A systematic literature review of UK university-industry collaboration for knowledge transfer: A future research agenda

Abstract

This systematic review establishes what is currently known and, more importantly, what is not known about knowledge transfer between UK universities and industry. The review focuses on four central measures related to university-industry (U-I) collaboration for knowledge transfer that have been previously identified in the literature: motivations; activities; barriers and outcomes. Different rationales underpin existing studies and we frame these using two perspectives; the socio-politic perspective and the contextual perspective. To date studies with a socio-political perspective have largely focused upon 'motivations' to engage in U-I collaboration but largely from academics' perspectives and tangible activities and outcomes have been the foci of the contextual perspective on KT but these have rarely been sector specific. We discuss these and other major findings in terms of policy implications for future research funding.

Keywords: Knowledge transfer; University-industry relations; United Kingdom; Technology transfer.

Introduction

Knowledge transfer (KT) between universities and industry (U-I) is seen as a priority area for research and innovation policy development across most countries (Kitagawa and Lightowler, 2013). There is considerable debate regarding aspects of this process, and different epistemic positions or ways of conceptualising knowledge also shape this research agenda (Evans and Scarbrough, 2014). Perkmann et al., (2013) have suggested four central measures (FCM) that characterise the process: (i) *activities* related to

knowledge transfer; (ii) *motivation* to develop university-industry links; (iii) *barriers* to knowledge transfer; and (iv) *outcomes* of the process and see these as key to directing future research.

Previous systematic reviews have also focused on: identifying firm/university characteristics and dominant aspects of collaboration (Agrawal, 2001; Ankrah and Al-Tabbaa, 2015) and recognizing distinctions between academic engagement and commercialization (Perkmann et al., 2013). This systematic review focuses on the FCM related to U-I links for KT in the UK (c.f. Perkmann et. al., 2013) to identify what is known and not known across each.

It differs from previous reviews in a number of ways. First, we believe that the FCM potentially differ across regions, economies and purpose of interaction and hence we draw upon this premise to delimit the review. For example, if the intention is to create an academic spin-off there is likely to be the need for intense interaction between universities and industry. Consequently, the barriers and motivations are likely to be quite dissimilar to other types of U-I collaboration. Hence one of the review strategies here was to remove studies where the anticipated outcome was a spin-off and focus upon efforts to practically engage in U-I KT. Second, we focused specifically on the UK because since the early 1990s, a number of policy initiatives introduced by successive governments have intended to further strengthen and enhance the quantity and quality of U-I links (Comunian, Taylor and Smith, 2014; Hewitt-Dundas, 2012; Calvert and Patel, 2003). Yet in spite of this, there have been few attempts to gather systematic data in order to analyse what has been the result of these policy initiatives or identify concrete issues that arise around the KT process in the UK. Hence we believe that this is the first review that covers the FCM of U-I collaboration for KT in the UK.

Third, in focusing upon the FCM we are able to classify existing studies across two perspectives, referred to as the socio-politic perspective and the problem-focused perspective in order to analyse both tangible and intangible aspects of KT. This is important as it has enabled us to develop a comprehensive analysis of the most frequent themes emerging from existing research and, in so doing identify gaps in our understanding of, and assumptions about the current conceptualisation of the process which we find lacking. This we argue is crucial to inform future policy directions in terms of a research agenda.

UK, as a world-leading economy with a globally recognised research-led higher education system, provides a strong context for this study. A number of recent UK Government reports have sought to increase awareness of the importance of knowledge transfer.

In 2007, the review of Government's science and innovation policy in the UK acknowledged the differentiation in the university sector and knowledge transfer activity (Hewitt-Dundas, 2012). The report stressed the importance of having a 'diversity of excellence' in the research base, distinguishing between 'research universities focusing on curiosity-driven research, teaching and knowledge transfer, and business-facing universities focusing on the equally important economic mission of professional teaching, user-driven research and problem-solving with local and regional companies' (HM Treasury, 2007, p.5). The recent Sainsbury Review uses selected indicators to illustrate the "dramatic increase in recent years in the amount of knowledge transfer from British Universities" (HM Treasury, 2007, p. 55).

KT is a strand of public policy that has developed and over the last 30 years is increasingly being seen as a priority area for research and innovation policy development in North America, Europe, and in many industrialized countries (European Commission, 2007).

Evidence on KT suggests there is still a gap when Europe is compared to the United States, even though the Knowledge Transfer Office (KTO) profession has been maturing all over Europe. While Europe performs better than Japan, we see a rising level in China that will become a fierce contender in the knowledge transfer landscape in the decades to come. Moreover, we see a significant heterogeneity in Europe. Although heterogeneity is present in the US as well, there exist significant differences between European countries, both in terms of the critical mass and professionalism of their KTO functions, such as in their performance, output and impact (Debackere et al., 2014).

At the UK policy level, research funding allocation, research policy, and the new research impact agenda remains centralized. In England and Scotland for example, we see similar sets of processes of incentivizing KT activities in parallel, underlined by common UK research and innovation policies, but also with diverging policy rationales. The spatial governance of higher education, research, and innovation policies in the UK is rather complex and asymmetrical. The provision of funding to support KT from the funding councils is relatively small compared to support for research and teaching (Kitagawa and Lightowler, 2012).

