledge that are out of the domain of academia, formal arrangements between academics and related intermediaries are expected to be vital for the relations. The above arguments lead to the following hypothesises:

> *H1: Inter-organisational relations between KIBS firms and academics for research collaboration place greater importance on cognitive proximity than for academic spin-offs.*
>
> *H2: Inter-organisational relations between KIBS firms and academics for the setting up of academic spin-offs place a greater importance on organisational proximity than for research collaboration*

We expect social proximity to be important to both types of relations. This is, regardless of whether the relations involve research collaboration or the development and implementation of early business strategies for spin-offs, trust and inter-personal relationships built through careers and education are important to facilitate knowledge generation and transfer. This leads to the following hypothesis:

> *H3: Inter-organisational relations between KIBS firms and academics for both research collaboration and academic spin-offs place importance on social proximity.*

Inter-organisational relations between KIBS firms and academics, regardless of whether they involve research collaboration or the setting up of academic spin-offs, involve different types of knowledge integration mechanisms, including specialists to coordinate the collaborations, regular meetings among collaborators, and the placement of researchers (Lam, 2011; Zahra et al., 2000). Research shows that despite the availability of technology for licensing, it is only in the cases of stronger links between the academic community and industry that university technology gets commercialised (Colyvas et al., 2002). Thus, we should expect that shared analytical knowledge between KIBS firms and academics would increase as the use of knowledge integration mechanisms deepens or strengthens. In other words, we should expect that cognitive proximity would be higher when the relations between academic and KIBS firms involve either multiple knowledge integration mechanisms or more intensive use of these mechanisms. That is, we have the following hypothesis:

H4: The greater the breadth or depth of the knowledge integration in inter-organisational relations between KIBS firms and academics, the greater the importance of cognitive proximity.

It should also be the case that the more focus is placed on knowledge integration, the greater the requirement to combine knowledge from different domains. This indicates that more synthetic knowledge would be involved in the case of the presence of the use of more or deeper processes of knowledge integration mechanisms. To facilitate knowledge generation and transfer, this would require higher levels of trust and formal arrangements in place for collaborators for these knowledge integration processes to work. This leads to the following hypothesis:

H5: The greater the breadth or depth of the knowledge integration in inter-organisational relations between KIBS firms and academics, the greater the importance of social and organisational proximity.

3. Data and Methods

The study is based on data from an original survey conducted between November 2018 and February 2019 (the survey is on-going). The survey asked academics about their relations with KIBS firms. The sampling frame is constructed based on information from several available online sources, including: 1) the list of academics who are working on current EPSRC collaborative research projects with KIBS, 2) the list of academics, from two UK leading universities based in London, Imperial College London and University College London, who set up spin-off companies. In total, we collected 281 contacts of academics. Within them, there are 128 academics who are currently collaborating with KIBS firms in EPSRC projects and 153 academics who set up university spin-offs. The survey received 29 responses form academics currently collaborating with KIBS firms in EPSRC projects and 24 responses from academics who set up university spin-offs (all via telephone). The overall response rate is 19%. We assessed the non-response rate at individual level using the characteristic comparison method (Lawton and Parasuraman, 1980). Respondents from research collaboration are overrepresented. We weighted the sample using the inverse response propensity through logistic regression modelling (David et al., 1983; Kalton and Flores-Cervantes, 2003). We asked each academic currently collaborating with KIBS firms in EPSRC projects to identify a KIBS firm and his/her relations with the firm. We asked each academic who set up a university spin-off to identify up to two KIBS firms and his/her relations with the firms. This resulted in 58 KIBS-academic relations for analysis.

Dependent variables. We assess how proximities are related to different types of KIBS-academic inter-organisational relations. The dependent variable is whether the relations are based on EPSRC projects or are for the setting up of academic spin-offs. We construct a dummy variable "EPSRC" whose value is coded 1 if the relation involves research collaboration and 0 if it involves the setting up of an academic spin-off.

