Open innovation and the formation of university–industry links in the food manufacturing and technology sector: evidence from the UK

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Abstract:

Purpose

Despite typically being regarded as 'low-tech,' the Food Manufacturing and Technology Sector is increasingly turning to open innovation practices involving collaboration with universities in order to innovate. Given the broad range of activities undertaken by this sector and the fact that it utilises analytical, synthetic, and symbolic knowledge for innovation, it makes an interesting case study on the factors that influence the formation of University-Industry links.

Design/methodology/approach

Using data from 249 collaborative projects that occurred between UK universities and food manufacturing and technology firms, the analysis utilises a logistic regression model based on a 'synthetic counterfactual approach' to modelling the probability a collaborative link will be established with one university and not others.

Findings

The results suggest that organisational proximity, conceptualised through the presence of prior ties between actors, have the largest influence on the formation of U-I links. In addition, spatial and technological proximity between actors also have a positive influence on link formation. This result suggests that the specificity of knowledge to the food sector is important in the formation of these U-I links.

Research limitations/implications

The results suggest that the open innovation practices of food manufacturing and technology firms are like other sectors, even though their innovation practices are considered to be different. However, the limitations of the paper mean that these findings may be specific to firms in the food manufacturing and technology sector in the UK.

Originality/value

The food sector is under-represented in empirical studies on university collaboration; this paper addresses this and provides new insights into the formation of these links.

Key Words: university-industry linkages; open innovation; spatial proximity; prior ties; food sector

JEL Classification: L66; O31; O32

1. Introduction

The Food Manufacturing and Technology Sector has typically been regarded as 'low- tech' in nature and lacking in innovative capacity (Ciliberti, Carraresi, and Bröring 2016; Maietta 2015). Despite this characterisation, there is increasing empirical evidence of innovative activity within the sector (Martinez and Briz 2000; Triguero, Córcoles, and Cuerva 2013), driven by advances in biotechnology and coupled with competitive pressures to enhance food standards, quality, longevity, and minimise waste (Carraresi and Banterle 2015; Traill and Meulenberg 2002). In parallel, open innovation practices have been increasingly adopted by firms within the food sector (Avermaete et al. 2004; Bigliardi and Galati 2013; Sarkar and Costa 2008). In particular, the increased adoption open innovation practices has encouraged higher levels of collaboration with universities in order to utilise their knowledge and expertise (National Centre for Universities and Business 2015; Saguy 2011).

In the UK, the food sector is an important part of the economy; consumers spent £219 Bn on food, drink and catering in 2017 (Department for Environment Food and Rural Affairs 2018). Employment in the entire sector accounted for 3.9 million jobs, with food manufacturing and technology employing over 400,000 people in over 8200 enterprises (Department for Environment Food and Rural Affairs 2018). Food related research has also been well supported, with UK universities receiving over £853 million of funding for food related research projects between 2000-2015, significantly augmenting the 'science base' in this field.

The formation of University-Industry (U-I) links, has been shown to be a complex process that is reliant upon many factors (Ankrah and AL-Tabbaa 2015; Perkmann et al. 2013; Perkmann and Walsh 2007; Vick and Robertson 2018). Within the extant empirical literature, the importance of proximities, i.e. the closeness of actors either spatially, organisationally, or

technologically, is particularly apparent in facilitating these links, typically easing the frictions that may prevent actors from different organisations working together to transfer knowledge effectively. However, the extant literature on U-I links typically treats this knowledge as a generic resource, while scholars have increasingly recognised that industries may rely on differing knowledge bases, not just in terms of the content of the knowledge but its *characteristics* (Asheim et al. 2007; Moodysson, Coenen, and Asheim 2008). One key characteristic of the food sector is that it that its diversity means that it uses analytical, synthetic, and symbolic knowledge in the course of innovation (Moodysson, Coenen, and Asheim 2008; Zukauskaite and Moodysson 2016). Thus, the knowledge required for innovation may be scientific in nature (analytical knowledge), focus on design and problem solving (synthetic knowledge), or be aesthetic in nature (symbolic knowledge) (Asheim et al. 2007; Martin 2012; Tether, Li, and Mina 2012; Zukauskaite and Moodysson 2016).

Given the importance of the food sector to the UK economy in terms of output and employment, coupled with its increased focus on open innovation activities involving collaboration with universities, this sector provides an interesting case study to enhance our understanding of U-I collaboration. Motivated by these developments and given the substantial level of investment in research in this area, this paper examines the interaction of food manufacturing and technology firms with universities in order to assess the factors that influence the development of collaborative links between the two. Therefore, the central research question posed in this paper is, given the diversity of the food manufacturing and technology sector and its utilisation of a broad knowledge base (Manniche and Testa 2010; Zukauskaite and Moodysson 2016) what factors influence the formation of U-I links involving firms in the food sector?

Using data on 249 collaborations initiated between 2000-2015, the analysis models the influence of spatial, organisational, and technological proximity plus the characteristics of a

university in order to assess the drivers of U-I links in this sector. The results find that organisational proximity has the largest influence on the formation of these links, followed by spatial proximity, and technological proximity. Thus, the paper's key contribution is that it highlights the fact that the most important factor in the development of U-I links within this sector is prior ties between partners, signalling the existence of organisational proximity. In addition, the evidence suggests that at first glance the food sector resembles others regarding the importance of the physical closeness of university partners in facilitating U-I links. Finally, the relevance of the knowledge and expertise of the university partner to the food sector are also important determinants of the formation of these links, highlighting the importance of technological proximity.

The paper is structured as follows; Section 2 presents the conceptual framework underpinning the analysis. Section 3 then outlines the methodology, while section 4 presents the results of the analysis. Finally, Section 5 discusses the implications of the results, while Section 6 concludes and discusses the implications of the findings.

2. Contextual Background and Theoretical Framework

2.1 Context: The UK Food Manufacturing and Technology sector

Despite making a significant contribution to the UK economy, the food sector is typically regarded as a low technology sector (Avermaete et al. 2004; Ciliberti, Carraresi, and Bröring 2016; Maietta 2015; Martinez and Briz 2000). Yet this label is something of a misnomer as growth within the food sector is increasingly driven by innovation (Alfranca, Rama, and von Tunzelmann 2002). In tandem, firms within the sector have increasingly adopted open innovation practices in the pursuit of new products and processes (Bigliardi and Galati 2013;

Sarkar and Costa 2008), driven in particular by increasing competition (Carraresi and Banterle 2015; Triguero, Córcoles, and Cuerva 2013). Furthermore, previous studies show that that the proportion of innovative firms in the food sector is at least one third, but could be as high as ninety percent (Avermaete et al. 2004; Martinez and Briz 2000; Triguero, Córcoles, and Cuerva 2013).

Given the sector's strategic importance the UK economy in terms of employment and value added, there have been several recent efforts to provide supporting infrastructure to promote innovation within the sector. One key example is the Government's setting up of the Agri-food Leadership Council, with an explicit aim of encouraging the adoption of new technologies and adaptation of existing technologies in the sector. In addition, the Government provided £70 million to create the Agri-Tech Catalyst to promote innovative activities (Department for Business Innovation and Skills 2013). Furthermore, the greater reliance on open innovation practices within the sector has resulted in an increased interest in the potential of universities as collaborative partners (National Centre for Universities and Business 2015; Saguy 2011). Indeed, between 2000-2015, over £950 million of research funding was awarded to projects focussed on food related projects, of which universities received over £853 million. Therefore, this funding highlights the fact that UK universities may represent significant sources of knowledge for this sector, which, coupled with the Government's current focus on the building of university links to enhance innovation and long-term economic performance as laid out in the current Industrial Strategy White Paper (HM Government 2017), emphasizes the importance of collaborating with universities for the food sector.