2. Background

We identified an array of concepts and definitions that have either been developed or drawn upon in existing research to characterise the KT process. Our review therefore grouped all of the following under the umbrella term *'knowledge transfer'* because in practice this is what the articles we reviewed had focused upon. These include the term itself (Ankrah, Burgess and Shaw, 2013; Rossi and Rosli, 2014; Lockett, Kerr and Robinson, 2008; Francis-Smythe, 2008) and: *technology transfer* (Lawson, 2013; Perkmann, King and Pavelin, 2011), *knowledge translation* (Evans and Scarbrough, 2014), *knowledge exchange* (Kitagawa and Lightowler, 2013; Hughes and Kitson, 2012;

Martinelli, Meyer and Tunzelmann, 2008), *knowledge sharing* (Dooley and Kirk, 2007), *complementarities among knowledge* (Crespi et al., 2011), *knowledge co-production* (Marcos and Denyer, 2012), *knowledge sourcing* (Hewitt-Dundas, 2013), *information transfer* (Gertner, Roberts and Charles, 2011), *absorptive capacity* (Sparrow et al., 2009; Bishop, D'este and Neely, 2011), *exploration* (Bishop, D'este and Neely, 2011), *exploitation* (D'este et al., 2012) and *open knowledge transfer* (Sharifi, Liu and Ismail, 2014). Notably some studies such as Martinelli, Meyer and Tunzelmann (2008) use both the terms 'technology' and 'knowledge' transfer interchangeably. Theoretically and empirically these are considered to be different concepts but having conducted this review we are confident that they were both used to mean the same process across U-I links.

What is evident across the majority of the studies reviewed, but appears to have often been neglected or overlooked, is the bi-directional knowledge flow across U-I links (D'este and Patel, 2007). Many recent studies of KT practices consider the policy conditions and dynamics which enable knowledge flows from academic researchers, to what are often referred to as 'knowledge users' within the industry sector (Kitagawa and Lightowler, 2013). Yet this study and others (Kitagawa and Lightowler, 2012) either use the term 'knowledge users' to refer to 'industry' or, implicitly and a priori, research has assumed that knowledge transfer is uni-directional. This is an overly simplistic assumption, based on a traditional broadcaster receiver model (Rogers, 1983) with academics pushing knowledge to passive industry 'users' which is now quite outdated in the UK's knowledge-based economy. In addition, many recent studies tend only to focus upon the actions and roles of individuals, especially academics in interpreting and constructing KT practices within U-I links which reinforces the notion of a uni-directional flow (Lam, 2011; D'este and Perkmann, 2011; Francis-Smythe, 2008; Tartari, Perkmann, Salter, 2014; D'este et al., 2012). Therefore, despite much research there is little currently

known about KT conceptualised as a bi-directional process or, indeed even the interpretations that are made of the KT process by industry stakeholders.

This gap in our understanding, in addition to the on-going ambiguity perpetuated by the multiple terms used to investigate 'KT' highlights that further research is required. Our systematic review elucidates these two key issues further and highlights other key issues by analysing the principal measures that have been used in UK empirical studies to date. The key issues we identified from existing studies on the FCM are:

1. Different channels/forms through which academic researchers interact with industry as an example of *activities* (e.g. D'este and Patel, 2007). These provide a more comprehensive picture of knowledge transfer channels, as opposed to solely focusing on academic patenting behaviour. There is abundant empirical evidence to suggest that the process of KT occurs through personnel mobility, informal contacts, consulting relationships, joint research projects etc., and that patenting and spin-offs actually play a comparatively small part in this process (Arundel and and Geuna, 2004; D'este and Patel, 2007).
2. Intrinsic and extrinsic motivational drivers and different types of stimuli to engage in a U-I link as an example of *motivations* (e.g. Lam, 2011; D'este and Perkmann, 2011). Different types of motivations have been attributed to university and industry actors for engaging in KT. Today's knowledge-based economy has shifted U-I links from sponsorship to partnership with on-going interaction as the focus (Ankrah, Burgess and Shaw, 2013). Simultaneously the proliferation of new knowledge has placed enormous resource pressures on individuals within universities, causing them to ally with industry for funding if they are to remain at the cutting edge in their fields.

3. The nature of the obstacles to collaboration, given that academia and industry are two different systems of knowledge production as an example of *barriers* (e.g. Bruneel, D'este and Salter, 2010). At the core of the barriers to U–I links are the different institutional norms governing public and private knowledge. Given these two different systems of knowledge production, U–I links are likely to be plagued with obstacles and weak attitudinal alignment. Understanding the perceived barriers to U–I links is important because it identifies the main challenges that emerge in the KT process (Dasgupta and David, 1994; Bruneel, D'este and Salter, 2010).

4. Assessing the 'value' of the full range of *outcomes* of U-I links in the short and long term is challenging. The actors engaged in the KT process often experience difficulties due to differing and incommensurate desired outcomes. In general, academics are focused upon research-based outcomes, while industry partners are more focused upon action-orientated outcomes (Henderson, McAdam and Leonard, 2006). Though there are studies highlighting beneficial results for both deriving from knowledge transfer as an example of *outcomes* (e.g. Ankrah et al., 2013).

We elaborate upon the implications of these key findings following our detailed synthesis of existing research in our final section. Next we discuss the methodological approach that was taken to conduct this systematic review.

3. Method

Differing from traditional narrative reviews, systematic reviews are increasingly being adopted in the social sciences (Burrows, 2000) and the management field (Ankrah and Al-Tabbaa, 2015) to ensure a reliable and rigorous process that reduces subjective bias and the risk of overlooking relevant literature. Within management research Tranfield et

al., (2003) suggest that findings should be articulated in two stages by firstly providing a detailed ‘descriptive analysis’ of the field; then reporting the findings of a ‘thematic analysis’, outlining that which is known and established as the core contribution, focusing on the extent to which consensus is shared across various themes, and secondly identifying key emerging themes for future research.

In order to do this we applied the following procedure. As a criterion of search and delimitation, we chose to focus on Knowledge Transfer (KT) and the management perspective only. The use of Boolean operators helped us to broaden our search by combining synonyms to appropriately cover the concept. We also used the truncation symbol and it allowed all ending variations to be searched. Our search contains many synonyms, historic terms and variants of search terms. Because of the lack of consensus on the keywords used for classifying articles on KT in U-I links, we combined keywords such as: transfer, alliance, collaboration, cooperation, relation, interaction, link and partnership.