Explanatory variables. Variables as proxies for proximities are constructed. An index "Cognitive" as a proxy for cognitive proximity is constructed based on a survey question asking each academic to indicate from 1 to 5, his/her agreement with each of the following statements with respect to his/her relations with the company (1=strongly disagree; 5=strongly agree): 1) we use/used a similar technical language and 2) we share/shared a common expertise (Heringa et al., 2014, Huber, 2012; Nooteboom et al., 2007) (alpha = 0.813). A second index "Trust" as a proxy for the trust dimension of social proximity is constructed based on the same survey

question mentioned above but with items: 1) we are/were equally willing to put effort into something that we ask each other to do, and 2) we are/were equally willing to share technical information with each other (Heringa et al., 2014, Huber, 2012) (alpha = 0.812). A further index "Organisational" as a proxy for organisational proximity is constructed based on the same survey question above but with different items as follows: 1) the behaviours of both parties in this relationship are/were governed by a written contract, and 2) the contract with this company states/stated precisely the activities to be performed in this relationship (Fitjar et al., 2016) (alpha = 0.902). All these variables are further transformed to dummy variables with scores above 3 coded as 1 to indicate a higher level of proximity and scores of 3 or below coded as 0 for a lower level of proximity. Finally, we asked each academic to indicate 1) whether he/she worked together with this company in other projects previously (yes = 1 and no = 0), and 2) whether he/she had professional relationship with project leaders/gatekeepers in the company before the collaboration (yes = 1 and no = 0). A dummy variable "Network" as a proxy for the networking dimension of social proximity is constructed with a value of 1 indicating a prior working or professional relationship (i.e., the answer is yes for either of the questions) between the academic and the firm.

We then consider the diversity and intensity of the use of different knowledge integration mechanisms (Lam, 2011; Zahra et al., 2000). We asked each academic to score from 1 to 5 the extent to which the KIBS firm use/used each of the following activities to capture, interpret, and integrate knowledge created in the collaborative relationship (1=never used; 5=widely used): 1) use of technical experts and consultants to synthesise knowledge, 2) use of generalist managers to coordinate the knowledge integration process, 3) regular formal reports and memos that summarise the knowledge exchanged, 4) information sharing meetings, 5) face-to-face discussion by both parties, and 6) placement of project researchers in the company. Similarly to Laursen and Salter (2006), who constructed variables for breadth and depth of innovation collaboration we construct variables for breadth and depth of knowledge integration mechanisms. First, we construct a variable "Breadth", showing the variety of use of knowledge integration mechanisms. We firstly transform all six items above, re-coding the values of 4 to 5 as 1, indicating a higher level of the use of the mechanisms, and the rest as 0. We then sum up the number of different types knowledge integration mechanisms that are highly used in a KIBS-academic relation. The values of the variable thus are integers and range from 0 to 6. This variable is further transformed into a dummy variable, with values indicating a high use of at least three types knowledge integration mechanisms recoded as 1 and rest as 0. We also construct an index using original scores of all the six mechanisms listed above named "Depth" (alpha = 0.656). We further transform this variable, re-coding the values of the upper one third of the responses as 1, indicating a higher intensity of the use of the mechanisms, and the rest as 0.

The analysing units in this study are the KIBS-academic relations. The analysing tool is STATA14. Multivariate probit regression is used for the assessment. We model nested probit equations using STATA's 'mvprobit' commend (Cappellari and Jenkins, 2003). When estimating discrete choice models with more than two alternatives, the multivariate probit model allows a covariance structure that is flexible. That is, the model assumes that error terms are joint normally distributed.

$$IP_m^* = \beta_m' X_m + \varepsilon_m,\ m = 1, 2, 3, ..., m$$

$$IP_m = 1 \text{ if } IP_m^* > 0 \text{ and } 0 \text{ otherwise}$$

ε_m, m = 1, 2, 3, ..., m, are the error terms distributed as multivariate normal with means zero and covariance matrix with diagonal elements equal to 1 and non-zero off-diagonal elements.

IP_m represents events with binary outcomes. X represents a set of explanatory variables. STATA's mvprobit command that applies the simulated maximum likelihood (SML) using the Geweke-Hajivassiliou-Keane (GHK) simulator to estimate the joint multivariate normal distribution. In this paper, we model three nested equations simultaneously. In the main equation, we hypothesise that whether the relation is based on an EPSRC project or setting up of an academic start-up is a function of proximities and breadth and depth of knowledge integration. At the same time, we hypothesise that, for breadth and depth of knowledge integration, individually they are a function of proximities.

4. **Findings**

The descriptive statistics and correlation table are shown in Table 1 and Table 2. Regression results are shown in Table 3.