Therefore, considering its strategic importance to the UK economy, the food manufacturing and technology sector represents an interesting case study to further our understanding of the factors that underpin the formation of U-I links. The central research question of this paper is

which factors influence the formation of U-I links involving firms from the food sector? In order to investigate this question, the remainder of this section outlines a conceptual framework for the analysis of the formation of U-I links.

2.2 Theoretical Background: Open Innovation and University-Industry Links

Within the open innovation paradigm, universities are increasingly recognised as significant sources of external knowledge and key nodes in these networks (Audretsch, Lehmann, and Wright 2012; Bok 2003; D'Este and Patel 2007; Huggins, Johnston, and Stride 2012; Striukova and Rayna 2015). Consequently, as academic knowledge becomes viewed as an ever more important input in the development of new ideas within firms (Huggins, Johnston, and Stride 2012; Kauffeld-Monz and Fritsch 2013; Mueller 2006; Rutten, Boekma, and Kuijpers 2003), the role and ethos of the higher education sector has broadened from its original missions of research and teaching, to encompass a third mission focussed on industry collaboration and the exploitation and commercialisation of knowledge (Laredo 2007; Pinheiro, Langa, and Pausits 2015; Thursby, Jensen, and Thursby 2001).

U-I linkages, therefore, are viewed as playing a prominent role in developing the capabilities of firms, as they are ultimately designed to leverage skills, knowledge, and resources into a firm in order to enhance competitiveness (Bishop, D'Este, and Neely 2011; Mäkimattila, Junell, and Rantala 2015). Indeed, collaborating with universities typically has a positive impact on the firms involved, with the extant literature highlighting a number of benefits to the firms involved including: increased sales, higher research productivity, promoting the development of patents, facilitating access to a broader range of external resources, encouraging learning within the firm, and broadening the scope of their activities (Abreu et al. 2008; Fontana, Geuna, and Matt 2006; Hagerdoorn, Link, and Vonortas 2000; Lööf and Broström 2006). Consequently, policymakers are increasingly promoting higher levels of

external engagement between firms and universities, particularly through collaborative linkages that aim to ensure these 'third mission' activities are capitalised upon (Dowling 2015; Lambert 2003; Thursby and Thursby 2002; Wilson 2012).

While U-I linkages may offer significant gains to firms, they are not necessarily risk free. This may be due in part to the fact that U-I linkages focus on new knowledge, ensuring that the project is focussed on the start of the innovation process, commonly referred to as the 'fuzzy front end' where the process is often inexact or unfocused (Alam 2006; Montoya-Weiss and O'Driscoll 2000). Furthermore, there are uncertainties relating to the problem of asymmetric information, as both parties are unaware of the likely knowledge and capabilities possessed by their potential partner ensuring that proper governance mechanisms are in place (Rossi 2010). Thus, while participation in inter-organisational knowledge networks is viewed as addressing the uncertainties faced by the firm in terms of development and, ultimately, survival (Beckman, Haunschild, and Phillips 2004), the actual process of network creation is itself an uncertain practice (Debackere and Veugelers 2005).

As such, in the context of the food manufacturing and technology sector, calls have been made for a 'paradigm shift' in order to break down barriers and develop a mutual vision between food businesses and universities for the pursuit of joint innovation projects (Saguy 2011). Indeed, within the context of the food technology and manufacturing sector, the European Commission has led attempts to circumvent any barriers to the development of U-I links in the food sector through the development of initiatives such as European Technology Platform for the Food sector (Food for Life). Thus, successful collaboration between the two can occur successfully (Braun and Hadwiger 2011).

2.3 Drivers of University-Industry Linkage Formation

Within the extant literature, a broad range of empirical studies of U-I links have highlighted the complexity of the formation of these collaborations. This section provides an overview of this work in order to build a conceptual framework for analysis.

Firstly, spatial proximity between firms and universities has been highlighted as one of the most significant factors in the formation of collaborative links between the two (Kuttim 2016; Morgan 2004; Muscio 2013; Ponds, van Oort, and Frenken 2007; Sonn and Storper 2008). In short, spatial proximity allows the actions of potential partners to be observed, permitting an assessment as to their effectiveness and probable contribution to a collaborative venture to be made (Gulati 2007; Wood and Parr 2005). This also increases the intensity of collaborative links, with higher levels of face-to-face interaction promoting collective learning (Capello and Faggian 2005; Storper and Venables 2004) and 'communication externalities' (Charlot and Duranton 2004, 2006; Gittelman 2007). Thus, it is argued that spatial proximity allows the transfer of tacit knowledge, which is often contextual in nature, permitting the richness of information to be passed from actor to actor (Howells 2002; Knoben and Oerlemans 2006; Torre and Gilly 2000). Consequently, the evidence suggests that spatial proximity between firms and their university partners not only makes interaction between the two parties more straightforward but also provides the ability to observe other actors to ensure they are acting as they should. In addition, collaborating with a local university is viewed as reducing the costs of collaboration as well as an investment in capacity building within the local knowledge infrastructure (Fitjar and Gjelsvik 2018).

Further evidence from the extant literature on the relationship between link formation and spatial proximity increasingly suggests that it is curvi-linear in nature, i.e. follows an inverted 'U' shape (Broekel and Boschma 2012; Johnston and Huggins 2016a, 2016b). This result is important as it suggests that there are limits to the influence of spatial proximity, meaning that beyond an optimal level, the physical closeness of actors no longer increases the

propensity for them to develop a collaborative link, but instead has a negative effect on linkage formation. Thus, the partner is required not to be too close, nor too distant (Fitjar, Huber, and Rodríguez-Pose 2016). As such, there may be limits to the influence of spatial proximity with extremely high or extremely low levels having an equally negative effect on the propensity for collaborative links to develop. Furthermore, spatial proximity may have its drawbacks in that it may act as a barrier to innovation whereby more effective collaboration is undertaken with those outside of the local market (Ben Letaifa and Rabeau 2013); though while universities are not necessarily competitors their activities with multiple firms in the locale may promote unintentional spillovers of knowledge. As a result, it has been suggested that spatial proximity is neither a sufficient nor necessary condition for the successful formation of collaborative links between firms and universities (Torre and Rallet 2005).

While spatial proximity is important, the importance of other types of proximity in the formation of U-I links has also been noted (Chen and Xie 2018; D'Este, Guy, and Iammarino 2013; Kuttim 2016). For example, organisational proximity and technical proximity have been shown to be important determinants of university-industry collaboration (D'Este, Guy, and Iammarino 2013; Knoben and Oerlemans 2006; Kuttim 2016). Organisational proximity has been conceptualised in terms of the similarities between agents based on shared knowledge, methods of working, relationships, and culture (Aguilera, Lethiais, and Rallet 2012; Knoben and Oerlemans 2006). While the concept remains rather ambiguous in nature, it has been defined as "actors that belong to the same space of relations" (Oerlemans and Meeus 2005). Within the extant literature, prior ties between actors have been seen as indicators of organisational proximity (Aguilera, Lethiais, and Rallet 2012; D'Este, Guy, and Iammarino 2013), providing an opportunity to develop similar routines, and behaviours (Torre and Rallet 2005). Furthermore, in some circumstances, there is evidence that organisational proximity can act as a substitute for spatial proximity (Capaldo and Petruzzelli

2014); thus, the problems of collaborating over significant distances may be mitigated by organisational similarities. Despite these advantages, there are drawbacks to organisational proximity. It may hinder flexibility and also leave the firm locked into an unproductive relationship (Boschma 2005). Furthermore, firms may be required to possess the requisite social capital in order to develop this type of proximity (Ben Letaifa and Rabeau 2013).

