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RESEARCH PAPER

University–industry linkages in the UK: emerging themes and 'unanswered' questions

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With university–industry engagement forming an integral part of the policy agenda, this paper underlines current issues and emerging themes in the dedicated literature. It utilises a comprehensive literature review, based on evidence from peer-reviewed journals/public reports published after 2005 in the UK. The paper integrates a wide range of disparate studies on university–industry knowledge transfer patterns, determinants and impacts, and offers a panorama that could be useful to inform on the variety of issues underlying knowledge transfer. Given the importance/complexity of university–industry interactions, a comprehensive study fills an existing gap. Second, due to its focus on current issues, the study opens the way to reflections and debates on critically 'unanswered' questions: how to deal with diversity/heterogeneity? How to increase quality in supply/quantity in demand for knowledge? How to increase impact on academics, universities, firms, economy and society?

Introduction

There is much evidence of the success of UK higher education on an internationally comparative scale and of the spectacular growth in the number and variety of linkages between higher education institutions (HEIs) and industry. The last data collected from the Higher Education–Business and Community Interaction Survey (HE–BCI) highlight an increase in the overall exchange of knowledge between UK HEIs and the public, private and third sectors, despite the crisis and uncertainty in the economy. The growth rate, financially, for the UK is 5%, from 3401 million in 2011–12 to 3570 million in 2012–13 (HEFCE, 2014a). Yet within the UK there is significant variation in the wealth and knowledge generation capabilities of the various universities, with some even arguing that universities cannot shoulder the burden for transforming the innovation capabilities of their regions (Huggins *et al*., 2008).

Measures to encourage university–industry interaction have a long history in the UK. The early 1980s saw the formation of the Alvey Programme as a significant attempt to ensure that UK industry and academia caught up with the US and Japanese lead in areas of IT (Charles *et al*., 2005). The 1990s saw an increased focus by the UK government on the impact of interactions between universities and business, with the introduction of the 'Realizing Our Potential' report (HMSO, 1993). Separate initiatives since then have provided funds for universities to invest in different types of knowledge transfer projects (Abreu *et al*., 2008). Third stream funding for the

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higher education sector began in 1999, with the introduction of funds specifically to support HEIs to increase their capability to respond to the needs of business and the wider community. Programmes such as 'University Challenge' and Higher Education Reach Out to Business and Community (HEROBC) illustrate the government's concern. With the Higher Education Innovation Funding (HEIF) that began in 2001, the government has largely supported a broad range of knowledge exchange activities and a significant culture change in higher education to embrace third stream working (PACEC/CBR, 2009). However, the Roberts Review of Skills (HM Treasury, 2002) recommended to both business people and higher education institutions to increase interactions, especially in science and engineering fields, while the Lambert *Review of Business–University Collaboration* (2003) suggested simpler and more predictable actions to bring academics and business together. Consequently, the government's Science and Innovation Investment Framework in July 2004 announced commitment to long-term funding for the third stream (HM Treasury, 2004). The Leitch Review of Skills (2006), the 'Sainsbury Review' (2007), the 'Innovation Nation' White Paper (DIUS, 2008) and the 'Higher Ambitions' framework (BIS, 2009) have all reaffirmed the need for stronger long-term relationships between business and universities, be it for skill improvement or fostering innovation. More recently, the Wilson Review (2012) and Sir Witty's Review of Universities and Growth (2013) made a number of recommendations to help UK business–university collaboration become a 'world leader' and encourage a British Invention Revolution.

Currently, there is a complex mixture of national and local support measures to encourage university–industry interactions, some evolving from previous programmes, some having continued over many years. The Department for Business, Innovation and Skills (BIS) granted the Higher Education Funding Council for England (HEFCE) a total £5.1 billion for financial year 2013–14 to support – among others – knowledge exchange and skills, mainly through the HEIF and the Workforce Development Programme (HEFCE, 2014b). In their turn, the Research Councils UK (RCUK) and the Technology Strategy Board (TSB) offer knowledge transfer schemes and collaborative research opportunities to universities and business, to help transform their results into innovative ideas. Many other organisations such as the National Centre for Universities and Business (NCUB), the Association for University Research and Industry Links (AURIL), the Institute for Knowledge Transfer (IKT), the Intellectual Property Office (IPO), Praxis–UNICO or the Local Enterprise Partnership Network (LEP) are also offering their support interactions. Appendix 1 offers a snapshot view of the main support structures/organisations and funding streams for university–industry linkages in the UK, while providing a short description of their roles and purpose.

This enormous knowledge exchange infrastructure, together with special attention paid to the third stream mission of universities, has led to various advancements and to an extensive literature and public debate around university–industry cooperation. This paper aims to highlight a number of emerging themes in the literature dedicated to the study of university–industry linkages in the UK that are high on the recent public agenda. The main contribution of the paper is that it integrates a wide range of disparate studies, offering a panorama on the variety of issues underlying knowledge transfer in the UK, while simultaneously highlighting a number of crucial 'unanswered' questions. To offer a broader perspective over the present literature, the first part of the study introduces the conceptual framework and the methodology, whilst in the second part seven key themes arising from the research are discussed.

Finally, the paper underlines current 'unanswered questions' that emerge from a transversal analysis of a wide range of disparate studies on university–industry engagements. Due to its comprehensive nature, this study could inform both those inside and outside the UK system about the variety of issues that should be considered in the knowledge transfer debate, and, by doing so, it fills a gap in the existing literature. At the same time, it furthers research directions and opens the way to reflections and debates on future actions.

Contextual framework and research method

The theoretical framework underlying university–industry links was highly influenced by economic and social developments, especially towards the end of the twentieth century. The transition to a knowledge-based society has led to the so-called 'second academic revolution' (Etzkowitz *et al*., 2000) and higher education institutions were/are expected to formalise a *third mission* and to generate, use and exploit their capabilities *outside* the university, through continuous interactions with the rest of society (Molas-Gallart *et al*., 2002). Etzkowitz (1983) coined the phrase 'entrepreneurial university' to describe the series of changes that reflect the more active role universities have taken in promoting direct and active transfer of academic knowledge. In turn, Clark (1998) profiled the entrepreneurial university as an institution with modernised strategies and structures to meet new societal expectations. In this context, universities interact with industry (businesses) and the government in the so-called Triple Helix Model and the synergies between the three institutional spheres are meant to generate wealth on the market by industry, normative control by government and novelty production in academia (Leydesdorff and Meyer, 2006).

Over the last decades, a huge variety of literature has been produced around university–industry linkages. Despite heterogeneity, previous studies attempting to provide a comprehensive literature review of university–business interactions and/or a conceptual framework have identified a number of key streams of research on this topic (Table 1).

Based on these findings, we have developed a simple conceptual framework to help investigate university–industry linkages in the UK. Figure 1 introduces the seven key research themes of our current study.

To answer the questions deriving from the above conceptual framework, this paper utilises a descriptive literature review process (Fink, 1998). The papers reviewed were selected from high-impact international databases, namely Web of Science, Web of Knowledge, ISI Proceeding, EBSCO–Business Source Complete, Academic Search Complete, Educational Resources Information (ERIC) and SCOPUS (Social Sciences and Humanities). Complementary information was taken from UK innovation surveys, benchmarking studies, surveys of academics, case studies, evaluation reports, policy papers, etc.