[Insert Tables 1, 2 and 3 about here]

Column 1 of Table 3 shows that the coefficient of "Cognitive" is positive and statistically significant, while the coefficient of "Organisational" is negative and statistically significant. This means that compared to KIBS-academic relations for setting up a spin-off firm, KIBS-academic relations for research collaboration has a higher cognitive proximity but a lower organisational proximity. Hypothesis H1 and hypothesis H2 are confirmed. At a first glance, we do not find social proximity (both in terms of trust and networking) as a determinant of types of KIBS-academic relations, as the coefficients of "Trust" and "Network" are neither statistically significant, as shown in column of Table3. However, regression results show that research collaboration is more likely to have a deeper degree of knowledge integration between KIBS firms and academics (i.e. the coefficient of "Depth" is positive and statistically significant in column 1 of Table 3). In addition, networking, or prior relationships, a dimension of social proximity, plays a significant role in having a deeper level of knowledge integration (i.e. the coefficient of "Network" is positive and statistically significant in column 3 of Table 3). This suggests that, indirectly, through a deeper process of knowledge integration, there is an additionally increased social proximity, in the form of networking, in KIBS-academic relations for research collaboration than for setting up an academic spin-off. Nonetheless, descriptive statistics of mean values of proximities by types of KIBS-academic relations (i.e. EPSRC projects or academic spin-offs) show that, regardless of the types of relations, the level of trust is in general high (Table 4). Hence, there is support for hypothesis H3. It should however be noted that although in general a high level of trust is present in inter-organisational relations between KIBS firms and academics, trust is not a determinant to differentiate whether a relation is based on a research collaboration or an academic spin-off. It is the networking effect that is more significant in research collaboration. This could be due to the reason that since most of KIBS-academic relations in research projects are formed at micro-level between KIBS firms and academics, prior relationship may play a more important role for the formation of the projects. In contrast, KIBS-academic relations in setting up academic spin-offs often are formed through university Technology Transfer Offices (TTOs). Thus, prior relationship is not

so important for such relations. Trust, the will to make the collaboration work, should be important regardless of what the types of the relations are.

[Insert Table 4 about here]

Proximities also play different roles in the breadth and depth of knowledge integration in relations between KIBS firms and academics. Column 2 in Table 3 shows that breadth of knowledge integration is positively associated with trust and networking. Column 3 in Table 3 shows that depth of knowledge integration is positively associated with networking. This confirms that social proximity is vital for knowledge integration but different aspects of social proximity work differently for different aspects of knowledge integration. We do not see that organisational proximity differs in the breadth and depth of knowledge integration. We however observe that cognitive proximity is more highlighted in the depth of knowledge integration. Therefore, there is some support for hypothesis H5 and hypothesis H4.

The key findings are thus as follows. First, cognitive proximity is significant in the formation of KIBS-academic relations and a differentiator in the intensity of knowledge integration mechanisms used. In other words, shared expertise and technical knowledge drive the formation of research collaboration more than that of the setting up of an academic spin-off, and influence the depth, but not the breadth, of knowledge integration in the relations. Second, organisational proximity, i.e. formal arrangements, is more significantly associated with the setting up of academic start-ups. This is fully in line with the argument that organisational proximity needs to be in place to facilitate effective production of synthetic knowledge with actors from different knowledge domains (Davids and Frenken, 2018). Organisational proximity however does not affect the breadth or depth of knowledge integration. Third, while social proximity is important for KIBS-academic relations in general, it is the networking dimension of social proximity that differentiates research collaboration and academic start-ups.

There are two main contributions of the paper. The first contribution is that we offer insights into the black box of how KIBS firms and academics interact with each other. We extend the contribution of Howells (2006) and Wright et al. (2008) that show the diverse roles of KIBS firms in the commercialisation of science, by demonstrating how proximities differ in different types of KIBS-academic relations. While social proximity is in general important, when academics act as knowledge providers in research collaboration with KIBS firms, shared expertise and technical knowledge are drivers for the formation of such relations. When KIBS firms act as knowledge providers in direct commercialisation of science such as in the setting up of academic start-ups (functions of KIBS firms see Appendix Table A1), organisational proximity, i.e. formal arrangements, is relatively more important.

The second contribution is to the debates on proximities in inter-organisational relations. While studies show the importance of having an optimum level of proximity to achieve the best outcomes in inter-organisational relations (Fitjar et al., 2016; Nooteboom et al., 2007; Uzzi, 1996), and that different type of proximities play a different role at different stages of product development (Davids and Frenken, 2018), we highlight the differentiated roles that proximities play in different types of inter-organisational relations and in different levels of the knowledge integration process. Thus, managers and policy-makers should pay attentions to measures to enhance specific proximities to foster different types of relations and different levels of knowledge integration.