In addition, technological proximity, referring to their similarity of knowledge, expertise, experiences, know-how of particular processes, machinery, or tools, (Knoben and Oerlemans 2006) has been proposed as an additional factor in the formation of U-I links. This type of proximity is viewed as enabling effective organisational learning as its presence means the actors involved in the collaboration are starting from the same point and understand the fundamentals of a particular field (Nooteboom 1999). Thus, where actors have a high level of technological proximity they are more likely to possess similar absorptive capacities (W M Cohen and Levinthal 1990). Where actors also share the same technical language they can more easily understand each other, making collaboration more effective (Huber 2012b). Again, there may exist drawbacks to technological proximity. Thus, its presence may merely ensure that knowledge is homogenous, i.e. where partner organisations share a knowledge base, they may be sharing similar knowledge. Consequently, any knowledge shared may not be truly new to the firm (Nooteboom 1999).

Beyond proximities, the characteristics of university partners have been shown to be an important determinant of the formation of their linkages with firms (Hewitt-Dundas 2012). Typically, the perceived quality of the academic partner is an important determinant in the formation of these linkages (D'Este and Iammarino 2010; Huggins, Johnston, and Steffenson 2008; Huggins, Johnston, and Stride 2012; Johnston and Huggins 2016a; Mansfield 1995). This suggests that they may act as an indicator of the likely performance of the university as a collaborative partner. Indeed, a university with a reputation as a generator of knowledge may

possess higher levels of intellectual property, which a firm may seek to exploit in its commercial activities.

Research quality, however, does not necessarily capture the networking capabilities of universities, only their ability to generate knowledge. Networking capabilities are broad in scope, typically covering activities such as consultancy, contract research and collaboration (D'Este and Patel 2007; Huggins, Johnston, and Stride 2012), representing interactions between academics and individuals *outside* of the academic world (Wesley M. Cohen, Nelson, and Walsh 2002). It has been argued that universities with higher levels of business engagement have a higher propensity to commercialise their knowledge (Perkmann et al. 2013). It follows, therefore, that these activities provide a signal to outside organisations that the university is more 'engaged' and connected to industry in terms of the ability not just to create knowledge but to also exploit it, i.e. Mode 2 knowledge creation (Gibbons et al. 1994). As such, higher levels of commercial engagement will promote the development of collaborative linkages.

Similarly, the intellectual property possessed by a university has also been shown to be an important factor in the development of its collaborative links, as it can be taken to represent the stock of novel knowledge held by an institution (Acs, Anselin, and Varga 2002; Petruzzelli 2011). Patents can be interpreted as a signal that the knowledge in question has a certain level of uniqueness, and only available from that institution. They also represent the university's stock of new knowledge in a codified and accessible form. Despite evidence to suggest that income from patenting activities is generally lower than income from collaborative links (Perkmann, King, and Pavelin 2011), a university's stock of patents can still be regarded as an important signal to firms. Patents have been demonstrated to be an important method through which knowledge is shared in scientific disciplines, although not always as prevalent in other modes of knowledge transfer (Bekkers and Bodas Freitas 2008;

Wesley M. Cohen, Nelson, and Walsh 2002; Narin, Hamilton, and Olivastro 1997). Again, it may be that the knowledge stock of a university may act as a signal of the suitability of a university as a partner.

One overlooked point within the literature on university links is that just as innovation practices vary across sectors (Malerba 2002), scholars have recognised that the type of knowledge utilised by an industries may also vary. Thus, industries may rely on differing knowledge bases, not just in terms of the content of the knowledge but its *characteristics* (Asheim et al. 2007; Moodysson, Coenen, and Asheim 2008). Three main types of knowledge base have been identified within the literature, analytical, synthetic, and symbolic (Moodysson, Coenen, and Asheim 2008). The first refers to scientific knowledge and a formal deductive method; synthetic knowledge focuses on design and problem solving, while symbolic knowledge is focussed on aesthetics (Asheim et al. 2007; Martin 2012; Tether, Li, and Mina 2012; Zukauskaite and Moodysson 2016). However, when examining U-I links, knowledge is treated as somewhat of a generic resource, little attention is paid to the composition of the knowledge base of the firms interacting and how this may influence the process.

In conclusion, the conceptual framework outlined in this section has highlighted the fact that the formation of U-I links is a complex process, reliant upon many factors including spatial, organisational, and technological proximities between partners as well as the characteristics of potential university partners. Given the importance of the food sector to the UK economy in terms of output, employment, and exports, coupled with its increased focus on open innovation activities involving collaboration with universities, plus the diversity of the sector and the resultant utilisation of all three broad types of knowledge, analytical, synthetic, and symbolic, means it provides an interesting setting for further empirical investigation into the formation of U-I links.

3. Data and Method

The empirical focus of this paper is to analyse the factors that underpin the formation of U-I linkages involving firms in the food manufacturing and technology sector. The conceptual framework outlines the significance of spatial proximity in the formation of these ties, as well as other types of non-spatial proximity based around repeated ties, as well as a broad range of other characteristics of the universities involved. Food manufacturing and technology based collaborative research projects involving universities and UK firms provide an interesting background for two reasons: 1) the importance of the food sector to the UK economy (Department for Environment Food and Rural Affairs 2018); and 2) perceived differences in the innovation activities of the food sector (Martinez and Briz 2000; Triguero, Córcoles, and Cuerva 2013).

3.2 Data Sources and Modelling Techniques

This section details the data and statistical techniques utilised in the analysis. The dataset used for the analysis in this paper was compiled using information from the Research Councils Gateway, which is a publicly available resource that lists all research projects funded through the UK's Research Councils. Overall, research projects in this broad area received over £950 million of public money between 2000 & 2015, the bulk of which went to universities (£853m). In total, projects involving collaborations between firms and universities received £39.5 million, highlighting the focus on pure academic, or Mode 1 type, research in this sector (Gibbons et al. 1994). To identify the relevant projects, a search was undertaken for all projects which contained the word ‘food’ either in the title or description. The details obtained for every research project fitting these criteria were systematically read and rigorously checked in order to confirm that it did indeed focus on food manufacturing and technology as well as involving a firm as a partner.

The final dataset contained details of 249 collaborative projects involving food manufacturing and technology sector firms, and which commenced between 2000 and 2014, thus had all been completed by 2018. In total, the identified projects involved 80 universities and 210 individual firms, covering three main collaborative funding schemes: Knowledge Transfer Partnerships (155), Feasibility Projects (32) and Collaborative R&D Projects (62) and accounted for over £39.5 million of investment during the time-period.[1] Where multiple firms were listed as partners, the lead firm, identified as such on the website, was the focus. However, where multiple universities were involved in a project, all were recorded in the dataset. Therefore, not all projects represent dyadic relationships with the 249 projects involving a total of 261 direct linkages.

The unit of analysis in terms of the firm was the business unit, as several projects involved subsidiaries of larger firms operating across multiple sites. This is an approach that is well established in the literature, allowing for a focus on the decision makers involved in the actual partnership (Bruneel, D'Este, and Salter 2010; Criscuolo 2005). For each project the specific business unit involved in each project was identified, which in turn was important to accurately map distances between the parties. The available documentation made it a relatively simple task to identify the business unit involved. However, where this was ambiguous, an internet search was used to find further details of the project, usually in the form of press releases announcing the partnership, which provided the relevant details. Where this was unsuccessful the individuals listed as academic leads were contacted to seek the relevant details.