Articles were filtered through two eligibility screens. The practical screen identified studies that: (i) covered the topic of the university (academic/higher education/science)–industry (business, SMEs) AND linkages/partnerships/relationships/collaboration/knowledge transfer in different combinations, dictions and truncations; (ii) in Abstracts/Summaries; (iii) published after 2005 (to keep the focus on current issues); (iv) for UK/Great Britain. The quality screen filtered for studies using exclusively the *peer-reviewed journals* criterion. For complementary

Table 1. Key streams of research on university–business linkages

Author(s)	Research topics
Agrawal (2001) University-to-industry knowledge transfer: literature review and unanswered questions	(1) **channels of knowledge transfer** (e.g. relative importance of various transfer pathways between universities and firms, such as publications, patents and consulting); (2) **firm characteristics** (company issues, such as internal organisation, resource allocation and partnerships); (3) **university characteristics** (issues relating to the university, such as licensing strategies, incentives for professors to patent, and policies such as taking equity in return for intellectual property); (4) **the geography in terms of localised spillovers** (the spatial relationship between firms and universities relative to performance in terms of knowledge transfer success).
Ankrah (2007) University–industry interorganisational relationships for technology/knowledge transfer: a systematic literature review	(1) **organisational forms of university–industry interorganisational relationships (U–I IORs)**: personal informal relationship, personal formal relationship, third party, formal targeted agreements, formal non-targeted agreements, focused structures; (2) **motivations for U–I IORs**: necessity, asymmetry, reciprocity, efficiency, stability, legitimacy; (3) **formation of U–I IORs**: define IOR, identify partners, make contact, assess partners, negotiation, agreement signing; (4) **activities during the operational phase of U–I IORs**: meetings & networking, communication, training, personnel mobility, employment, other activities; (5) **factors that facilitate or inhibit U–I IORs**: capacity and resources, legal issues, institutional polices and contractual mechanisms, management and organisation issues, issues relating to the technology, political issues, social issues, other issues (e.g. awareness, geographical proximity etc.); (6) **benefits of U–I IORs**: economic, institutional and social; (7) **drawbacks to U–I IORs**: deviation from mission or objective, quality issues, conflicts, risks.

Mathieu (2011) University–industry interactions and knowledge transfer mechanisms (KTM): a critical survey	(1) **the relative importance of KTM** as perceived by the involved stakeholders: informal contacts, participation in conference professional networks and boards, mobility of people, cooperation in education, cooperation in R&D, contract R&D, publications, sharing of facilities, intellectual property management, academic entrepreneurship (spin-offs); (2) **the factors affecting the organisation of university–industry interactions**: individual characteristics, characteristics of the firm, industrial sector, characteristics of the university or 'Public Science Research (PSR)-related factors', characteristics of the university department, group-level variables, characteristics of the knowledge/ technology, characteristics of the relation, environment of the relation, scientific disciplines; (3) **the interrelatedness of different KTMs**; (4) **the impact of increased university interactions on traditional academic missions**.
Perkmann *et al.* (2013) Academic engagement and commercialisation: a review of the literature on university–industry relations	Antecedents: (1) **individual characteristics**: demographics, career trajectory, productivity, attitudes, motivations, identity; (2) **organisational context**: TT support, formal incentives, university/ department quality, leadership, department climate; (3) **institutional context**: scientific discipline, regulation, public policy. Consequences: (1) **scientific output**: productivity, agenda; (2) **educational output**; (3) **commercial output**.
Polt *et al.* (2001) Benchmarking industry–science relations: the role of framework conditions	(1) **industry–science relations by type of interaction**: collaborative research, contract research, personnel mobility, cooperation in graduate education, vocational training of employees, use of intellectual property rights, start-ups, informal contacts; (2) **framework conditions**: legislation and regulations, public promotion programmes, intermediary structures, institutional settings;

(*Continued*)

Table 1. (*Continued*)

Author(s)	Research topics
	(3) **enterprise sector**: size of R&D, sector and enterprise structure, competition–market structure, absorption capacities, innovation performance; (4) **public research sector**: size of R&D, disciplinary structure, types of organisations, transfer capacities, research performance; (5) **incentives**: mutual learning, personnel mobility, codified and tacit knowledge, knowledge network externalities; (6) **barriers**: information asymmetries, low market transparency, incompatible objectives/different cultures, high transaction costs, financing restrictions, uncertainty of outcome, large spillovers.

DETERMINANTS →	FORMS & MECHANSIMS OF INTERACTION →	IMPACTS
(2) **University-related** (disciplinary mix; research quality; individual characteristics; institutional and organisational factors) (3) **Firm-related** (sector and size; absorptive capacity; geographical proximity) (4) **Context-related** (policy agenda; structural features of the UK higher education sector; structural features of the UK higher business sector)	**(1) University–industry cooperation patterns** (conceptual delimitations; channels of interactions; barriers to university–business cooperation)	(5) **Impact on individuals and universities** (faculty motivations for interaction; impacts on universities) **(6) Impact on firms** (companies' motivations for interaction; impact on firms' performance) **(7) Impact on economy and society** (pathways to impact; direct impacts on innovation; wider impacts)

Figure 1. Conceptual framework for studying university–industry linkages

information, we only selected those sources that had been mentioned at least once in an official (governmental) policy paper.

This search yielded approximately 100 sources that were relevant and based on evidence of sufficient quality to help explore the emerging themes and still 'unanswered questions' in university–business linkages in the UK.

Emerging themes from the literature on university–business linkages in the UK

(1) University–industry cooperation patterns in the UK

Conceptual delimitations. Recent observers of cooperation patterns in the UK have pointed to the evolving and multi-faceted nature of university–industry links. While recognising the fact that *technology transfer* resulting in patent-based activities such as spin-outs and licensing is only one aspect in university–industry interactions, policy makers and higher education institutions have all cast their attention towards wider concepts, such as knowledge transfer, knowledge exchange or academic engagement. *Knowledge transfer* is the term used widely within the government and Research Councils (e.g. Lambert, 2003; HM Treasury, 2004) and denotes the two-way transfer of ideas, research results, expertise and skills between universities and business. On the other hand, the term *knowledge exchange* is usually associated with third stream policies and

funding (e.g. HEFCE, HEIF) and acknowledges the interdependent and evolutionary nature of interactions (Abreu *et al*., 2008), but also the participation of multiple parties, including public and third sectors. Knowledge exchange activities can be broadly subdivided into five areas: skills and human capital development, facilitating the research exploitation process, knowledge sharing and diffusion, exploiting the physical assets of the HEI and supporting the community (PACEC/CBR, 2011). Finally, *academic engagement* is another 'competing' term usually defined as knowledge-related collaboration by academic researchers with non-academic organisations not only in formal, but also in informal activities, like providing *ad hoc* advice and networking with practitioners (Perkmann *et al*., 2013).

The enlargement of the public agenda towards knowledge exchange has also moved the focus from the traditional *entrepreneurial university model* to the *connected university model* that goes beyond the commercial exploitation of research to new users and new forms of interaction (Kitson *et al*., 2009b). Moreover, those that are still casting their attention to academic entrepreneurship/entrepreneurial universities are advised to widen the current notion to include any activity that occurs beyond the traditional roles of teaching and/or research, is innovative, carries an element of risk and leads to financial rewards for the individual academic or his/her institution (Abreu and Grinevich, 2013).

Channels of knowledge transfer/exchange, their importance and frequency of use. Many authors have attempted to rank-order the preferred channels and types of university–business interactions. To a great extent, the studies under review show that *informal activities and the so-called 'public space' functions* (meetings and conferences, forums, networks, social interactions etc.) are the most widespread form of interaction [Cosh *et al*. (2006) – *informal contacts*; D'Este and Patel (2007) – *meetings and conferences*; Abreu *et al*. (2008) – *common networks*; Abreu *et al*. (2009) – *attending conferences* and *participating in networks*; Salter *et al*. (2010) – *conferences* and *sponsored meetings* etc.]. Secondly, as revealed by the above-mentioned studies, but also from statistics in the HE–CBI survey (HEFCE, 2014a), *contract and collaborative research* are the most important interactions for higher education institutions in cash terms, as they generate about 60% of the total income obtained from external sources. At the opposite end, *technology transfer activities* (licensing, patenting, spin-outs) are the least common form of interaction (Cosh *et al*., 2006; D'Este and Patel, 2007; Abreu *et al*., 2009), generating less than 3% of the total income that universities attracted from external sources in 2012–13 (HEFCE, 2014a). The explanations lie in the fact that *people are more important than patents* (Hughes and Kitson, 2010), or, as pointed out by the Lambert Review (2003), the more exciting collaborations arise as a result of like-minded people getting together to address a problem.

Barriers to university–industry cooperation. A wide range of constraints that hinder university–industry interactions are emphasised in the investigated literature be it in the

form of *orientation-related* (cultural differences) or *transaction-related* barriers (Bruneel *et al*., 2010).