The selection of the keywords was based on the KT process: the transfer of tangible and intellectual property, expertise, learning and skills between academia and the non-academic community. For academics, KT can be a way of gaining new perspectives on possible directions and approaches for research. This two-way exchange of KT does not necessarily imply that innovation occurs. For that reason, the keyword "innovation system" and its derivatives were not used. “Technology transfer” was used as a keyword because it is closely related to (and may arguably be considered a subset of) knowledge transfer.

Alternative options for studies that concentrate interest on the formation of spin-out business or the licensing of intellectual property (IP), based only on the outputs of university science and technology-related research could be to search for articles in the

field of science, technology and innovation and use keywords related to the national/regional innovation system, for example.

Firstly, all research published on this topic in journals (drawing upon the multiple terms offered earlier) from 1995 to 2015 were identified. This time period was selected as there has been a rapid intensification in the volume of U-I links since the 1980s, the largest increase occurring after the introduction of a number of major policy measures in the mid-1990s (Calvert and Patel, 2003).

We conducted an extensive search based on titles and abstracts of published, peer-reviewed articles held in two bibliographical databases services - SCOPUS and ProQuest (ABI-Inform Global) - using a series of keywords (see Appendix A) to ensure that all potentially relevant studies were identified. These databases were selected because they provide a widest coverage of the literature in the area under study. Additionally a manual search was performed in two key journals with the highest article counts from the database search (*Research Policy* and *Journal of Technology Transfer)*. This step was included because of the lack of consensus on the keywords used for classifying articles on KT in U-I links. These procedures yielded 638 results.

Studies were then selected according to eligibility criteria established using a three-step screening process:

1. Initially the titles and abstracts were examined to determine potentially relevant articles to include i.e. the articles discussed or reported upon one or more of the FCM. A manual search of the key journals was also performed considering titles and abstracts for judgments about inclusion. After removing duplicates, this procedure produced 113 results.
2. Following this, selected full-text articles were retrieved for a second-stage screening involving the application of the inclusion/exclusion criteria at a much

greater level of detail. The exclusion criteria eliminated irrelevant papers discarding non UK studies, research on spin-offs, literature reviews, non-empirical work and conference papers. This produced 56 results.

The tabulation technique was then applied (Miles and Huberman, 2008; Pawson, 2006). Each one of the 56 remaining articles was read repeatedly and major findings were synthesized by the authors, compiling the following information in a tabular form: 1) Authors 2) Research question 3) Data 4) Method 5) Variables/themes 6) Findings. Figure 1 illustrates the study selection procedures:

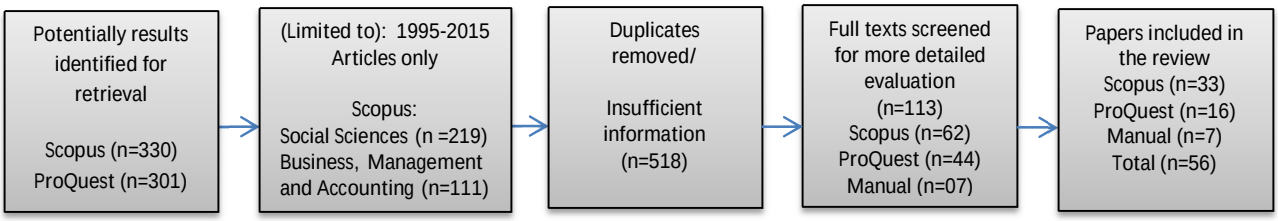

Fig. 1 - Study selection procedures

Following this two-stage reporting as advocated by Tranfield et al. (2003), we present both a descriptive analysis next i.e. findings and our thematic analysis within the discussion.

4. Findings

Here we largely focus upon data selection and the methodological approach that were adopted in the 56 KT studies we identified. In so doing it offers an opportunity to reflect upon, revise and/or consider a shift of methodological attention and data selection for future research and structure of KT research design, thus diminishing risks of publication bias.

As highlighted in Figure 2 the majority (70%) of articles were published from 2010 onwards, which reflects the current and growing interest of UK researchers in the FCM of KT.

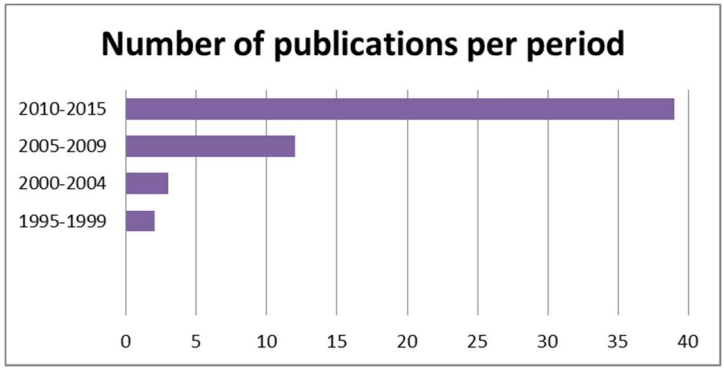

Fig. 2 - Articles published per period. (The graph includes 2015 from Jan. to Oct.).

Two journals (*Research Policy* and *The Journal of Technology Transfer*) stand out because they have published 21 of the 56 articles across a range of 30 journals. Research on the FCM has produced predominantly phenomenon-focused studies. We also identified 7 predominant UK investigators (see Table 1), and 2 different but complementary perspectives of analysis, which are explored further in the discussion.

24 studies collected data from both academia and industry actors whereas 27 studies drew upon data derived only from academics. 5 studies focused on analysing industry data. Additionally, the majority of studies focus upon academic scientists (Tartari, Salter and D'Este, 2012; Lam, 2011; D'Este and Perkmann, 2011; Lam, 2010; Tartari and Salter, 2015; D'Este et al., 2012, Francis-Smythe, 2008; Hughes, 2011), rather than KT at a departmental/university level (Perkmann, Kingb, and Pavelin, 2011; Abreu and Grinevich, 2013; Senker and Senker, 1997). Only one study has addressed the consequences of U-I links on science and engineering doctorates' careers (Lee and Miozzo, 2015). This suggests that until now the framing and focus in the UK has been on individual academics as a proxy for universities as the suppliers of knowledge and

industry collaborators as the users of that knowledge. This is now quite an outdated view of university industry collaboration which is more reminiscent of traditional mode 1 type knowledge production (Gibbons et al., 1994) and is surprising given that the vast majority of studies have occurred since 2005. A need to link the 'pull' from industry with the 'push' from research was highlighted some time ago by Lockett, Kerr and Robinson (2008) but this does not appear to have occurred.