The empirical analysis utilises a logistic regression model in order to examine both collaborations that did occur and the set of possible collaborations that did not. Therefore, the model examines the factual and, what has been termed, the 'synthetic counterfactual' in order to examine what did occur and what *may* have occurred (Agrawal, Kapur, and McHale 2008;

D'Este, Guy, and Iammarino 2013; Johnston and Huggins 2016a). this approach is useful for modelling the formation of U-I links as it identifies the influence of various factors in the process based on whether or not a partnership occurred between an individual firm and a university. Thus, it captures the characteristics of all universities within the model, allowing us to analyse the factors that do and do not promote the facilitation of a collaborative link.

As no *a priori* restrictions on potential partners were applied to the model, every Higher Education Institution in the UK was treated as a potential a partner for a food sector firm, giving a total of 133 potential university partners for each firm[2]. Therefore, for each partnership that did occur there are 132 that did not, giving a total data set containing 33117 observations. Accordingly, a binary dependent variable (COL) was constructed, equal to 1 where an actual collaboration occurred and 0 where it did not. This was the basis for the following multinomial logit model:

$$PROB(COL = 1) = \alpha + \beta PROX + \beta PRIOR + \beta CHAR + \in \quad (1)$$

where PROX is the spatial proximity of the partners, PRIOR captures the existence of a previous collaboration, and CHAR is a vector of attributes for each potential university partner.

3.3 Independent Variables

This section outlines the construction of the proximity and characteristics variables included in the model. Firstly, the spatial proximity variable, SPROX, was calculated as the inverse of the square root of distance between the firm and university in each linkage, following D'Este et al (2013) and Crescenzi et al (2017). The distances were calculated as the crow fly distances between the two in KM, measured through mapping software via the postcodes obtained following their identification and recording of their full postal address.

As there is no single method for capturing organisational or technological proximity within the extant literature, scholars have sought to capture this variable in several ways. Typically, organisational proximity is measured as repeated interactions between parties (D'Este, Guy, and Iammarino 2013), or overall interaction between a university and a particular sector (Johnston and Huggins 2016a). Here, the former approach was followed as it captured the existence of a previous collaboration informing the formation of a subsequent collaboration.

In terms of the characteristics of universities, background information was obtained on engagement with the food manufacturing and technology sector through collaborative links, the overall research intensity of an institution, commercial links and the total number patents held. The variable COLLAB captures the number of collaborative projects undertaken by each university and the food manufacturing and technology sector, indicating the level of previous interaction and reflecting their ability to work with firms. Whereas the RESEARCH variable capture the number of pure academic research projects in the food sector undertaken by each university. Therefore, these two variables can be utilised as proxies for technological proximity (Huber, 2012a).

University characteristics were captured in three variables. A proxy variable for research intensity (KCAP) was operationalised as a composite of the number of academics returned by an institution in both the 2008 Research Assessment Exercise and 2014 Research Evaluation Framework[3]. The number returned was averaged across both and normalised according to the number of academics employed by each institution, again averaged across the two census periods. Research intensity is captured, therefore, in terms of the numbers of academics publishing sufficient work to be eligible for inclusion. The variable LINKS captures the commercial links possessed by each institution using data available from the HEFCE Higher Education Business and Community Interaction Survey (HEBCIS), which records all types of interaction with the business community. The total number of links formed during the period

2003-2015 between a university and external organisations through interactions such as contract research and consultancy links was recorded. Finally, the patents variable (PAT) was calculated as the total number held by each university.

Table 1 presents a correlation matrix of the variables used in the model and highlights two factors. The first is that the correlation coefficients on the main variables are all within tolerable levels. Furthermore, robustness checks found that the Variance Inflation Factors (VIF) for each variable were under 5, suggesting that there is no underlying problem with the model.

[insert Table 1 around here]

4. Results

This section presents the results of the empirical analysis of 249 collaborative projects involving universities and firms from the food manufacturing and technology sector. Two logistic regression models are presented (Table 2), the first of which (Model 1) examines the effects of spatial proximity, the orientations of the university towards food sector research, and prior ties between partners. Model 2 then builds on this base model though the addition variables that capture the general characteristics of the universities.

The results of this analysis highlight the fact that spatial proximity has a significant and positive effect on the formation of a collaborative linkage between a firm in the food manufacturing and technology sector and a university. Therefore, the firms appear to lean towards collaborating with universities that are geographically close, a result which fits with the extant literature (D'Este, Guy, and Iammarino 2013; Johnston and Huggins 2016a; Muscio 2013). The results also highlight a significant negative coefficient on the squared term for spatial proximity, suggesting that the relationship is 'curvi-linear in nature.' Thus, these findings provide further evidence of the fact that there may be an optimal level of spatial proximity for the formation of U-I links, beyond which the chance of collaborative links developing no longer increases (Johnston and Huggins 2016a). as such, the formation of these U-I links, as with those from other sectors, are not necessarily driven by firms partnering with the closest university but one located within an optimum distance.

The analysis also highlights the significant and positive influence of prior ties between partners in facilitating the development of U-I linkages. This result is important as it not only confirms existing evidence of the importance of this facto (Agrawal, Kapur, and McHale 2008; Hewitt-Dundas, Gkypali, and Roper 2019; Johnston and Huggins 2016a) but the

magnitude of the coefficient highlights the fact that this is the most important factor in determining the formation of these links.

Thirdly, the results from Model 1 also highlight that it is important that universities possess knowledge and expertise that is relevant to the food and drink sector in order to form collaborative links with these firms. The results from the regression suggest that the greater the amount of relevant research a university undertakes in this field, the greater the probability that a collaborative link will develop with firms in the sector. Indeed, these results highlight the importance of universities engaging in relevant research for developing links with food sector firms as the coefficients on both the pure (RESEARCH) and applied (COLLAB) variables are significant and positive. However, it is participation in collaborative projects with the food sector which has the larger influence on the propensity for these firms to collaborate with a particular university Therefore, it appears that the specificity of a university partner's knowledge to the food industry is important for the formation of these links.

With respect to the broader characteristics of universities, Model 2 shows that these do not appear to influence the formation of U-I links with firms in this sector. As such, the results obtained here appear to run contrary to what has generally been found in the literature, with previous research suggesting that the characteristics of the potential university partner are significant influences on the formation of these links (Hewitt-Dundas 2011; Johnston and Huggins 2016a; Laursen, Reichstein, and Salter 2011). Thus, in this case, the findings suggest that traditional academic indicators around knowledge creation and appropriation activities, i.e. academic outputs and patents, may not actually be of use in terms of promoting the formation of collaborative linkages. Again, this highlights the importance of specificity of knowledge in this area, the fact that the U-I links are facilitated by generating knowledge that

is of use to the firms, something that has been shown to increase the credibility of university partners in the eyes of firms (Johnston and Huggins 2018).

[Insert Table 2 around here]

5. Discussion

Motivated by the fact that university-industry linkages have come to be regarded as increasingly important to the innovation efforts of firms in the food manufacturing and technology sector, this paper set out to examine the factors that influence their formation. Given the sector's reliance on a broad knowledge base, encompassing all three main types of knowledge, analytical, synthetic, and symbolic, (Zukauskaite and Moodysson 2016) the sector provides an interesting case study and further empirical insights into the factors that underpin the formation of U-I links.

The results make a timely contribution to the extant literature as they provide evidence that the formation of these U-I links result from a combination of organisational, spatial, and technological proximity The fact that prior ties are the most important factor meant that organisational proximity is the dominant factor in the formation of these links. Furthermore, the evidence of a curvi-linear relationship between spatial proximity and partner selection suggests that while distance is important, the firm does not just choose the closest partner, as beyond an optimal level of spatial proximity the probability of a linkage forming begins to decrease. Yet, while it has been argued elsewhere that the effect of spatial proximity may have been over-stated (del-Corte-Lora, Vallet-Bellmunt, and Molina-Morales 2017), the fact that it is still a significant determinant of U-I links for firms in this sector, as well as within the extant literature, shows that this factor is still important. Therefore, the results confirm previous findings within the extant literature around the importance of spatial proximity and its curvi-linear influence (D'Este, Guy, and Iammarino 2013; Giuliani and Arza 2009;

Hewitt-Dundas, Gkypali, and Roper 2019; Johnston and Huggins 2016a; Muscio 2013), suggesting that the open innovation practices of food manufacturing and technology firms are similar to others, despite the fact that their innovation practices are considered to be different (Capitanio, Coppola, and Pascucci 2010; Martinez and Briz 2000).