Cultural barriers are predominantly cited in the surveys of firms: more than half of the participants in the Bruneel *et al*. (2009) study (private organisations with formal involvement in EPSRC collaborative projects) cited the long-term orientation of universities as the 'classical' barrier to cooperation, mainly because business and academia operate with different objectives and timeframes (Mina and Probert, 2012). Similar to most large organisations – particularly those operating in the public sector – universities are not the most entrepreneurial institutions, given their hierarchical structure, the impersonal nature of relationships, the conservatisms, the lack of entrepreneurial talent or the inappropriate compensation methods (Kirby, 2006). As a result, different authors point to the absence of entrepreneurial culture in universities (Cosh *et al*., 2006), lack of strategic focus, business know-how and propensity to risk (Mina and Probert, 2012), lower sense of urgency and mutual lack of understanding about expectations and working practices (Bruneel *et al*., 2010). Negative perceptions of academics also persist, particularly by SMEs: they view universities as being 'full of long haired weirdoes … who don't understand the real world and they don't actually appreciate that universities now have got business targets, as well as academic targets' (Lockett *et al*., 2008, p.669). From an industry perspective, cultural barriers are doubled by some important *transaction-related barriers* resulting from complex administrative procedures (rules and regulations imposed by universities or government funding agencies), potential conflicts over intellectual property, absence or low profile of university transfer offices or the high costs of engagement, given the shift towards Full Economic Costing in universities (Bruneel *et al*., 2009, 2010).

Despite these evidences, cultural barriers and conflict over intellectual property are not considered important in academic surveys (Abreu *et al*., 2009; Hughes and Kitson, 2012; Mina and Probert, 2012). For academics, *the lack of time* in fulfilling all roles is the most important constraint, but not the only one, as the lack of resources, bureaucracy and inflexibility of university administrators, as well as the insufficient rewards resulting from interactions (e.g. promotion criteria) also have a negative influence on external engagement (Abreu *et al*., 2009; PACEC/CBR, 2009; Hughes and Martin, 2012; Mina and Probert, 2012). Besides, *communication-related barriers* (lack of information; poor marketing, technical or negotiation skills etc.) lead to difficulties in identifying companies with appropriate profiles (Decter *et al*., 2007; Kitson *et al*., 2009a; Salter *et al*., 2010). What is interesting to note is the fact that while academics think that barriers to engagement are falling (Salter *et al*., 2010) or remain similar over time (Ulrichsen, 2014), firms find a considerable increase in barriers to interactions (Bruneel *et al*., 2009), thus reflecting a divergence in collaborative experience (Salter *et al*., 2010), but also, again, a cultural difference in terms of reciprocal expectations.

(2) University-related determinants of university–business interactions

A central common finding across the investigated literature is that a number of university-related factors have a significant influence on the mix, breadth and importance of interactions; among them, the disciplinary mix, academic/research quality, individual characteristics and institutional and organisational factors are the most prevalent.

Disciplinary mix. Studies have found significant differences across disciplines in terms of engagement with business (D'Este and Patel, 2007; Perkmann and Walsh, 2007; Martinelli *et al*., 2008; Abreu *et al*., 2009; Hughes and Kitson, 2010; Salter *et al*., 2010; PACEC/CBR, 2011; Abreu and Grinevich, 2013), even if empirical evidence was collected mostly from the engineering disciplines that are traditionally close to industrial application. Abreu *et al*.'s (2009) survey shows that academics from all disciplines, including humanities and the social sciences, are engaged in the knowledge exchange process, but to different degrees, with academics in engineering being the leaders and arts and humanities performing the worst. Engineers have an above average propensity to engage in activities such as joint research, contract research, consultancy and prototype and testing activities (PACEC/CBR, 2011) and are more proficient as compared to academics from mathematics and physics (D'Este and Patel, 2007). Universities with a medical school are more efficient in university technology transfer (Siegel *et al*., 2008). At the other end, social sciences and humanities also maintain links to industrial partners, but differ in the form of engagement (Martinelli *et al*., 2008), as informal activities are predominant in their case (Abreu and Grinevich, 2013). Finally, academics in the arts disciplines are more likely to organise student projects and undertake community-based activities (PACEC/CBR, 2011).

Research quality. Results indicate a predominantly positive relationship between research quality (at institutional and departmental level) and university–industry interactions. Research quality appears to be positively associated with the frequency of university–industry links (D'Este and Iammarino, 2010), with increased benefits for firms [Bishop *et al*. (2011): firms that dominantly interact with top-ranked departments are two times more likely to assess benefits associated with downstream related activities], increased participation in networks [Huggins *et al*. (2010): '*research rich' universities tend to be more networked and outward looking*] and increased propensity for firms to collaborate locally [Laursen *et al*. (2011): being located close to a lower-tier university reduces the propensity for firms to collaborate locally, while co-location with top-tier universities promotes collaboration, especially for high-research and development intensive firms]. Research quality also explains firms' preferences for certain types of interaction: thus, the six most research intensive HEIs are mainly demanded for enhancing technology, product development and increasing sales; at medium research intensive HEIs, there is greater demand than average for workforce training, management systems and graduate recruitment strategy support; while there is a wider spread of demand for the low research intensive HEIs, which includes access to grants and their facilities, support for customer growth, and enhanced branding, marketing and recruitment (PACEC/CBR, 2009). However, the positive associations between research quality and university–industry interactions are not systematic (D'Este *et al*., 2013) and not homogeneous across scientific disciplines [D'Este and Iammarino (2010) and Salter *et al*. (2010): EPSRC grant holders have a higher level of engagement than the general population of UK academics; Perkmann *et al*. (2011): in technology-oriented disciplines, faculty quality is positively related to industry involvement; on the contrary, in the social sciences there is a negative relationship between faculty quality and particularly the more applied forms of industry involvement]. Conclusions argue for a differentiated approach to promoting a university–industry relationship, but also for an increased attention for the

institutional context, which seems to be much more important in this respect (D'Este *et al*., 2013).

Individual characteristics. Among the individual factors influencing university–industry interactions, prior experience of collaboration and academic status (being a professor) are extremely important in explaining the probability of a university researcher engaging in a greater variety of interactions (D'Este and Patel, 2007), given the fact that experience lowers academics' perceptions of the barriers to industry collaboration (Tartari *et al*., 2012). However, this does not mean that older academics are more engaged, since results suggest that younger academics are less risk-averse (Mina and Probert, 2012) and show a higher probability to be engaged in interactions (D'Este and Patel, 2007). At the same time, early career individuals are strongly influenced by peer effects: looking for inspiration, they tend to mimic the average behaviour of their departmental work colleagues through social learning and social comparison (Tartari *et al*., 2014). Finally, characteristics reflecting professional security, advantage and productivity (prior publication record), but also the level of reputational importance placed on scientific compared to commercial achievements, matters in shaping academics' involvement (Haeussler and Colyvas, 2011). Further differences can be observed with respect to faculty attitudes towards knowledge/technology transfer and awareness of the university's respective code of practices (Martinelli *et al*., 2008).

Institutional and organisational factors. The existence of an institutional strategy for knowledge transfer that seeks to maximise both funding and dissemination, simple and efficient processes, a flexible platform and internal capability and culture (Sharifi and Liu, 2010) is crucial in shaping universities' engagement with businesses, especially if this strategy is reinforced by strong leadership at the highest institutional level (PACEC/CBR, 2011). To date, the evidence provided by the institutional strategies submitted by universities to HEFCE as part of the HEIF funding programme suggests that knowledge exchange has finally become embedded within many higher education institutions (PACEC, 2012), but it is not well-honed and routinised to the same degree as traditional university missions (D'Este *et al*., 2013). Resource allocation in the form of expenditure on IP protection (Lockett and Wright, 2005), level of R&D investment to fund early stage operations (McAdam *et al*., 2009), but also available ring-fenced funding pots (PACEC/CBR, 2011) are also important strategic considerations, together with the incentive mechanisms that are still problematic, since many academics feel support by their department and their university for their engagement efforts, but few considered this activity as rewarded or valued by their department or university and not recognised in hiring and promotion policies (Salter *et al*., 2010).