Quantitative research also predominates representing 54% of all studies. A further 35% of studies were qualitative and 6 studies combined approaches. Hence the majority draw upon survey data and analysis is characterised by regression. Table 1 presents a breakdown of review articles by year, journal, leading authors and data type.

Synthesis of studies	Number of articles
1995-1999	2
2000-2004	3
2005-2009	12
2010-2015	39
Research Policy	15
The Journal of Technology Transfer	6
Technovation	3
International Journal of Entrepreneurial Behaviour & Research	3
Cambridge Journal of Economics	2
Studies in Higher Education	2
Regional Studies	2
Others	23
Total	56
P. D'este	8
A. Salter	6
M. Perkmann	4
V. Tartari	3
A. Lam	3
N. Lockett	3
S. Robinson	3
Quantitative data	30
Qualitative data	20
Mixed Methods (Quantitative & Qualitative)	6

Table 1 - Breakdown of articles according to: year, journal, leading author and data type

We also noted a relative lack of studies exploring one specific sector/discipline and its particularities. Only 15 studies focused on one discipline. 4 considered the life/health sciences (Dooley and Kirk, 2007; Swan et al., 2007; Jonga and Slavova, 2014; Evans and Scarbrough, 2014); 4 focused on consulting and business/management services (Marcos and Denyer, 2012; Henderson, McAdam and Leonard, 2006; Laursen and Salter, 2004); 3 focused on engineering (Perkmann and Walsh, 2009; Lawson, 2013a; Lawson, 2013b); and one focused upon the ICT sector (Lockett et al., 2009). Therefore almost 75% of studies were treating KT as a generic phenomenon across sectors. In the UK (and elsewhere) it is likely that the FCM found within the KT process will differ significantly. For example, organizations in different sectors have very different motivations for engaging with universities but there has been no comparative systematic analysis of these motivations and what the implications of this are for future policy making. Special attention could also be dedicated to some sectors in terms of analysing all FCM in sectors such as in the life/health sciences and the creative industries. Both represent major areas of interest for European policy-makers because of their contribution to national economic growth and both differ considerably in terms of the U-I links for KT.

Moreover, the emphasis to date has been on formal KT activities. Only 4 articles (Ankrah et al., 2013; Lockett, Kerr and Robinson, 2008; Johnston, Robinson and Lockett, 2010; Swan et al., 2007) have included an analysis of a range of intermediaries involved in UK U-I interactions situated within and outside university structures and key stakeholder organisations. The role of formal and informal relations draws attention to the different types of intermediaries that might influence KT. Wright et al., (2008) stated that the relevance of these different types of intermediaries and the importance of what is still considered to be ‘informal’ KT had been neglected and this appears to still be the case

today. A reconsideration of what constitutes KT in light of the importance of intermediaries in enabling KT is now therefore highly pertinent.

2 quantitative studies analysed data from collaborative grants awarded by the Engineering and Physical Sciences Research Council (EPSRC), and 2 studies have drawn upon Economic and Social Research Council (ESRC) datasets. It therefore appears to be a significant omission that there has been no published analyses of datasets available through grants awarded by the Arts and Humanities Research Council (AHRC), the Biotechnology & Biological Sciences Research Council (BBSRC), the Medical Research Council (MRC), the Natural Environment Research Council (NERC) or the Science and Technology Facilities Council (STFC), despite datasets being available. Datasets from the Higher Education Funding Council for Wales (HEFCW) and the Scottish Further Education Funding Council (SFEFC) were also only drawn upon in one piece of research conducted by Sharifi, Liu and Ismail (2014). Therefore to date there has been little exploitation of existing datasets that could potentially shed light on KT in the biomedical sector which is characterised by high levels of university industry collaboration and where significant Government investment has been made. The creative industries are also significant wealth generators in the UK (Chapain, Clifton and Comunian, 2013) and KT will naturally differ significantly in terms of the FCM from that of the life/health sciences sector, in terms of the types of stakeholders involved, size of industry player etc.

Notably, 9 articles drew specifically on data derived from the Higher Education-Business and Community Interaction (HE-BCI) Survey administered throughout the UK by the Higher Education Funding Council for England (HEFCE). Rossi and Rosli (2014) have recently highlighted some important limitations associated with the measurement of U-I KT performance in this survey. They emphasise that the choice of indicators is strongly oriented towards quantifying the outputs of KT activities, notably the income that has

been generated. Whilst this is clearly important in policy terms of assessing the financial impact of research funding, the characteristics and quality of the interactions through which KT takes place and the longevity of such collaborations have not been considered in relation to the overall financial impact. Research in this area could again generate important insights to inform policy direction and future funding arrangements.

The only indicators in the survey that aimed to capture some interactional aspects measure the number of contracts issued, partner 'types' and location in a unidirectional manner i.e. KT *from* universities *to* industry. As Rossi and Rosli (2014) point out universities that perform activities that are not specifically measured in this survey, or whose outputs may not be reflected correctly in terms of the income they generate, were therefore unable to correctly report upon their engagement in KT. Our systematic review corroborates these arguments. 16% of published studies in this review are based solely on analysing this dataset and more generally our review highlights that there has been a predominant focus on selecting and analysing quantitative datasets as highlighted in Table 2.