However, it is organisational proximity, manifested in the form of prior collaborations, that are the most important factor facilitating the creation of a U-I linkage. This finding, coupled with the importance of technological proximity, suggest that these relationships have a human element, i.e. it is important for the actors to be able to work in similar ways and possess similar expertise. This observation may result from the utilisation of synthetic and symbolic knowledge within the sector which requires close relationships between agents in order to understand their nuances and tacit dimension.

The importance of prior ties with a university coupled with the evidence that universities engaging in higher numbers of collaborative projects with the sector as a whole also have a positive effect on the formation of a U-I linkage, suggests that U-I links in the food sector may be more likely to be long term in nature. The evidence highlighting the importance of the specificity of a university's knowledge and networking activities in the development of U-I links in this sector, suggests that it is important for the firms to engage with a partner that is appropriate for their needs. As such, once an appropriate partner is identified, there may be an incentive to re-partner later.

These findings build on previous work that suggests that the influence of different types of proximity is driven by the underlying knowledge base of the sector (Mattes 2012). Accordingly, the observation of the importance of a range of proximities in food sector U-I links may reflect its broad knowledge base (Manniche and Testa 2010; Zukauskaite and

Moodysson 2016). Thus, there may be a need to understand the knowledge base of a sector in order to understand the drivers of the associated U-I links.

Indeed, the more general characteristics of a university, in terms of research intensity, the extent of a university's network and level of new knowledge creation, do not appear to influence affect the formation of U-I linkages directly, somewhat contrary to previous work in this area (D'Este, Guy, and Iammarino 2013; D'Este and Patel 2007; Johnston and Huggins 2016a). Again, these findings indicate that the formation of these U-I links are driven by a university's offer to the food sector rather than its overall capabilities. Therefore, the capability of a university to apply its knowledge to the food manufacturing and technology sectors appears to be driving the partner selection process in these cases. Firms appear to be looking for a potential signal that the knowledge they obtain through the collaboration will be able to be absorbed into the firm and utilised successfully. It is not the *prima face* characteristics of the university that are important, but its ability to produce relevant knowledge.

The analysis has set out several insights into the role of proximities in the formation U-I links between food manufacturing and technology firms and UK universities. While reiterating their importance, these finding also highlight the implicit importance of networking, both formal and informal, among individuals required (Huggins, Johnston, and Thompson 2012). While spatial proximity is straightforward to assess, either a university partner is physically close or not, in order to assess and develop organisational and technological proximity inter-personal interactions are required. Thus, the firm needs to possess a degree of social or network capital in order to develop these relationships and proximities (Huggins 2010; Huggins, Johnston, and Thompson 2012). In addition, the noted drawbacks to organisational and technological proximity, around the increased homogeneity of knowledge and reduced flexibility (Boschma 2005; Nooteboom 1999; Steinmo and Rasmussen 2016) suggests that

one potential drawback from these U-I relationships is that the firms may be in danger of becoming embedded in less productive relationships in the long run.

6. Conclusion

Motivated by previous findings that within the food manufacturing and technology sector the use of open innovation practices has increased, particularly those involving collaboration with universities, this paper set out to examine the factors that influence the formation of such links. The analysis demonstrates that that, for food manufacturing and technology firms, the factors driving the formation of U-I links are: the existence of organisational proximity, manifest in prior relationships between the two organisations, the spatial proximity of the partner university, and technological proximity, manifest in the ability of the university partner to engage with the sector through creating both pure and collaborative research funding in these areas. As such, the importance of the prior ties and levels of relevant research show that the process of U-I linkage formation is much more complex than merely minimising the distances between partners to facilitate collaboration. In addition, the non-linear relationship between spatial proximity and the formation of U-I links highlights the fact that there are limits to its influence in this process, echoing previous findings which highlight the existence of a curvi-linear relationship (D'Este, Guy, and Iammarino 2013; Johnston and Huggins 2016a).

Given that the food manufacturing and technology sector utilises knowledge that can encompass the three categories of analytical, synthetic, and symbolic, it provides an interesting case study in the formation of U-I links. As such, it is perhaps unsurprising that the findings suggest that multiple factors govern the formation of these links. Indeed, for this sector, the formation of U-I links is not merely a simple process of minimising physical distance between partners. Instead, the findings point to the fact that the formation of these

links is primarily based on the university partner having had previous experience of working with the firm itself or having previous experience of collaborating with other firms in the sector as well as undertaking research in the field relevant to the sector as well as being conveniently located in proximity to the firm.

Consequently, the broader implications for understanding the roles of universities in open innovation suggests that both spatial, relational, and technological influences are important. More generally, in terms of open innovation processes involving the collaboration between firms and universities, these results highlight the multiple role of proximities in facilitating U-I links (Agrawal, Kapur, and McHale 2008; Knoben and Oerlemans 2006; Perkmann and Walsh 2007).

There are several implications of these findings for the development of U-I links in the food sector. Firstly, from the perspective of firms in the sector, managers should focus on obtaining appropriate knowledge and expertise by seeking a partner that has previous experience with working with their sector. As such, it would be advisable for them to ignore general ranking metrics; instead, the focus should be on the specificity of knowledge to the food sector not the overall performance of the institution. Furthermore, while following this process is advisable, managers should be aware of the danger of being locked into unproductive ties in the long term (Geldes et al. 2015).

Secondly, from a university perspective, Technology Transfer Officers (TTOs) should aim to highlight the specificity of their institutions' knowledge base to the food sector in order to facilitate links. This will then allow them to take advantage of the sector's reliance upon organisational and technological proximity. This appears to be particularly relevant as the results clearly highlight the fact that that existing collaborative links between food sector firms and universities are not based on the overall research prowess of a university and its

ability to create new knowledge; instead, the findings suggest that their formation is facilitated by the ability to understand the applicability and specificity of university knowledge, i.e. the extent to which firms consider they can utilise it in their commercial endeavours. Finally, in terms of the implications of these findings for policymakers, it is suggested that when promoting the formation of U-I links there is a need to first understand the types of knowledge used by a sector. This will then enable the development and adoption of appropriate strategies and policies focussing on the exploitation of the appropriate type of proximity in the formation of the collaborative link (Mattes 2012).

The paper has some limitations that should be acknowledged. In particular, it is noted that these findings may be specific to firms in the food manufacturing and technology sector in the UK. Consequently, further confirmatory work is required in order to examine this sector within alternative contexts as well as with different sectors. Future research applying a similar methodology to other sectors, as well as other country contexts, is required in order to provide confirmatory evidence with which to assess the generalisability of the findings.

Notes:

[1]These three funding schemes are the main methods of funding U-I collaborations in the UK:

- The Knowledge Transfer Partnership (KTP) scheme provides public funding for collaborative projects undertaken by universities and other organisations from both the public, private, and third sectors. This scheme involves the recruitment of an 'associate', a graduate student to work within the organisation and dedicated specifically to the project in question. The partner organisation is eligible for one-third of the costs if an SME and half if a larger firm; the scheme is open to all disciplines.
- Collaborative R&D projects are designed to provide public funding to develop and test a new product or service. Grants vary from £25,000-£5million and can cover up to 60% of the project's costs. These grants are restricted to firms in the science, engineering and technology sectors and require firms to work with other organisations on the project, although a university partner is not compulsory.