Besides institutional factors, organisational structures (technology transfer offices – TTOs; Knowledge Transfer Offices – KTOs) are also crucial for technology/knowledge transfer and universities have devised different formalised structures, often in terms of hierarchical, control-oriented structures (Howells *et al*., 2009). Nevertheless, despite their vital role and substantial governmental support,[1] TTOs/KTOs are the least frequent contact channel between academics and companies. In

Abreu *et al*.'s (2009) survey, the most frequently cited intermediaries or 'boundary spanners' who facilitate and manage contractual and relational interactions of knowledge exchange were individuals associated with external organisations (80%), and the least frequently cited initiator was the university TTO (24%). Similarly, KTOs were the least frequent mechanism for interactions between academics and external organisations in the PACEC/CBR survey, with only 13% of academics choosing this route (PACEC/CBR, 2009). The Wilson Review (2012) points to the ambiguities and the lack of coherence in KTOs' actions and companies claim that the expectations of TTOs are unrealistic (Bruneel *et al*., 2009). Looking for explanations, Bruneel *et al*. (2009) argue that only after 2008 did many UK universities invest in professional systems for technology transfer and they need a period for adjustments, while Abreu *et al*. (2009) think many of the interactions are informal and people-based and do not require the contractual and transactional inputs. Since *the capabilities* and *routines* of the universities are crucial for TTO/KTO operations (Lockett and Wright, 2005), developing them further poses an important challenge for both policy makers and universities.

(3) Firm-related determinants of university–business interactions

Firm sector and size. Evidence from the investigated literature shows university–industry relationships are widely practised, but differences exist across industries (Perkmann and Walsh, 2007) and across types of firms (Howells *et al*., 2012). Firms in various sectors have very different structures, display varied reliance on R&D, innovate in different ways, work with a range of technology solution clock-speeds and thus adopt different approaches to collaboration (Docherty *et al*., 2012; Mina and Probert, 2012). Yet, university–industry interactions are not confined to the high-technology sectors and manufacturing industries, but also include many so-called low-technology sectors and even services (Abreu *et al*., 2009): pharmaceuticals and energy being the top partners in cooperation (Mina and Probert, 2012). Beside firm sector, firm size is a very strong predictor for university–industry links, with smaller firms at a considerable disadvantage (unless they are not connected with the research base from the start); 'big ticket' large R&D performers, large corporations and the public sector are establishing and benefiting most from interactions with universities (PACEC/CBR, 2009; Huggins *et al*., 2010; Mina and Probert, 2012). Although much of university knowledge transfer is based on establishing links with SMEs (Huggins *et al*., 2010) and SMEs were the most frequent target for third stream activity (PACEC/CBR, 2009), it is clear that SMEs do not yet have the capacity to engage, given the fact that they account for a small fraction of R&D, lack resources and relevant bridging skills and have a narrower portfolio – as compared to large companies (Docherty *et al*., 2012).

Firm absorptive capacity. University–industry interactions are also highly influenced by firms' absorptive capacity (i.e. a firm's ability to recognise the value of new information, assimilate it, and apply it to commercial ends) (Cohen and Levinthal, 1990; Hotho *et al*., 2011). In other words, organisations that embrace dynamic capabilities (Zahra and George, 2002) are more likely to thrive in a competitive environment. Firms must have a certain level of absorptive capacity before entering into cooperation with universities; more specifically, they need an open innovation

strategy capturing the increasing propensity to work across traditional boundaries of operation (Perkman and Walsh, 2007; Mina *et al*., 2014), internal capability [Abreu *et al*. (2008): specific structures, procedures, internal networks and enabling gatekeepers who sit at the interface and explain the issues, identify the appropriate researchers and translate the results throughout the organisation] and relevant management processes, so that individuals can secure the internal commitment and resources needed to take part in projects (Ternouth *et al*., 2010). Evidence suggests that in the UK business services are more active open innovators than manufacturers (Mina *et al*., 2014) and that engagement in open innovation increases with the proportion of science and engineering graduates in the workforce (Frenz and Oughton, 2006) and with the level of firm R&D expenditure (Frenz and Oughton, 2006; Mina and Probert, 2012), even though higher levels of R&D are not a prerequisite for successful collaborations (e.g. for access to problem solving) (Bishop *et al*., 2011). In this respect, to break away from the limitations of internal R&D capacity and firm-based careers for scientists, firms (usually those in high-tech sectors/fast-moving industries) extended their knowledge boundaries into the established internal labour markets of the universities, leading to the formation of a pool of joint human resources or an 'extended internal labour market' (ELIM model) that enables firms to shape the knowledge and competences they need (Lam, 2007).

Geographical proximity. Although it is widely acknowledged that geographic proximity favours the firm–university interactions – witness the many companies, such as Rolls Royce, Lloyds Register, Jaguar Land-Rover and Boeing which have moved or are moving their research scientists or activities onto university campuses (Docherty *et al*., 2012) – findings from the UK studies show that co-locational effects are visible only among top-tier/research-excellent universities (D'Este and Iammarino, 2010; Laursen *et al*., 2011), among certain industries (Abramovsky and Simpson, 2011) and certain types of interactions (Bishop *et al*., 2011).

Firms appear to give preference to the research quality of the university partner over geographical closeness (this is particularly true for high-research and development intensive firms) (Laursen *et al*., 2011) and university–industry partnerships exhibit a curvilinear relationship with the research excellence of university departments (D'Este and Iammarino, 2010). Similarly, Abramovsky and Simpson (2011) found evidence of co-location of R&D facilities for pharmaceutical and chemical firms with high research-rated chemistry/material science departments, but in other industries, co-location with production appears to play a more important role than immediate proximity to universities.

Proximity seems to be more important for R&D intensive business [Mina and Probert (2012): for later stages of the R&D process, less R&D intensive investments and services proximity to markets is far more important], for small business than for large ones [Abreu *et al*. (2008): for large firms, the relationship is much more important than the increase in transaction costs implied by distance] and for benefits associated with direct assistance in problem solving [Bishop *et al*. (2011) found no support for the argument that closer geographical proximity between firms and their university partners would enhance the probability of obtaining any of the other potential benefits from university collaboration].

(4) Context-related determinants of university–business interactions

Policy agenda. Factors such as legislative framework, government policy and funding streams are important drivers for university–industry cooperation and the introductory part of our study has already pointed to the diversity of initiatives in this respect. The UK has a very complex science, engineering and technology system (SET policies) and the 10-year framework for investment in science and technology was a welcome step in providing a long-term perspective within which to work (HM Treasury, 2004; Hughes, 2007). Meanwhile, recent years have witnessed a plethora of policy interventions at both national and regional level; since business and entrepreneurial development has been listed as one of four strategic goals for the country's universities (Kirby, 2006), policy pressures for universities to improve national economic competitiveness have increased (Perkmann and Walsh, 2007; Huggins *et al*., 2010). As pointed to by a number of authors, these policies for encouraging knowledge transfer are more diverse than in the USA (Decter *et al*., 2007), but they are often limited to a uniform, 'copy-cat' approach (Huggins *et al*., 2011) and generally fail to acknowledge the diversity of universities and the variation and complexity in their actions (Howells *et al*., 2009), while placing too much weight on the notion of entrepreneurial universities and technology transfer (Kitson *et al*., 2009a; Hughes, 2011).

Critics also think the UK has a diffuse university–industry ecosystem, characterised by a greater width than quality of interactions (Cosh and Hughes, 2010), by overlapping roles and institutions in the process of innovation creation (Pickernell *et al*., 2009a) and by somewhat confusing targets: for example, some funds encourage American style outcomes such as patents, licences and spin-off companies, other funding requires universities to support local small industry in exchange for large investments in university infrastructure; one approach influences universities towards being more entrepreneurial, whilst a conflicting message encourages an almost philanthropic approach to local industry support (Decter, 2009). At the same time, arguments prevail that the UK failed to develop appropriate structures and incentive mechanisms adapted to Mode 2, triple helix and open innovation thinking, given the long-rooted differences between business and university cultures and to an overemphasis on 'basic ' as opposed to 'applied' research (Hughes, 2011). Moreover, Howells and Edler (2011) argue that structural innovations to improve industry–academic collaborations had some unintended consequences: the new actors and organisational forms that were established to close the structural gap between science and industry (e.g. former Faraday Centres, TTOs or the network structures) led to the adverse effect of losing close ties between university academics and industry, because the vast majority of businesses in the UK use customers and suppliers and not intermediaries in the innovation process. Revising current policies becomes a challenge since doubts exist about their long-term effectiveness and their ability to transform the modus operandi of the country's universities (Kirby, 2006) and there is a belief among academics that the emphasis on third stream mission activities has already gone too far (Hughes, 2011).