Data	Number of articles
Engineering and Physical Sciences Research Council (EPSRC)	12
Higher Education-Business and Community Interaction (HE-BCI) Survey	9
Research Assessment Exercise (RAE)	6
Higher Education Statistical Agency (HESA)	5
UK Innovation Survey (UKIS)	3
European Patent Office (EPO) Database	3
Economic and Social Research Council (ESRC)	2
Higher Education Funding Council for Wales (HEFCW)	1
Scottish Further Education Funding Council (SFEFC)	1

Table 2 – Quantitative data sources

Qualitative studies have tended to focus on specific, formal KT arrangements such as those associated with the Warwick Manufacturing Group (WMG), Faraday Partnerships, Surrey Research Park, CLAHRC's (Collaborations for Leadership in Applied Health

Research and Care), InfoLab21 (a Lancaster University initiative), or a single research-intensive university and there appears to be little or no published qualitative research on KT occurring at the individual/department level. It is also notable that only 2 qualitative studies (Barnes, Pashby and Gibbons, 2002; Marcos and Denyer, 2012) have included data from project documentation and participant observation of project meetings to supplement data derived from semi-structured interviews. Relying on single sources/key informants may not necessarily enable a substantive analysis of something as complex as KT at an institutional level to be fully explored. However several qualitative studies did focus upon, or included an analysis of the role of intermediaries situated within and outside university structures who were formally or informally enabling KT, which has not been considered at all in quantitative studies. Two studies also adopted a longitudinally approach to the study of KT (Lockett et al., 2009; Evans and Scarbrough, 2014). Such analyses are crucial if we are to further our understanding of changes or transitions over time across the FCM particularly for example, how barriers to KT might change over time. Longitudinal research has the potential to identify situation-specific barriers that emerge within the KT process and their importance is increasingly recognised as a significant method for policy evaluation (Perkmann et al., 2013).

5. Discussion

In reviewing all of the studies that were selected we identified two distinctive rationales underpinning the majority of studies which we characterise as either a socio-political or contextual perspective on KT.

Studies that have adopted a socio-political perspective focus unsurprisingly upon political and social factors influencing KT and largely consider more intangible aspects of the process. Those studies that have adopted a contextual perspective focus on contextual factors (e.g. breadth/type of interaction, degrees of collaboration, resources to manage

interactions, geographical proximity, industrial sectors, etc.) in order to build a better understanding and characterization of the U-I environment. Conceptually, it is important to highlight that we view these two perspectives as connected and complementary, both offering important insights into KT in the UK.

Next we present the findings from 35 of the 56 studies analysed around the 4 central measures from either of the perspectives we have identified since their findings directly address our research question. The purpose of this section is to synthesise the results from the most frequently emerging themes identified related to KT across U-I links.

5.1 Central measure 1 - Activities

Studies that adopted a socio-political perspective emphasised that KT was a social process and the key role played by boundary spanners or knowledge intermediaries that facilitate the process. This is stressed by Gertner, Roberts and Charles (2011) and others such as network intermediaries (Johnston, Robinson and Locket, 2010); the importance of formal boundary spanning positions within teams – knowledge broker positions (Evans and Scarbrough, 2014); key individuals as "boundary spanners" who work at the interstices of U-I activities providing 'knowledge spillover' effects (Swan et al., 2007); and "linked scientists" and the emergence of a hybrid space structured around the linked mobility of people (Lam, 2011). Prochorskaite (2014) reported a preference for networking and group-based activity over one-to-one consultancy.

From a contextual perspective numerous activities that comprise KT were identified in studies across particular sectors and other studies categorised activities occurring across U-I more generally related to KT. Abreu and Grinevich (2013) for example, highlighted the distinction between activities that are more informal and based on knowledge that is not easily protected with IP (intellectual property) and more formal activities. In a similar vein Hughes (2011) demonstrated that offering and receiving informal advice in order to

solve problems was the most frequent form of interaction in terms of KT in the UK. According to Crespi et al. (2011), researchers that are involved in some patenting activity are also involved in other forms of informal university–industry relationships, but researchers that specialize in patenting appear to devote little attention to the other more informal KT activities.

Laursen and Salter (2004) focused on the innovation activities of firms, and found that they are shaped by firms' internal strategies for knowledge exploration and exploitation. Hewitt-Dundas (2012) built a distinction between 'high research intensive and low research intensive' universities and was then able to characterise activities as high relational (e.g. collaborative research), medium relational (e.g. contract research and consultancy) and as low relational knowledge transfer activities (e.g. licensing and spin-outs). Perkmann and Walsh (2009) identified four types of U-I activity differing with respect to their "appliedness" (e.g. proximity to market): 1) problem solving, 2) technology development, 3) ideas testing, 4) knowledge generation.

Table 3 offers key distinctions between the ways in which KT activities have been analysed across the two perspectives. The evidence in this table suggests that most of the activities (i.e. problem-solving, commercialization) appear to be a one-way channel for knowledge transfer (KT). By its definition, KT means the two-way transfer of ideas, research results, expertise or skills between parties. Characterizing the activities for knowledge transfer has received lots of attention in the UK literature. What remains unanswered, for example however, is how/which of these activities could facilitate the process of knowledge exploitation i.e. knowledge transfer and adoption.

Socio-political Perspective	Contextual Perspective
• Network intermediaries • Flexibility • Openness and connectivity of network structures • Encouraging network participation • Building trust in relationships through mutual Understanding	• Problem-solving activities mediated through informal softer relationships • Offering and receiving informal advice - the most frequent form of activity Hughes (2011)