- Feasibility Studies provide funding for firms to evaluate the potential of a project, prior to its undertaking it on a larger scale. The projects can be undertaken either individually or collaboratively, but do not require a university as a partner.

[2]Specialist institutions such as drama, dance, and music schools were excluded as potential partners as their areas of specialism are not relevant.

[3]The Research Assessment Exercise (RAE) and Research Evaluation Framework (REF) are methods of assessing the quality of published research outputs of UK academics. The RAE took place in 2008 and the REF in 2014; to be returned by their institution an academic is required to have published four pieces of work in peer-reviewed journals of national or international standing.

This research was undertaken in collaboration with the National Centre of Excellence for Food Engineering (NCEFE) at Sheffield Hallam University. The author wishes to thank them for their support for this project. The author would also like to thank the editor, Dr. Carlo Giglio, for his comments on earlier drafts, along with the two anonymous referees whose comments have allowed the paper to be strengthened considerably.

References

Abreu, M, Grinvich, V., Hughes, A., Kitson, M., and Ternouth, P. 2008. *Universities, Business and Knowledge Exchange*. London: The Council for Industry and Higher Education.

Acs, Z, L Anselin, and A Varga. 2002. "Patents and Innovation Counts as Measures of Regional Production of New Knowledge." *Research Policy* 21(7): 1069–85.

Agrawal, Ajay, Devesh Kapur, and John McHale. 2008. "How Do Spatial and Social Proximity Influence Knowledge Flows? Evidence from Patent Data." *Journal of Urban Economics* 64(2): 258–69.

Aguilera, A, V Lethiais, and A Rallet. 2012. "Spatial and Non-Spatial Proximities in Inter-Firm Relations: An Empirical Analysis." *Industry and Innovation* 19(3): 187–202.

Alam, Ian. 2006. "Removing the Fuzziness from the Fuzzy Front-End of Service Innovations through Customer Interactions." *Industrial Marketing Management* 35(4): 468–80.

Alfranca, Oscar, Ruth Rama, and Nicholas von Tunzelmann. 2002. "A Patent Analysis of Global Food and Beverage Firms: The Persistence of Innovation." *Agribusiness* 18(3): 349–68.

Ankrah, Samuel, and Omar AL-Tabbaa. 2015. "Universities–Industry Collaboration: A Systematic Review." *Scandinavian Journal of Management* Vol. 31, No. 3, pp. 387-408

Asheim, Bjorn, Lars Coenen, Jerker Moodysson, and Jan Vang. 2007. "Constructing Knowledge-Based Regional Advantage: Implications for Regional Innovation Policy." *International Journal of Entrepreneurship and Innovation Management* 7(2/3/4/5): pp.

140-155.

Audretsch, David B., Erik E. Lehmann, and Mike Wright. 2012. “Technology Transfer in a Global Economy.” *The Journal of Technology Transfer* 39(3): 301–12.

Avermaete, T., Viaene, J., Morgan, E., Pitts, E., Crawford, N. and Mahon, D 2004. “Determinants of Product and Process Innovation in Small Food Manufacturing Firms.” *Trends in Food Science & Technology* 15(10): 474–83.

Beckman, C M, P R Haunschild, and D J Phillips. 2004. “Friends or Strangers? Firm-Specific Uncertainty, Market Uncertainty, and Network Partner Selection.” *Organisation Science* 15(3): 259–75.

Bekkers, Rudi, and Isabel Maria Bodas Freitas. 2008. “Analysing Knowledge Transfer Channels between Universities and Industry: To What Degree Do Sectors Also Matter?” *Research Policy* 37(10): 1837–53.

Bigliardi, Barbara, and Francesco Galati. 2013. “Models of Adoption of Open Innovation within the Food Industry.” *Trends in Food Science & Technology* 30(1): 16–26.

Bishop, Kate, Pablo D’Este, and Andy Neely. 2011. “Gaining from Interactions with Universities: Multiple Methods for Nurturing Absorptive Capacity.” *Research Policy* 40(1): 30–40.

Bok, D. 2003. *Universities in the Marketplace: The Commercialization of Higher Education*. Princeton: Princeton University Press.

Boschma, Ron. 2005. “Proximity and Innovation: A Critical Assessment.” *Regional Studies* 39(1): 61–74.

Braun, S, and K. Hadwiger. 2011. “Knowledge Transfer from Research to Industry (SMEs) –

An Example from the Food Sector." *Trends in Food Science & Technology* 22 Supplement 1: S90–96.

Broekel, T, and R Boschma. 2012. "Knowledge Networks in the Dutch Aviation Industry: The Proximity Paradox." *Journal of Economic Geography* 12(2): 409–33.

Bruneel, Johan, Pablo D'Este, and Ammon Salter. 2010. "Investigating the Factors That Diminish the Barriers to University-Industry Collaboration." *Research Policy* 39(7): 858–68.

Capaldo, Antonio, and Antonio Messeni Petruzzelli. 2014. "Partner Geographic and Organizational Proximity and the Innovative Performance of Knowledge-Creating Alliances." *European Management Review* 11(1): 63–84.

Capello, R, and A Faggian. 2005. "Collective Learning and Relational Capital in Local Innovation Processes." *Regional Studies* 39(1): 75–87.

Capitanio, Fabian, Adele Coppola, and Stefano Pascucci. 2010. "Product and Process Innovation in the Italian Food Industry." *Agribusiness* 26(4): 503–18.

Carraresi, Laura, and Alessandro Banterle. 2015. "Agri-Food Competitive Performance in EU Countries: A Fifteen-Year Retrospective." *International Food and Agribusiness Management Review* 18(2): 37–62.

Charlot, S, and G Duranton. 2004. "Communication Externalities in Cities." *Journal of Urban Economics* 56(3): 581–613.

———. 2006. "Cities and Workplace Communication: Some Quantitative French Evidence." *Urban Studies* 43(8): 1365–94.

Chen, Hongjun, and Fuji Xie. 2018. "How Technological Proximity Affect Collaborative

Innovation? An Empirical Study of China's Beijing–Tianjin–Hebei Region." *Journal of Management Analytics* 5(4): 287–308.

Ciliberti, Stefano, Laura Carraresi, and Stefanie Bröring. 2016. "Drivers of Innovation in Italy: Food versus Pharmaceutical Industry" ed. Rosa Caiazza, Tiziana Volpe, John L. Sta. *British Food Journal* 118(6): 1292–1316.

Cohen, W M, and Daniel A Levinthal. 1990. "Absorptive Capacity: A New Perspective on Learning and Innovation." *Administrative Science Quarterly* 35(1): 128–52.

Cohen, Wesley M., Richard R. Nelson, and John P. Walsh. 2002. "Links and Impacts: The Influence of Public Research on Industrial R&D." *Management Science* 48(1): 1–23.

Crescenzi, R., Filppetti, A. and Iammarino, S. (2017) "Academic inventors: collaboration and proximity with industry" *Journal of Technology Transfer* Vol. 42 No. 4 pp. 730-762.

Criscuolo, Paola. 2005. "On the Road Again: Researcher Mobility inside the R&D Network." *Research Policy* 34(9): 1350–65.

D'Este, P., and P. Patel. 2007. "University-Industry Linkages in the UK: What Are the Factors Underlying the Variety of Interactions with Industry?" *Research Policy* 36(9): 1295–1313.

D'Este, P, and S Iammarino. 2010. "The Spatial Profile of University-Business Research Partnerships." *Papers in Regional Science* 89(2): 335–50.