Structural features of the UK higher education sector. The UK higher education system has its own strengths in relation to university–industry interactions, since the UK academic community is acknowledged as one of the best in the world and most

individual universities comprise academics from different backgrounds, different disciplines and different approaches, thus creating a stimulating platform for knowledge exchange (Abreu *et al*., 2009). According to Rose *et al*. (2012), the patterns of business engagement are related to the histories of the individual universities, but also to the major waves of reform that transformed them from elitist education for a minority to education for the masses and shifted the agenda relating to the relationship between universities, industry and government during the Thatcher years. In Decter's (2009) opinion, the history of UK universities has provided a context which is less open to industry than in the US and for these reasons UK universities are less efficient than those in the US with regards to knowledge production processes (Siegel *et al*., 2008) and exhibit lower levels of absolute efficiency in technology/knowledge transfer (Chapple *et al*., 2005).

A key disruptive effect in the UK system was the move away from the two-tier system of universities and polytechnics towards a single unitary system of universities in the early 1990s: to some extent, this made the combined systems more open in terms of network interaction effects, although in other ways university networks remain constrained around their own tight collaborative trajectories and communities of interaction (Howells and Edler, 2011). At the same time, the Research Assessment Exercise (RAE) and its replacement, the Research Excellence Framework (REF) is considered a key barrier to knowledge transfer, even if it was intended to reward excellence and relevance. Given its overriding imperative to publish in high-ranking, discipline-specific journals, RAE/REF discouraged inter-disciplinarity (Howells and Edler, 2011), application-oriented research collaborations (Howells and Edler, 2011) and regionally relevant research and consultancy (Charles *et al*., 2005). Academics have perceived the applied work as of less value in RAE/REF terms (Decter, 2009) and have avoided publishing in practice-based journals (Salter *et al*., 2010). At the same time, the 'publication treadmill' left academics little time for engagement or commercial activities (Salter *et al*., 2010) and many academics believe that more time spent working with industry may jeopardise their prospects for career advancements (BIS, 2009). Since the new REF considers the impact of past research on the economy and society (BIS, 2009; PACEC, 2012; Witty, 2013), prospects are more optimistic, but higher education institutions will have to face another challenge related to the student fees regime (PACEC, 2012) or ongoing uncertainty over public sector programmes and public sector funding (Ulrichsen, 2014).

Structural features of the UK business sector. When compared to international standards, UK businesses' appetite for research and investment is lower and declining (Cosh *et al*., 2006) and it seems that the private sector component of the R&D target in the 2004–14 investment framework will not be met (Hughes, 2007). This situation poses important challenges to university–industry links, as businesses are less interested in and more sceptical of university technology (Decter *et al*., 2007) and the willingness to invest is sensitive to the government policy agenda and a business-friendly operating environment (Mina and Probert, 2012). Rather worryingly, UK businesses are less likely than, for example, their US counterparts to commit the necessary resources required for effective interactions with universities (Hughes and Kitson, 2012). Moreover, when sourcing university knowledge, UK firms prefer horizontal relationships (collaborations and alliances) and do not have supply–chain relationships with the universities, which

are more advantageous in some respects (Huggins *et al*., 2011). Similarly, UK firms appear to be involved in a more explorative (or exploitative) manner in sourcing knowledge and are mainly focused on knowledge for radical innovation, converse to US firms, which concentrate more on knowledge to achieve incremental improvement to their products and processes (Huggins *et al*., 2011).

The economic recession introduced a larger degree of uncertainty over potential demand for knowledge (PACEC, 2012) and shortage of finance which attributed to the current macroeconomic framework is expected to determine a poor appetite among investors for risk financing (Mina and Probert, 2012). Under these circumstances, stimulating demand for knowledge has become urgent (Kitson, 2009b) and more challenging than before.

(5) Impact on academics and universities

Faculty motivations for interaction. Different surveys have questioned academics' motivations for interactions as a means to discover the perceived benefits of cooperation. Furthering research is by far the main reason that motivates engagement with industry. In Abreu *et al*.'s (2009) survey, 73% of academics who engage with an external organisation believed it had given them new insights into their research work, 70% believed it had led to new contacts in the field and 62% believed it had led to new research projects. Similarly, the most common factor cited as being 'very important' or 'crucial' for the interaction with industry in Salter *et al*. (2010) was securing additional research income, but also finding interesting and rewarding research problems and developing research into a practical application outside academia. Since academic entrepreneurship and business engagement – by definition – involve any activity that occurs beyond the traditional academic roles and leads to financial rewards for the individual academic or his/her institution (Abreu and Grinevich, 2013), *getting additional income* becomes a motivation and analyses show that a 1% increase in HEFCE funding for knowledge exchange is associated with a 0.3–0.37% increase in knowledge exchange income per academic FTE (Ulrichsen, 2014). Despite these advantages, few academics engage with industry for purely financial gains (Salter *et al*., 2010) and furthering their research (either through learning or through access to in-kind resources such as industry-provided equipment, materials and data for research) is much more important than getting financial rewards (D'Este and Perkmann, 2011). Beside research-related and financial rewards, there are other possible benefits for interaction be it in terms of an increase in reputation, prestige, influence or social benefits (Abreu and Grinevich, 2013) and improvement of career prospects [Tartari *et al*. (2014): academic scientists may decide to engage with industry because they aspire to achieve their colleagues' performance levels], be it purely in terms of 'support for business' (Decter *et al*., 2007) or to keep up with research conducted by industry (Salter *et al*., 2010).

Impact on universities. For universities, engagement with industry represents first *a new source of revenue* (Cosh *et al*., 2006; Decter *et al*., 2007) and income generation is becoming increasingly important as a long-term goal for knowledge exchange activities (PACEC/CBR, 2009). In cash terms, the income from different external pathways more than tripled in real terms between 2001 and 2010, showing that

external users have become more willing to pay for access to university services, inputs and facilities (Hughes and Kitson, 2012). Moreover, engagement is a positive *response to UK government pressures*, but also an opportunity for *good PR* (Decter *et al*., 2007).

Aside from these benefits, engagement with industry poses important challenges as tensions exist between the third mission and the missions of teaching and research (Cosh *et al*., 2006). Critical arguments stress a conflict of interest between the academic pursuit of freedom of creative research and the focused strategic research aimed at commercial objectives (Hughes, 2011), possible prejudices for the current high standing of UK research (Kirby, 2006; Hughes, 2011), especially if engagement leads to less basic research (Abreu *et al*., 2009), to unintended consequences, for example on the long-term accumulation of fundamental knowledge (Mina and Probert, 2012) or to less internal collaboration (Martin and Turner, 2010). Several arguments contradict these assumptions: according to PACEC/CBR (2009), initial concerns about whether the emphasis on the third stream mission would impact on the traditional teaching and research roles have proven to be unfounded, because many synergies between knowledge exchange, teaching and research have been realised. For academics, science and commerce go hand-in-hand (Haeussler and Colyvas, 2011) and many of them report a positive impact of their interactions on their research (Hughes, 2011), but also on their teaching activities (Abreu *et al*., 2009). Besides, since the notion of an academic 'ivory tower' seems to be a myth as far as the UK is concerned (Hughes and Kitson, 2012), academic scientists changed from 'ivory tower traditionalists' to 'entrepreneurial scientists' – thus becoming active agents seeking to shape the relationships between science and business, showing a continued diversity in their work orientations (Lam, 2010). With a view to the future, finding a proper balance between research and university–industry links appears to be a challenge, given the fact that industry engagement is currently more closely aligned with academics' primary role of conducting scientific research and this means a somehow disconnected 'third mission' (Tartari *et al*., 2014).