• Active network learning • Strengthening cooperation through capacity building • Culture change Johnston, Robinson and Lockett (2010) • Boundary spanning activities • Formal boundary spanning positions within teams • Knowledge broker positions Evans and Scarbrough (2014) • Key individuals who work at the interstices of KT activities 'knowledge spillover' effects • 'boundary spanners' who broker relationships across networks Swan et al., (2007) • boundary spanning roles of the KT partners in facilitating the knowledge transfer process Gertner, Roberts and Charles (2011) • 'boundary spanners' • pool of human resources • The 'linked scientists', whose work roles and careers span the two sectors Lam (2011) • Preference for networking and group-based activity over one-to-one consultancy (Prochorskaite, 2014).	• Informal activities based on transferring knowledge that is not easily IP protected are engaged in by older, more senior, male academics, who have access to more networks and tend to be less risk averse • Academics involved in more basic research and research in fields such as the physical sciences and engineering will tend towards more formal activities • More applied research, in the social sciences, creative arts and humanities, will favour more informal activities between U-I Abreu and Grinevich (2013) • Academic researchers involved in patenting activity are also involved in other forms of U-I relationships • Researchers that specialize in patenting devote less attention to the other KT activities (Crespi et al., 2011). • Direct contribution of universities to industrial practice is highly concentrated in a small number of industrial sectors (firms who have capability in R&D) • Being a large firm increases the probability of using university knowledge • KT activities of firms are shaped by internal strategies for knowledge exploration and exploitation (Laursen and Salter, 2004). • Academic staff in High Research Intensive universities perform more high relational (e.g. collaborative research), medium relational (e.g. contract research and consultancy) and low relational KT activities (e.g. licensing and spin-outs) Hewitt-Dundas (2012) • Types of activities differing with respect to their "appliedness": a) problem solving, b) technology development, c) ideas testing, d) knowledge generation Perkmann and Walsh's (2009)

Table 3 - Distinctions between analysis of KT activities across the two perspectives

5.2 Central measure 2 - Motivations

The difficulties inherent in collaborative research lay not with the approach itself but with the motives and behaviours of the actors involved argue Marcos and Denyer (2012). The discussions raised by these authors from a socio-political perspective were the differing motivations of academic scientists and industry. Lam (2011) as well as Tartari, Perkmann and Salter (2014) investigated academic's motivations and found that there is a primacy of self-motivation rather than external regulation. Academics are driven by the competition for professional status and achievement (Tartari, Perkmann and Salter, 2014) and reputational/career rewards in their commercial pursuits. The financial rewards are seen as important only by a small minority (Lam, 2011). A further motivation of course

highlighted by D'Este and Perkmann (2011) is that most academics engage with industry to further their research rather than commercialise it.

From the industry perspective motivations or lack of motivation rested on the issue of trust. Huggins and Kitagawa (2012) emphasized that innovation policy should include broader elements of U-I 'proximity' than simply geography. Specifically addressing the motivations of small businesses to engage in KT, Darabi and Clark (2012) revealed that customisation of the relationship can help to manage the expectations of small firms. This can increase their confidence and lead to higher levels of trust around working with academics.

From the contextual perspective the majority of studies reported geographical proximity as a driving force for U-I interaction. According to D'Este, Guy and Iammarino (2012), it makes U-I research partnerships more likely and it is crucial for assessing problem-solving as an important benefit (Cook, Bhamra and Lemon, 2006). In addition, Helmers and Rogers (2015) indicate that close proximity to universities motivates and benefits small firms, but not necessarily large firms. Consistent with this finding, work by Laursen, Reichstein and Salter (2011) shows that for firms with high levels of absorptive capacity, geographical proximity is of less concern when selecting a university to collaborate on a project. Preceding this research Vedovello (1997) stressed almost 20 years ago that geographical proximity is the driving force for informal links. Formal links develop through more obvious factors such as the academic expertise and technical ability the universities possess.

Table 4 highlights the distinctions regarding motivations across the two perspectives. The overall evidence in this table suggests that geographical proximity is not a sufficient condition for the formation of U-I connections. Howells, Ramlogan and Cheng (2012), emphasise that in the UK universities remain poor status providers as sources of

information for innovation or as collaborative partners. Customers and clients, followed by suppliers are still considered the most important sources of information about innovation. Customisation of the U-I relationship is an example of 'knowledge proximity' rather than geographical. Therefore further research is required into what is necessary for the dialogue (common language), maintenance (pre-defined and shared goals), and fortification (mutual benefits) of the U-I links.

Socio-political Perspective	Contextual Perspective
• Problems inherent in collaborative research lie with the motives and behaviours of the actors involved Marcos and Denyer (2012) • Regional contexts as an influencing factor on the economic and innovative performance of universities • Science and innovation policy should include broader elements of 'proximity' than a geographical one Huggins and Kitagawa (2012) • Reasons for U-I links are associated with human resource management and service-related activities. This is higher than the proportions reporting that interactions were driven by the innovation-related activities According to Hughes (2011) • Mutual understanding and customisation of the relationship in order to manage the expectations of SMEs Darabi and Clark (2012) • 'Pro-social' motivation • The great majority of the scientists are motivated by the reputational/career rewards in their commercial pursuits. Lam (2011) • Salience of enjoyment-based intrinsic motivation among the 'entrepreneurial' scientists • Self-motivation rather than external regulation in driving commercial behaviour • Competition for professional status and achievement as a motivation for academic scientists' to collaborate with industrial users of their research (Tartari, Perkmann and Salter, 2014) • Academics engage with industry to further their research rather than to commercialise their knowledge D'Este and Perkmann (2011)	• Universities remain poor status providers as sources for information on innovation and as collaborative partners in the innovation process • Customers and clients, followed by suppliers are the most important sources of information about innovation Howells, Ramlogan and Cheng (2012) • Geographical proximity and prior joint experience makes U-I research partnerships more likely D'Este, Guy and Iammarino (2012) • 'Proximity' as a motivation • Smaller firms benefit from close proximity to universities, but large firms do not • Less innovative large firms and weaker research universities are located in the same geographical area more by accident • More innovative large firms and world-class research universities co-locate Helmers and Rogers (2015) • Geographical proximity is of less concern when choosing a university partner to collaborate on an innovation project for firms with high levels of absorptive capacity (Laursen, Reichstein and Salter, 2011). • Geographical proximity is crucial for assessing problem-solving as an important benefit • Interactions with top quality universities have a positive influence on the benefits associated with firms' downstream activities Cook, Bhamra and Lemon (2006) • Geographical proximity between universities and firms is a motivation for informal links Vedovello (1997)

Table 4 - Distinctions between motivations across the two perspectives

5.3 Central measure 3 – Barriers

From a socio-political perspective barriers have been studied in terms of knowledge boundaries (Swan et al., 2007; Lockett, Kerr and Robinson, 2008) and institutional and individual barriers (Francis-Smythe, 2008).