D'Este, Pablo, Frederick Guy, and Simona Iammarino. 2013. "Shaping the Formation of University-Industry Research Collaborations: What Type of Proximity Does Really Matter?" *Journal of Economic Geography* 13(4): 537–58.

Debackere, Koenraad, and Reinhilde Veugelers. 2005. "The Role of Academic Technology

Transfer Organizations in Improving Industry Science Links." *Research Policy* 34(3): 321–42.

del-Corte-Lora, Víctor, Teresa M. Vallet-Bellmunt, and F. Xavier Molina-Morales. 2017. "How Network Position Interacts with the Relation between Creativity and Innovation in Clustered Firms." *European Planning Studies* 25(4): 561–82.

Department for Business Innovation and Skills. 2013. *A UK Strategy for Agricultural Technologies*. London: HM Government.

Department for Environment Food and Rural Affairs. 2018. *Food Statistics Pocketbook 2018*. London: Office for National Statistics.

Dowling, A. 2015. *The Dowling Review of Business-University Research Collaborations*. London: Department for Business Innovation and Skills.

Fitjar, Rune Dahl, and Martin Gjelsvik. 2018. "Why Do Firms Collaborate with Local Universities?" *Regional Studies* Vol. 52 No. 11 pp. 1525-1536.

Fitjar, Rune Dahl, Franz Huber, and Andrés Rodríguez-Pose. 2016. "Not Too Close, Not Too Far: Testing the Goldilocks Principle of 'Optimal' Distance in Innovation Networks." *Industry and Innovation* 23(6): 465–87.

Fontana, Roberto, Aldo Geuna, and Mireille Matt. 2006. "Factors Affecting University–Industry R&D Projects: The Importance of Searching, Screening and Signalling." *Research Policy* 35(2): 309–23.

Geldes, Cristian, Christian Felzensztein, Ekaterina Turkina, and Aurélia Durand. 2015. "How Does Proximity Affect Interfirm Marketing Cooperation? A Study of an Agribusiness Cluster." *Journal of Business Research* 68(2): 263–72.

Gibbons, M., Limoges, C., Nowotny, H., Schartzman, S., Scott, P and Trow, M. 1994. *The New Production of Knowledge*. London: SAGE Publications.

Gittelman, Michelle. 2007. "Does Geography Matter for Science-Based Firms? Epistemic Communities and the Geography of Research and Patenting in Biotechnology." *Organisation Science* 18(4): 724–41.

Giuliani, Elisa, and Valeria Arza. 2009. "What Drives the Formation of 'Valuable' University–Industry Linkages?" *Research Policy* 38(6): 906–21.

Gulati, R. 2007. *Managing Network Resources: Alliances, Affiliations and Other Relational Assets*. Oxford: Oxford University Press.

Hagerdoorn, J, A Link, and N Vonortas. 2000. "Research Partnerships." *Research Policy* Vol. 29 No. 4-5 pp. 567–86.

Hewitt-Dundas, Nola. 2011. "The Role of Proximity in University-Business Cooperation for Innovation." *The Journal of Technology Transfer* 38(2): 93–115.

———. 2012. "Research Intensity and Knowledge Transfer Activity in UK Universities." *Research Policy* 41(2): 262–75. http://www.sciencedirect.com/science/article/pii/S0048733311002058.

Hewitt-Dundas, Nola, Areti Gkypali, and Stephen Roper. 2019. "Does Learning from Prior Collaboration Help Firms to Overcome the 'Two-Worlds' Paradox in University-Business Collaboration?" *Research Policy* 48(5): 1310–22.

HM Government. 2017. *Industrial Strategy. Building a Britain Fit for the Future*. London: Department for Business, Engergy, and Industrial Strategy. www.gov.uk/beis.

Howells, J R L. 2002. "Tacit Knowledge, Innovation and Economic Geography." *Urban*

Studies 39(5–6): 871–84.

Huber, Franz. 2012a. "Do Clusters Really Matter for Innovation Practices in Information Technology? Questioning the Significance of Technological Knowledge Spillovers." *Journal of Economic Geography* 12(1): 107–26.

———. 2012b. "On the Role and Interrelationship of Spatial, Social and Cognitive Proximity: Personal Knowledge Relationships of R&D Workers in the Cambridge Information Technology Cluster." *Regional Studies* 46(9): 1169–82.

Huggins, R. 2010. "Forms of Network Resource: Knowledge Access and the Role of Inter-Firm Networks." *International Journal of Management Reviews* 12(3): 335–52.

Huggins, R, A Johnston, and R Steffenson. 2008. "Universities, Knowledge Networks and Regional Policy." *Cambridge Journal of Regions, Economy and Society* 2(1): 321–40.

Huggins, R, A Johnston, and C Stride. 2012. "Knowledge Networks and Universities: Locational and Organisational Aspects of Knowledge Transfer Interactions." *Entrepreneurship & Regional Development* 24(7–8): 475–502.

Huggins, R, A Johnston, and P Thompson. 2012. "Network Capital, Social Capital and Knowledge Flow: How the Nature of Inter-Organizational Networks Impacts on Innovation." *Industry and Innovation* 19(3): 203–32.

Johnston, Andrew, and Robert Huggins. 2016a. "Drivers of University-Industry Links: The Case of Knowledge Intensive Business Service Firms in Rural Locations." *Regional Studies* 50(8): 1330–45.

———. 2016b. "The Spatio-Relational Nature of Urban Innovation Systems: Universities, Knowledge Intensive Business Service Firms, and Collaborative Networks." *Journal of*

Urban Technology 23(1): 29–52.

———. 2018. “Partner Selection and University-Industry Linkages: Assessing Small Firms’ Initial Perceptions of the Credibility of Their Partners.” *Technovation* 78 pp. 15-26.

Kauffeld-Monz, M, and M Fritsch. 2013. “Who Are the Knowledge Brokers in Regional Systems of Innovation? A Multi-Actor Network Analysis.” *Regional Studies* 47(5): 669–85.

Knoben, J, and L Oerlemans. 2006. “Proximity and Inter-Organizational Collaboration: A Literature Review.” *International Journal of Management Reviews* 8(2): 71–89.

Kuttim, Merle. 2016. “The Role of Spatial and Non-Spatial Forms of Proximity in Knowledge Transfer.” *European Journal of Innovation Management* 19(4): 468–91.

Lambert, R. 2003. *Lambert Review of Business University Collaboration*. Norwich: HMSO.

Laredo, Philippe. 2007. “Revisiting the Third Mission of Universities: Toward a Renewed Categorization of University Activities?” *Higher Education Policy* 20(4): 441–56.

Laursen, K, T Reichstein, and A Salter. 2011. “Exploring the Effect of Geographical Proximity and University Quality on University-Industry Collaboration in the United Kingdom.” *Regional Studies* 45(4): 507–23.

Ben Letaifa, Soumaya, and Yves Rabeau. 2013. “Too Close to Collaborate? How Geographic Proximity Could Impede Entrepreneurship and Innovation.” *Journal of Business Research* 66(10): 2071–78.

Lööf, Hans, and Anders Broström. 2006. “Does Knowledge Diffusion between University and Industry Increase Innovativeness?” *The Journal of Technology Transfer* 33(1): 73–90.

Maietta, O. 2015. “Determinants of University–Firm R&D Collaboration and Its Impact on Innovation: A Perspective from a Low-Tech Industry.” *Research Policy* 44(7): 1341–59.

Mäkimattila, Martti, Timo Junell, and Tero Rantala. 2015. “Developing Collaboration Structures for University-Industry Interaction and Innovations” ed. Dr Carl Abbott and Professor James A. *European Journal of Innovation Management* 18(4): 451–70.