(6) Impact on firm-level innovation and performance

Companies' motivations for interaction. Companies' motivations for interactions with universities can be conceptualised in a variety of different ways. Evidence suggests firms are becoming increasingly focused on using universities as *a site for recruitment* (Bruneel *et al*., 2009) and conventional outputs in terms of educated people are the most highly valued by innovating business (Cosh and Hughes, 2010) and by SMEs (Pickernell *et al*., 2009b). According to Bishop *et al*. (2011), through access to skilled personnel through recruitment, universities can shape firms' assimilation and transformation capabilities, thus enhancing their downstream activities. Beside access to skills and training, interactions with academics enable companies to identify issues of which they were previously unaware (Abreu *et al*., 2008), improve understanding of the foundations (Bruneel *et al*., 2009) and thus develop their *explorative capabilities* (Bishop *et al*., 2011). Collaborating with a university enables participation in novel scientific debate, gives insights into emerging technologies (Decter *et al*., 2007; Perkmann *et al*., 2011) and facilitates access to state-of-the-art research, with publications being particularly important in this respect (Cosh and Hughes, 2010; Hughes and Kitson, 2012). Third, improving their *exploitative capabilities*

through direct assistance in problem solving, getting expertise for some challenges and for ongoing R&D programmes is another strong reason for engagement (Abreu *et al*., 2008; Bruneel *et al*., 2009; PACEC/CBR, 2009; Bishop *et al*., 2011; Perkmann *et al*., 2011; Hughes and Kitson, 2012) and it conforms to a model characterised by demand pull driven contributions, where university scientists respond to specific problems posed by industry (Bishop *et al*., 2011). Finally, firms also engage with universities to capture intellectual property (Bruneel *et al*., 2009), leverage R&D funding (Perkmann *et al*., 2011), reduce R&D costs (Decter *et al*., 2007; Bruneel *et al*., 2009), prevent competitors from acquiring technology (Decter *et al*., 2007) or get access to universities' R&D facilities (Hughes and Kitson, 2012), but these motivations are less important than the ones mentioned before (skills, access to new ideas and problem solving).

Impact on firm performance. In the literature on innovation systems, universities are portrayed as important sources of knowledge and active partners in firms' innovation chains. Despite these expectations, findings from the UK Innovation Survey show that only 2–3% of the innovative companies in the UK used universities or other higher education institutions as sources of information (BIS, 2014). Industrial surveys and other different studies confirm that universities *per se* play quantitatively smaller roles as a source of knowledge for business innovation than either the business sector itself or a variety of organisations intermediating between the university and business sectors (Cosh *et al*., 2006; Howells *et al*., 2009; Pickernell *et al*., 2010; Hughes and Kitson, 2012). Collaboration with universities is less valued by UK firms (Cosh and Hughes, 2010) and is also rated lowest in terms of overall importance to firm performance (Clifton *et al*., 2010).

Although universities are not the initial favoured collaborators, when collaboration occurs, it has a positive influence and firms collaborating with universities are four times more likely to innovate (Howells *et al*., 2009). Similarly, in their study of UK SMEs, Clifton *et al*. (2010) identified significant differences between SMEs collaborating with universities compared with those not doing so in terms of the self-rated capacity to innovate, as well as for product changes. In their turn, Harris *et al*. (2010) found that collaboration with HEIs had a positive statistically significant impact on Total Factor Productivity (TFP) (the latter was around 12% higher for firms cooperating with universities), although large differences exist in this effect across industries. Cosh *et al*. (2011) think the relatively low usage of universities is unlikely to be due to dissatisfaction with the outcome, since about a quarter of the firms that used universities/HEIs in sourcing information considered it highly important, so the challenge for the future is to bring academia and business together and make them work together at least once.

(7) Impact on economy and society

Pathways to impact. Previous studies have identified a number of different channels or 'pathways to impact' through which universities may contribute to innovation and economy. Their most celebrated role is as well-springs of discoveries, ideas and technologies, thus increasing the stock of useful knowledge (e.g. publications, patents). Some of these ideas have great commercial value (e.g. the creation of new

instrumentation of methods; the enhancement of technological problem-solving capacity; the generation of spin-offs etc.) and have implicitly a direct contribution to innovation (Kitson *et al*., 2009b; Hughes and Martin, 2012; PACEC, 2012). By supplying graduates, universities produce a skilled workforce that is often a crucial resource for local businesses (Kitson *et al*., 2009b; Hughes and Martin, 2012; PACEC, 2012). At the same time, universities act as significant employers and purchasers in many areas (Kitson *et al*., 2009) and due to their stability and permanence, they attract other key resources for economic development (educated people, firms, venture capitalists, etc.) (Cosh *et al*., 2006), thus underlying the innovation conditions in place (PACEC, 2012). Not least, and more subtly, universities provide a locus for coordinating local activity and offering an anchor around which clusters/networks can form (Kitson *et al*., 2009b).

Given the fact that the role of universities depends highly on the local economic structure (Lester, 2005), the region represents an important 'task environment' from which both firms and universities operate and can constrain or stimulate growth (Howells *et al*., 2009). Lester (2005) has argued that four main types of local economic evolution can be influenced by university–industry interactions: *new industry formation* (developing entirely new sectors, often based on novel technologies and university research); *industry transplantation* (bringing existing – but often higher value – industries to a region); *diversification into technologically-related industries* (for example, in helping 'phoenix industries' to develop from declining firms); and *upgrading of existing industries* (providing technical problem solving advice and skills development for existing businesses). Beside these direct contributions, universities can also support local economic growth through a diverse set of mechanisms, e.g. regenerating disused sites in the local economy to support local innovation; creating more coordinated innovation infrastructure and support for the local economy; providing business support, mentoring, networking and training to local small and medium-sized enterprises (SMEs); working to attract inward investment, and supporting SMEs to realise export potential by leveraging experience of operating in, and infrastructure located in, overseas markets; and working actively with the Local Enterprise Partnership to strengthen local innovation (PACEC, 2012; Ulrichsen, 2014).

Goddard and Puukka (2008) think universities' contributions to regional development should not be confined to their capacity to support innovation, but also to their potential to enhance cultural and community development. Similarly, universities should not be expected to act exclusively within the regional frontiers, but to become integrative network nodes in a global–regional innovation system in which the key aspect is the capacity to combine external resources and influences with local needs (Benneworth and Hospers, 2007). As Huggins *et al*. (2008) highlight, appropriate knowledge sources are now less likely to be local and future investments must be placed within a globalised knowledge environment and, in many ways, universities are the 'multinationals' of this environment.

(Direct) impacts on innovation. Even if the paradigm of open innovation considers universities as a major source of knowledge and a potential partner in the new models, evidence suggests that universities have not been recognised yet as an entity which could play the same game in the national and global innovation systems (Sharifi and Liu, 2010). Thus, Howells *et al*. (2012) think we should place care on

Table 2. 'Unanswered' questions and policy implications

Main findings	'Unanswered' questions	Policy implications
■ University–industry links are multi-faceted and evolving. ■ Informal activities and the so-called 'public space' functions are the most widespread forms of interaction.	**How to deal with diversity?**	**Broaden the knowledge transfer/exchange agenda and support a wide variety of interaction channels** (D'Este and Patel, 2007; Abreu *et al*., 2009); do not favour single engagement channels, such as technology transfer (Kitson *et al*., 2009a) or starting up new ventures (Salter *et al*., 2010); pay attention to important forms of collaboration that are set aside in policy design and evaluation, for example student training (Bruneel *et al*., 2009).
■ Technology transfer activities are the least common form of interaction. ■ Policies in the UK placed too much weight on encouraging American-style outcomes (patents, licences, spin-offs etc.).		**Stress relational, rather than transactional aspects of knowledge transfer; encourage public space roles** (Abreu *et al*., 2009; Hughes, 2011); develop Mode 2 relationships, more informal, softer relationships, which permit a reflexive interplay between the commercial and university sectors (Hughes, 2011).
■ The UK has a diffuse university–industry ecosystem, characterised by a greater width than quality of interactions.		**Improve quality, not quantity** (Hughes, 2007; Cosh and Hughes, 2010); rationalise and formalise relationships (select a smaller number of high quality interactions) (Mina and Probert, 2012); pay more attention towards the character and distribution of different kinds of relations rather than the volume of innovative outputs (Haeussler and Colyvas, 2011); provide more clarity on the intention of funding (Decter, 2009) and more transparent systems (Decter *et al*., 2007); focus on ensuring a greater degree of coordination of existing policy levels than on introducing new initiatives (Hughes, 2007); monitor the richness of interactions rather than simply counting the quantity (Bruneel *et al*., 2009).
■ Important variations in engagement exist by type of university and academic disciplines, with arts and humanities performing the worst. ■ Individual characteristics are extremely important in explaining academics' engagement in a greater variety of interactions.	**How to deal with heterogeneity?**	**Consider the heterogeneity of the higher education sector** (Howells *et al*., 2009; Martin and Turner, 2010) and **a possible division of labour among universities:** some universities may specialise in advanced research and others in business engagement (Sainsbury Review, 2007; Perkmann *et al*., 2011); there may be a key supporting role for local/