Knowledge boundaries are related to high novelty areas and in terms of U-I links here prior experience did not exist (Swan et al., 2007). Additionally, the status of knowledge transfer activities as a "third mission" is also considered as a constraint (Lockett, Kerr and Robinson, 2008). The lack of time and incentives were mentioned as individual barriers, while the lack of reward/incentive/investment and bureaucracy were measured as institutional barriers (Francis-Smythe, 2008).

From a contextual perspective two significant distinctions were made by Bruneel, D'Este and Salter (2010) and Tartari, Salter and D'Este (2012) between orientation-related barriers (differences in incentives and orientation) and transaction-related barriers (potential conflicts between university and industry over intellectual property and university regulations). Both small and large firms indicate that they face more transaction-related barriers. In contrast, academics perceive orientation-related barriers as greater but these are naturally lower for academics with entrepreneurial experience and for those who trust their industry partners. Internal capability to manage interactions and handling university bureaucracy were highlighted by Hughes (2011) and Hughes and Kitson (2012) as a significant barrier for industry.

Table 5 presents the way in which barriers have been researched across the two perspectives. It is important to highlight here that most of the research to date has explores barriers within either an unspecified context or a very particular type of U-I interaction. No studies have attempted to compare and contrast barriers across various types of U-I activities. For instance, in commercialisation activities (patenting, spin-out companies, licensed research), some barriers will have specific implications, which are not

comparable to barriers across other types of U-I link such as joint research, contract research or consultancy services.

Socio-political Perspective	Contextual Perspective
• KT barriers arise in situations of high novelty: • In the development of radical innovations • In situations where the parties involved need to combine their expertise, but have not worked together before Swan et al. (2007) • Lack of time • Lack of incentives • Status of KT as 'third mission' • Intellectual property rights • Perceptions of academics that technology transferred is not 'cutting edge' Lockett, Kerr and Robinson (2008) • Institutional barriers: lack of reward/incentives for department; • Lack of investment in core academic/research KT staffing (i.e. mostly project-based) • Bureaucracy (form-filling) required to engage in KT processes • Individual barriers: academics' time available to pursue KT is too fragmented • Lack of academics' time to engage in KT • Lack of reward/incentives for academics • Mismatch of academic and commercial timescales Francis-Smythe (2008)	• Businesses consider that they lack the internal resources to manage interactions with universities/academics • Universities are concerned about the problems of university bureaucracy Hughes and Kitson (2012) • The most frequently cited factors constraining interactions are not university-based. They are largely to do with the lack of resources in the firm to manage the interaction Hughes (2011) • Differences between SMEs and large companies are relatively small, with both types of firms indicating that orientation-related barriers (differences in incentives and orientation) are lower than transaction-related barriers (conflicts over intellectual property and university administration procedures) • Prior experience of collaboration lowers orientation related barriers and a greater level of trust reduces the impact of both types of barrier • Breadth of interaction diminishes the orientation-related, but increases transaction-related barriers • Interactions that involve informal and frequent face-to-face contacts contribute significantly to attenuating the orientation-related barriers, while broader interactions (both education and contract-based) increase the extent of transaction-related barriers Bruneel, D'Este and Salter (2010) • Orientation barriers are more strongly perceived by academics than transaction barriers (conflicts between university and industry over IP and university regulations) • 'Short-term time horizons of industry partners' • 'Lack of suitable partners' • Conflicts over IP and the rules and regulations only seem to afflict a minority of academics. Tartari, Salter and D'Este (2012)

Table 5 - Distinctions between barriers across the two perspectives

5.4 Central measure 4 – Outcomes

After analysing the results of previous research from a socio-political perspective perhaps the most important finding from this review relates to the lack of research regarding the relatively intangible outcomes from U-I links i.e. ideas for new projects, opportunities or opening up of entire new areas for research or, importantly, negative outcomes. Only two studies have considered these. Rossi and Rosli (2014) analysed the indicators included in the HE-BCI survey and stressed some limitations with current approaches to the measurement of university-industry KT performance, highlighting that they are restricted to only quantifying the outputs of KT activities. This need for studies exploring intangible

outcomes could well point to the over-emphasis placed on 'knowledge products' and may explain why overall knowledge/technology transfer do not seem to be viewed as very effective across this systematic review. Evaluating the knowledge transfer process by looking for tangible outcomes is perhaps looking in the wrong place (Ankrah et al., 2013). They identified beneficial outcomes for both academia and industry by categorising outcomes as institutional, economic and social.

Within the contextual perspective, the majority of studies have a shared emphasis on research-based outcomes/publications (Banal-Estañol, Jofre-Boneta and Lawson, 2015; Banal- Estañol, Macho-Stadler and Pérez-Castrillo, 2013; Henderson, McAdam and Leonard, 2006; Perkmann and Walsh, 2009; Lee and Miozzo, 2015). This review has also highlighted that existing studies have focused on applied outcomes from U-I links and outcomes that have not necessarily resulted in publications are likely to be significantly under-represented.