Malerba, Franco. 2002. “Sectoral Systems of Innovation and Production.” *Research Policy* 31(2): 247–64.

Manniche, Jesper, and Stefania Testa. 2010. “Knowledge Bases in Worlds of Production: The Case of the Food Industry.” *Industry & Innovation* 17(3): 263–84.

Mansfield, E. 1995. “Academic Research Underlying Industrial Innovations: Sources, Characteristics, and Financing.” *The Review of Economics and Statistics* 77(1): 55–65.

Martin, Roman. 2012. “Measuring Knowledge Bases in Swedish Regions.” *European Planning Studies* 20(9): 1569–82.

Martinez, M, and J Briz. 2000. “Innovation in the Spanish Food & Drink Industry.” *The International Food and Agribusiness Management Review* 3(2): 155–76.

Mattes, Jannika. 2012. “Dimensions of Proximity and Knowledge Bases: Innovation between Spatial and Non-Spatial Factors.” *Regional Studies* 46(8): 1085–99.

Montoya-Weiss, Mitzi M., and Tony M. O’Driscoll. 2000. “From Experience: Applying Performance Support Technology in the Fuzzy Front End.” *Journal of Product Innovation Management* 17(2): 143–61.

Moodysson, Jerker, Lars Coenen, and Bjørn Asheim. 2008. “Explaining Spatial Patterns of Innovation: Analytical and Synthetic Modes of Knowledge Creation in the Medicon

Valley Life-Science Cluster." *Environment and Planning A: Economy and Space* 40(5): 1040–56.

Morgan, Kevin. 2004. "The Exaggerated Death of Geography: Learning, Proximity and Territorial Innovation Systems." *Journal of Economic Geography* 4(1): 3–21.

Mueller, Pamela. 2006. "Exploring the Knowledge Filter: How Entrepreneurship and University-Industry Relationships Drive Economic Growth." *Research Policy* 35(10): 1499–1508.

Muscio, Alessandro. 2013. "University- industry Linkages: What Are the Determinants of Distance in Collaborations?*." *Papers in Regional Science* 92(4): 715–39.

Narin, Francis, Kimberly S. Hamilton, and Dominic Olivastro. 1997. "The Increasing Linkage between U.S. Technology and Public Science." *Research Policy* 26(3): 317–30.

National Centre for Universities and Business. 2015. *Leading Food 4.0: Growing University-Business Collaboration for the UK's Food Economy*. London: National Centre for Universities and Business.

Nooteboom, B. 1999. "Innovation, Learning and Industrial Organisation." *Cambridge Journal of Economics* 23(2): 127–50.

Oerlemans, L, and M Meeus. 2005. "Do Organizational and Spatial Proximity Impact on Firm Performance." *Regional Studies* 39(1): 89–104.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Brostrom, A., D'Este, P., Fini, R., Guena, A., Grimaldi, R., Hughes, A., Krabel, S., Kitson, M., Llerena, P., Lissoni., F., Salter, A., Sobrero, M. 2013. "Academic Engagement and Commercialisation: A Review of the Literature on University–Industry Relations." *Research Policy* 42(2):

423–42.

Perkmann, Markus, Zella King, and Stephen Pavelin. 2011. “Engaging Excellence? Effects of Faculty Quality on University Engagement with Industry.” *Research Policy* 40(4): 539–52.

Perkmann, Markus, and Kathryn Walsh. 2007. “University-Industry Relationships and Open Innovation: Towards a Research Agenda.” *International Journal of Management Reviews* 9(4): 259–80.

Petruzzelli, Antonio Messeni. 2011. “The Impact of Technological Relatedness, Prior Ties, and Geographical Distance on University–Industry Collaborations: A Joint-Patent Analysis.” *Technovation* 31(7): 309–19.

Pinheiro, Rómulo, Patricio V. Langa, and Attila Pausits. 2015. “The Institutionalization of Universities’ Third Mission: Introduction to the Special Issue.” *European Journal of Higher Education* 5(3): 227–32.

Ponds, R, F van Oort, and K Frenken. 2007. “The Geographical and Institutional Proximity of Research Collaboration.” *Papers in Regional Science* 86(3): 423–43.

Rossi, Federica. 2010. “The Governance of University- industry Knowledge Transfer.” *European Journal of Innovation Management* 13(2): 155–71.

Rutten, R, F Boekma, and E Kuijpers. 2003. “HEIs, Regions and the Knowledge-Based Economy.” In *Economic Geography of Higher Education: Knowledge Infrastructure and Learning Regions*, eds. R Rutten, F Boekma, and E Kuijpers. London: Routledge, 244–52.

Saguy, I S. 2011. “Paradigm Shifts in Academia and the Food Industry Required to Meet

Innovation Challenges." *Trends in Food Science & Technology* 22(9): 467–75.

Sarkar, Soumodip, and Ana I.A. Costa. 2008. "Dynamics of Open Innovation in the Food Industry." *Trends in Food Science & Technology* 19(11): 574–80.

Sonn, J W, and M Storper. 2008. "The Increasing Importance of Geographical Proximity in Knowledge Production: An Analysis of US Patent Citations, 1975 -1997." *Environment and Planning A* 40(5): 1020–39.

Steinmo, Marianne, and Einar Rasmussen. 2016. "How Firms Collaborate with Public Research Organizations: The Evolution of Proximity Dimensions in Successful Innovation Projects." *Journal of Business Research* 69(3): 1250–59.

Storper, M, and A Venables. 2004. "Buzz: Face-to-Face Contact and the Urban Economy." *Journal of Economic Geography* 4(4): 351–70.

Striukova, Ludmila, and Thierry Rayna. 2015. "University-Industry Knowledge Exchange" ed. Dr Carl Abbott and Professor James A. *European Journal of Innovation Management* 18(4): 471–92.

Tether, B S, Qian Cher Li, and A Mina. 2012. "Knowledge-Bases, Places, Spatial Configurations and the Performance of Knowledge-Intensive Professional Service Firms." *Journal of Economic Geography* 12(5): 969–1001.

Thursby, J G, R A Jensen, and M C Thursby. 2001. "Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major U.S. Universities." *Journal of Technology Transfer* 26(1–2): 59–70.

Thursby, J G, and M C Thursby. 2002. "Who Is Selling the Ivory Tower? Sources of Growth in University Licensing." *Management Science* 48(1): 90–104.

Torre, Andre, and Jean-Pierre Gilly. 2000. “On the Analytical Dimension of Proximity Dynamics.” *Regional Studies* 34(2): 169–80.

Torre, Andre, and Alain Rallet. 2005. “Proximity and Localization.” *Regional Studies* 39(1): 47–59.

Traill, W. Bruce, and Matthew Meulenberg. 2002. “Innovation in the Food Industry.” *Agribusiness* 18(1): 1–21.

Triguero, Ángela, David Córcoles, and María C. Cuerva. 2013. “Differences in Innovation Between Food and Manufacturing Firms: An Analysis of Persistence.” *Agribusiness* 29(3): 273–92.

Vick, Thais Elaine, and Maxine Robertson. 2018. “A Systematic Literature Review of UK University–Industry Collaboration for Knowledge Transfer: A Future Research Agenda.” *Science and Public Policy* 45(4): 579–90.

Wilson, T. 2012. *A Review of Business-University Collaboration*. London: Department for Business Innovation and Skills.

Wood, G A, and J B Parr. 2005. “Transaction Costs, Agglomeration Economies, and Industrial Location.” *Growth and Change* 36(1): 1–15.

Zukauskaite, Elena, and Jerker Moodysson. 2016. “Multiple Paths of Development: Knowledge Bases and Institutional Characteristics of the Swedish Food Sector.” *European Planning Studies* 24(3): 589–606.