■ Significant variations exist in engagement by firm size and sector.		regional universities in developing enabling factors and a knowledge creation role for universities at national and international level (Clifton *et al.*, 2010); universities with strong regional orientation may focus on the development of regional skills and connectivity with regional businesses, while universities with an international orientation may help attract international R&D investments (Kitson *et al.*, 2009a).
■ University–industry links are dependent on local contexts and tend to be concentrated mainly within UK's core and most competitive regions. ■ Policies for encouraging knowledge transfer generally failed to acknowledge the diversity of universities, individuals, firms and local contexts.		**Avoid one-size-fits-all policies, which are far too simplistic** (Mina and Probert, 2012); reflect the highly differentiated needs and requirements from a variety of collaboration modes (Bruneel *et al.*, 2009); take account of differences between academic disciplines (Hughes, 2007; Perkmann *et al.*, 2011) and create more opportunities for academics working in fields with little entrepreneurial opportunities (Salter *et al.*, 2010); pay attention to local work contexts (Tartari *et al.*, 2014) and to the characteristics of individual researchers (D'Este and Patel, 2007); do not translate fascination with successful cases (e.g. Oxfordshire) into a 'one-size-fits-all' policy (Lawton-Smith, 2007); plan the knowledge transfer process both generically and individually, as different firms might need to call on different kinds of support at different times (Lockett *et al.*, 2009); bear in mind the specific needs of different sectors (Hughes, 2007) and develop differentiated sector-strategies to match specific sectoral systems of innovation (Docherty *et al.*, 2012).
■ Firms cite orientation-related barriers (long-time orientation of universities, lack of entrepreneurial culture, lack of strategic focus etc.) as being important. ■ For academics, lack of time in fulfilling their roles, as well as the lack of resources, bureaucracy and insufficient rewards have a negative influence on external engagement. ■ Both academia and industry still find many transaction and communication-related barriers that limit cooperation.	**How to increase quality in knowledge supply?**	**Stimulate cultural change** and **apply the principles of entrepreneurship theory in practice;** formulate a high-level strategy that demonstrates the university's strategic commitment, make it clear that the university encourages this form of behaviour, provide the university's staff with the knowledge and support to start their own businesses and create an environment that reduces the risk involved (Kirby, 2006); embrace the open university knowledge transfer

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Table 2. (*Continued*)

Main findings	'Unanswered' questions	Policy implications
		model, where performance is associated with a well-balanced incentive system for all involved stakeholders, a system of communication, signalling and managing the process and a model to improve the interest of users (Sharifi and Liu, 2010); pay attention to social learning and social comparison processes when encouraging industry engagement (Tartari *et al.*, 2014) and develop a flexible and responsive culture that emphasises both internal and external collaboration (Martin and Turner, 2010); include separate initiatives in a broad-based programme of cultural change within universities (Docherty *et al.*, 2012).
■ Efficiency in knowledge transfer is reinforced by leadership, strategy, incentive systems, norms, values, culture and organisational structures. ■ Technology/knowledge transfer offices are the least frequent contact channel between academics and companies.		**Professionalise technology/knowledge transfer offices (TTOs/KTOs):** better align the roles of various boundary spanners inside universities (Abreu *et al.*, 2009); expand TTO activities to consider both formal and informal interactions (Abreu and Grinevich, 2013); reconfigure TTOs into smaller units (Chapple *et al.,* 2005); upgrade business skills, capabilities and authority of TTO/KTO staff (Chapple *et al.,* 2005; Lockett and Wright, 2005; Phan and Siegel, 2006; CBI, 2009); train both administrators and research staff in how to build links (D'Este and Patel, 2007; Kitson *et al.*, 2009b); outsource consultancy services from industry experienced consultants when necessary (McAdam *et al.*, 2009); ensure that TTOs in universities are performing at the standard set by leading UK institutions (e.g. larger research-intensive universities, e.g. Cambridge, Manchester) or/and have absorbed the good practice initiatives in the wider pool of pre- and post-1992 institutions (Kitson *et al.*, 2009b).
■ University–industry interactions are highly influenced by firms' absorptive capacity, openness and R&D propensity.	**How to increase quantity in the**	**Stimulate firms' absorptive capacity**: introduce stimuli in the demand (Huggins and Kitagawa, 2012), develop policies that consider different stages of company evolution (Abreu

■ Smaller firms do not yet have the capacity to engage, given their low R&D profile, lack of resources and relevant bridging schemes.	**demand for knowledge?**	*et al*., 2009) and enhance risk-taking and innovation in businesses (Docherty *et al*., 2012); do not focus on single spatial scales for the implementation of policy, build instead on creating connective capacities and networks (Kitson *et al*., 2009b); educate universities about the absorptive capacity problems and use experience as a proxy in knowledge transfer: encourage firms with low absorptive capacity to use KTPs, innovation vouchers and problem-solving services and firms with a high absorptive capacity towards sponsored/collaborative research and technology development (Ternouth *et al*., 2010); market the use of university technology as an 'outstanding route' for company R&D, to replace lost R&D activities (Decter *et al*., 2007).
■ Geographical proximity to universities is important especially for R&D intensive firms and for small firms. ■ When compared to international standards, UK businesses' appetite for R&D is low and declining.		**Strengthen SMEs participation:** improve access for SMEs (Hughes, 2007); exploit public spaces to bring SMEs onto campuses (PACEC, 2012); use more effectively public procurement for small high-technology businesses (Hughes, 2007); develop different standard route maps for firms' development (Lockett *et al*., 2009); increase cash-flow to innovative SMEs emerging from the science base, particularly those in high-growth areas for the economy (Docherty *et al*., 2012).
■ Furthering research is by far the main reason that motivates academics' engagement with industry. ■ Research quality is positively associated with university–industry interactions. ■ Apparent tensions exist between external engagement and teaching and research missions, although many synergies have been realised.	**How to increase impact on academics and universities?**	**Find a proper balance between research and business engagement** and **encourage multi-disciplinarity** (Kitson *et al*., 2009b): avoid simplistic distinctions between applied and basic research in key allocation decisions (Hughes, 2011); create cross-disciplinary research programmes and collaborative research partnerships (Huggins *et al*., 2008); abandon the 'silo' mentality that currently discourages inter-disciplinarity in universities (Mina and Probert, 2012); do not

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Table 2. (*Continued*)

Main findings	'Unanswered' questions	Policy implications
		press academics to become entrepreneurs, as the benefits of university–industry collaboration are best attained by a cross-fertilisation that enables both academic research and industry application (D'Este and Perkmann, 2011); guarantee academic autonomy (D'Este and Perkmann, 2011); guarantee academic freedom, which is of fundamental importance to the future well-being of society (Abreu *et al*., 2009).
■ RAE/REF had a negative impact on application-oriented research and multi-disciplinarity. ■ 'Publication treadmill' associated with RAE/REF left academics little time for external engagement.		**Incentivise engagement** (Wilson, 2012; Witty, 2013)**:** use less regulation whenever possible (Wilson, 2012); consider a broader range of incentives and refrain from overly focusing on monetary incentives (D'Este and Perkmann, 2011); time spent in industry should be valued for academic career advancement purposes (Kitson *et al*., 2009b), for hiring and promotion policies (Salter *et al*., 2010); ensure that the new REF gives proper recognition to excellent business – relevant research (CBI, 2009) and inter-disciplinarity (Kitson *et al*., 2009b); increase impact weighting in the next REF to 25%, to strengthen the incentive on universities to achieve effects such as benefits to local businesses (Witty, 2013).
■ Firms are increasingly focused on using universities as a site for recruitment and conventional outputs in terms of educated people are the most highly valued by companies. ■ Universities *per se* play smaller roles as a source of knowledge for business innovation than the business sector itself. However, when collaboration occurs, it has a positive impact.	**How to increase impact on firms, economy and society?**	**Bring academia and business together** and **encourage the use of universities as a source of talent** (Bruneel *et al*., 2009); consider university-provided training as a conduit through which firms and universities come together, with relationships deepening over time (Pickernell *et al*., 2010); develop models of good practice for the movement of staff between business and universities (CBI, 2009) and support mobility across boundaries (Lam, 2007); encourage firms to explore the 'extended internal labour markets' to gain access to open knowledge networks of university researchers and shape the competencies they need (Lam, 2007); invest in time spent on joint work and the exchange of ideas, materials and tools (Mina and Probert, 2012).