Socio-political Perspective	Contextual Perspective
• Higher Education–Business and Community Interaction (HE-BCI) survey - the choice of indicators is strongly oriented towards quantifying the outputs of KT activities, especially the income received from them • The characteristics and quality of the interactions through which KT takes place (for example their duration, the number of partner organisations and people involved, the partners' satisfaction with the interactions, their perception of what they learned from the interactions and the short- and long-term benefits they received) are not considered. Rossi and Rosli (2014) • Common beneficial outcomes for both actors: • Patents • Business opportunities • Public grant • Access to new technological developments • Publications • Contribute to economic development • Enhancement of reputation • The highest levels of beneficial outcomes are institutional, and economic and social outcomes were less beneficial Ankrah et al. (2013)	• Doctoral projects with industrial involvement have reduced scientific productivity in terms of publications Lee and Miozzo (2015) • Joint research with industry often results in academic publications while this is less true for relationships with more applied objectives, such as contract research and consulting • More basic projects are more likely to generate academic output; they also offer fewer cross-boundary learning opportunities Perkmann and Walsh (2009) • Collaborating with firms that have a high average scientific level and that have similar interest to the researchers improves the research output of government grants. Banal-Estañol, Macho-Stadler and Pérez-Castrillo (2013) • The number of publications increases both with the presence of EPSRC funding and with the fraction of EPSRC funding in collaboration with industry, but only up to a certain point • For degrees of collaboration above 30–40%, research output declines • There are degrees of collaboration that may be excessive in the sense of being detrimental in terms of research productivity • High degrees of collaboration can also bring gains in terms of patenting or better employment prospects for graduates Banal-Estañol, Jofre-Boneta and Lawson (2015)

Table 6 - Distinctions between outcomes across the two perspectives

In summary the analysis also highlighted that far more research has been conducted on motivations to engage in U-I links within the socio-political perspective and this research has been primarily qualitative. Outcomes have largely been researched quantitatively from the contextual perspective and overall most studies have not been sector specific.

6. Final considerations and a future research agenda

In this paper we sought to provide a twofold contribution from our systematic review by firstly developing a descriptive analysis of the overarching emphasis in prior research and to define the methodologies that have been used to investigate U-I links for KT, highlighting pertinent issues here. Secondly we provided a thematic analysis of the content of published evidence. We have highlighted the two overarching rationales that have underpinned existing studies and, within each their major findings. The discussion has provided key insights which future policies/funding and research needs to address if U-I links for KT are to be better understood and promoted. To conclude therefore we point out some key issues that remain un- or under-investigated which we believe should guide future policy and research.

In terms of our descriptive analysis it is clear that there already exist numerous datasets held by a number of major research councils that could be interrogated in order to better understand sector specific issues around U-I links. This is an important gap in existing research in this field that urgently needs to be addressed. Developing and more importantly maintaining U-I links for KT is not a standardised process across sectors and industries and future policies need to be tailored especially with regard to high value creation sectors such as the creative industries and biomedical sectors where the 4 central measures for KT will inevitably differ significantly. Our descriptive analysis also highlighted that in order to develop a better understanding of the *effectiveness* of KT practices over time, future research should be directed at numerous qualitative aspects of

KT. Whilst these aspects are likely to be measured through attitudinal data obtained both quantitatively (via surveys) and qualitatively through interviews, the data could then be combined with more tangible outcome measures to also include a qualitative assessment of feedback effects of these practices (i.e. a bi-directional analysis). The collection and analyses of such datasets could provide much stronger indications of the potential for universities and industry to engage in longer term, on-going KT arrangements without the need for Government funding than the findings from current studies offer and this is something that UK policy makers have long grappled with.

Reinforcing this point our thematic analysis across the 4 FCM highlighted that research on *activities* has to date largely assumed and investigated KT a uni rather than bi-directional process of KT. Future funded studies should explore the two-way transfer of ideas, research results, expertise and/or skills that occurs in U-I links and consider what facets of the process better enable knowledge creation. Future research here could also investigate which specific types of links/activities also facilitate the further process of knowledge exploitation and adoption as part of the process of collaboration. The important role that informal advice plays in KT, what forms it takes and access to informal advice etc. all require far more investigation and are key issues for future research, specifically in terms of correlation with positive outcomes.

Further research is also required on motivations to engage in U-I links, specifically the notion of proximity in terms of formal and informal communication channels, the importance of informal relations (a priori) and the role of internal and external intermediaries in the processes of KT. All of these facets of the process have been shown to play important roles in KT but to date there has been very little research on each or indeed their cumulative role. These aspects together with barriers to the development of U-I links for KT require future research to adopt a longitudinal approach in order to

investigate KT as a process influenced by multiple factors over time. Considerable policy emphasis and funding has been targeted at developing U-I links but the majority that occur in the UK exist only in the short term. What barriers therefore exist to the establishment of long term U-I links that characterise the research landscape in other countries? In addition, longitudinal research should also be funded to identify context specific barriers as this is a major omission currently.

Finally, it is necessary to better define both intangible or 'less tangible' outcomes in U-I links and their importance. Future investigations could focus on revealing the significance of outcomes like ideas for new projects, opportunities or opening up of entire new areas for research, or even negative outcomes. U-I links that are more applied in nature and do not necessarily result in publications should also be explored. Both of these areas could be explored in terms of the tangible benefits that ultimately accrue again signalling the way for far more process orientated longitudinal research. As a final point, we cannot over emphasise the relative lack of attention that has been paid in previous research to industry views on what constitutes the benefits from U-I links. Until we have more substantive qualitative and quantitative investigation of sector specific requirements, expectations and examples of successful collaborations, policy efforts and funding to promote collaboration are only ever going to be partial and constrained.

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Appendix A

Keyword combinations for advanced searches:

('university-industry' OR 'academi*' AND 'transfer*' AND 'UK' OR 'United Kingdom')

('universit*' OR 'academi*' OR 'higher educational institution' AND 'business' OR 'industr*' OR 'firm*' AND 'UK' OR 'United Kingdom')

(‘alliance*’, OR ‘collaboration*’ OR ‘cooperation*’ OR ‘relation*’ AND ‘technology transfer’ OR ‘knowledge transfer’ AND ‘UK’ OR ‘United Kingdom’)

(‘academi*’ OR ‘university*’ AND ‘industry’ AND ‘interaction*’ OR ‘link*’ OR ‘partnership*’ AND ‘UK’ OR ‘United Kingdom’)