Finally, it should be noted that as studies showing the lack of significance of geographical proximity in inter-organisational relations (Fitjar and Huber, 2015; Fitjar et al., 2016) and the fact that most of our academics are based in leading universities in London, which is also the most influential business hub in the UK, this paper does not address the effect of geographical proximity. Furthermore, studies have explored institutional proximity defined as shared values or institutional environment/arrangements at micro-level (North, 1990). Institutional proximity in research collaboration has been explored in terms of whether actors belong to the private, the public, the non-profit or the higher education sectors (e.g., Ponds et al., 2007). As relations considered in this study are all between KIBS firms and academics, the effect of institutional proximity has not been discussed.

5. Conclusion

This paper explored how KIBS firms interact with academics in formal research collaboration and in academic spin-offs, and the different mechanisms to integrate knowledge in such relations. We confirm the importance of social proximity in inter-organisational relations and uncover the specific roles of cognitive proximity in research collaboration and organisational proximity in the setting up of academic spin-offs. The paper addressed the debate in proximities and inter-organisational relations. We show that proximities differ in different types of inter-organisational learning relations and in different levels of knowledge integration.

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Table 1: Descriptive statistics (weighted results)

Variable	Mean	Std. Err.
EPSRC	0.228	0.047
Cognitive	0.527	0.076
Trust	0.641	0.074
Network	0.485	0.075
Organisational	0.504	0.075
Breadth	0.231	0.062
Depth	0.225	0.057

Table 2: Correlation table (weighted results)

	EPSRC	Cognitive	Trust	Network	Organisational	Breadth	Depth
EPSRC	1.000						
Cognitive	0.290**	1.000					
Trust	0.211	0.325	1.000				
Network	0.261**	0.015	-0.072	1.000			
Organisational	-0.174	0.210	0.200	-0.438***	1.000		
Breadth	0.103	0.191	0.370***	0.199	0.103	1.000	
Depth	0.382***	0.269**	0.284**	0.187	0.104	0.670***	1.000

*** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level

Table 3. Multivariate probit regressions (weighted results)

	(1) EPSRC	(2) Breadth	(3) Depth
	Coefficient (Robust Std. Err.)	Coefficient (Robust Std. Err.)	Coefficient (Robust Std. Err.)
Cognitive	0.693 (0.399)*	0.396 (0.313)	0.810 (0.406)**
Trust	0.274 (0.452)	1.395 (0.408)***	0.597 (0.445)
Network	-0.027 (0.435)	0.855 (0.365)**	0.959 (0.364)***
Organisational	-1.063 (0.548)*	0.392 (0.409)	0.570 (0.467)
Breadth	-0.318 (0.794)		
Depth	2.316 (0.782)***		
Constant	-1.353 (0.526)*	-2.768 (0.472)***	-2.592 (0.552)***
ε12= -0.701***, ε13= -0.604, ε23=0.727***			
N=58			
Likelihood ratio test of ε12=ε13= ε23=0; Chi2(3)=8.559, p=0.036			
Wald statistics= 64.24***			
Log pseudo likelihood= -73.572			

*** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level

Table 4: Mean values of proximities by types of inter-organisational relations (research collaboration or spin-offs) (weighted results)

	Mean value of proximity
Cognitive	
Spin-off	0.448
EPSRC	0.793
Trust	
Spin-off	0.586
EPSRC	0.828
Network	
Spin-off	0.414
EPSRC	0.724
Organisational	
Spin-off	0.552
EPSRC	0.345

Appendix Table A1: Roles played by KIBS in the process of setting up academic spin-offs (1=not at all; 5=to a great extent) (unweighted results)

Function of KIBS in academic spin-offs	Mean score
Supported the licensing of your technology	**2.276**
Offered affordable working space	1.897
Helped to accelerate milestones	**2.483**
Offered space for social interaction	2.034
Facilitated networking and peer mentoring	2.241
Advised on IP	**3.172**
Advised on business strategy/management team	2.138
Contributed to technological development	1.828
Acted as deal broker/maker	2.138
Provided early-stage funding	1.621
Provided multistage, benchmarked financing	1.138