■ Universities' direct impact on innovation systems is moderate; instead, there are multiple indirect impacts on the creation of innovation conditions in place. ■ The region represents an important task environment for a university–industry link, even if UK academics prefer international rather than regional connections.	**Think global and act local (**Pickernell *et al*., 2009a**)**; identify key priority areas for the future (PACEC, 2012; Wilson, 2012; Mina and Probert, 2012); pay more attention to social processes and open innovation contexts affecting university–industry interactions (Johnston *et al*., 2010), but also to the global environment within which knowledge flows (Huggins and Kitagawa, 2012); mobilise collaborative national clusters to win global markets (Witty, 2013); embrace the 'connected university model' (build networks, nurture local clusters, promote cross-sectoral collaborations, create national and international connections), as it holds the key for future economic growth (Kitson *et al*., 2009b).
■ When estimating the impact, it is important to consider universities as parts of a system, be it global, national or regional and not in isolation.	**Strengthen regional conditions:** put universities at the heart of Local Enterprise Partnerships (Wilson, 2012; Witty, 2013) and any other local growth and innovation strategies (Hughes, 2007; PACEC/CBR, 2011); do not overemphasise the role universities may play independently in the innovation and productivity enhancing processes (Hughes and Kitson, 2010); improve the knowledge base of relatively lagging regions (Huggins *et al*., 2010); do not focus exclusively on new industry formation, but also on diversification, transplantation, upgrading of local industries (Lester, 2005); ensure appropriate transport and infrastructure policy, to help support physical building (Kitson *et al*., 2009b); carefully manage the tensions between national sector based schemes and those operating at regional level (Hughes, 2007).

assessing the role of universities in open innovation systems, while Lawton Smith (2007) recommends not to study universities' roles in innovation systems in isolation from political pressures. Most of the empirical evidence in terms of impact on innovation agrees with the assumption that *the onus placed on universities to become bases of commercialisable knowledge in many regions was probably too heavy* (Huggins *et al*., 2008), since apparent demand from the regional business community to interact and make use of the knowledge-based services of the higher education sector is weak (Huggins *et al*., 2008). It is true that the UK has some celebrated cases – the 'Cambridge phenomenon' and 'enterprising Oxford' (a world centre for biomedical research) – that have inspired policy makers and increased confidence in universities' potential (Lawton Smith, 2007). However, an in-depth analysis shows that even though Oxfordshire is a national centre of the biotechnology sector, having key ingredients of a concentration of firms and R&D investment, the role of Oxford University (a world centre for medical research) is secondary at the regional level rather than being dominant as might be expected: the availability of skills in the region is far more significant in explaining success (Lawton Smith and Bagchi-Sen, 2010).

Different explanations exist for the moderate role of universities in regional innovation systems. Lester (2005) argues that university–industry interactions in the UK were mainly focused on the creation of new industries (e.g. the formation of high-tech clusters in knowledge generating sectors such as ICT, biotechnology etc.) and neglected other important types of economic evolutions, such as industry transplantation, diversification of upgrading of existing industries. Huggins *et al*. (2008) think the level of latent demand from businesses is significantly higher, but underexploited.

Other authors point to the differences in regional conditions (Howells *et al*., 2009; Harris *et al*., 2010; Huggins *et al*., 2010; Huggins and Kitagawa, 2012): for example, Huggins *et al*. (2010) show that networks of links between academia and industry tend to be concentrated mainly within the UK's core and most competitive regions, which are also the location for a significant proportion of the UK's most R&D-intensive firms and of a number of 'elite' universities; on the contrary, networks in more peripheral regions are less dense and are not based on the same reputational effects as found in many competitive regions. Similarly, Harris *et al*. (2010) found large differences across regions in terms of impact of cooperation on firms' total factor productivity, while Huggins and Kitagawa (2012) brought evidence on university–industry links from the devoted regions, concluding that Scotland appears fairly well advanced in this regard as compared to Wales, where the establishment of links has been more problematic. Innovation policy is also mentioned among the factors explaining failures, as it is often difficult to ascribe improved regional competitiveness only to improvements in knowledge-based infrastructure/intermediary institutions (Huggins *et al*., 2008). Not least, as suggested by the literature, UK academics tend to be more globally connected as compared to UK businesses (Abreu *et al*., 2009) and, recognising the risk that private sector demand will not meet the desired supply, universities are taking steps to diversify overseas into key markets including the USA, China and India (PACEC, 2012).

(Indirect) wider impacts. If universities' direct impacts on specific innovations are found to be minor and predominantly local, higher spillover effects are associated with skills provision (Frenz and Oughton, 2006; Harris *et al*., 2010; Huggins *et al*.,

2010) and the creation of innovative conditions (Clifton *et al*., 2010; PACEC, 2012). Harris *et al*. (2010) found that a 10% increase in the percentage of graduates leads to an increase between 0.6% and 1.4% of total factor productivity, depending on the sector. Frenz and Oughton (2006) argue that the most consistent findings of regional total factor productivity growth studies is that the stock of human capital enhances the absorptive capacity of firms, facilitating regional knowledge spillovers and ultimately growth; similarly, Huggins *et al*. (2010) concluded that the most important role of universities continues to be their human capital creation capabilities and ability to produce highly skilled and employable new labour market entrants in the form of their graduates.

With respect to their support for the creation and strengthening of the underlying innovative conditions, 75% of UK universities are now offering enterprise and entrepreneurship training; 71% provide support for student enterprise; 60% have developed their local innovation infrastructure to act as a visible point of entry into the universities and bring together the various innovation support services; 52% provide expertise to support local economic development; and 30% actively support the creation and strategic development of Local Enterprise Partnerships. At the same time, universities are increasingly becoming exporters themselves, providing knowledge exchange services to key overseas markets (PACEC, 2012).

With a view to the future, in Kitson *et al*.'s (2009b) opinion, the recession presented a unique chance for universities to realise economic benefits.

Discussion and conclusions

This paper highlights the fact that despite the great importance placed on university–industry linkages, the impacts are extremely tenuous. Thus, technology and knowledge transfer activities and the promotion and strengthening of contributions to economy and society still leave a number of 'unanswered' questions: *how to deal with diversity/heterogeneity? How to increase quality in supply/quantity in demand for knowledge? How to increase impact on academics, universities, firms, economy and society?* By a transversal analysis, our current literature review identified a number of possible answers to these questions, with important policy implications (Table 2).

Given the multi-faceted nature of university–industry links, but also the significant variations in engagement by type of university, academic disciplines, individual characteristics, firm size and sector, local contexts etc., dealing with diversity and heterogeneity are important issues for policy makers, who are also challenged to find the best means to improve quality in knowledge supply, reduce barriers in cooperation and to increase quantity in demand for knowledge, and stimulate firms' absorptive capacity. In terms of impact, finding a proper balance between research and external engagement and bringing academia and business together to address the key challenges of the future are the most important challenges to be considered when preparing the university–industry links agenda for the future.

While this study integrates a wide range of disparate studies on university–industry engagements, it has certain limitations. First, the area is developing so rapidly that certain issues might not be *current*. For example, multiple changes happened in the activities of technology/knowledge exchange offices after the extensive third stream funding. Second, this paper was not intended to offer a one-off snapshot diagnosis to serve political debates, but to give some useful insights and directions for future studies.

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Note

1. The HE-BCI survey tracked 8095 employed in a dedicated business and community role in 2012–13 (HEFCE, 2014a).

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Appendix 1. Main support structures/organisations and funding streams for university–business linkages in the UK

Higher Education Funding Council for England (HEFCE)/ Higher Education Innovation Fund (HEIF)/	HEFCE is the public body in charge of the distribution of public money for higher education to universities and colleges in England. HEFCE funds directly knowledge exchange and skills through the **Higher Education Innovation Funding (HEIF)** and employer engagement schemes (e.g. **The Workforce Development Programme**), but also through dedicated amounts from the block grant funding for research (e.g. **Multi-institutional collaboration in innovation and research**) **HEIF 2011–15** offers funding to the following infrastructure/activity categories: - **Facilitating the research exploitation process**: access points for external organisations; business development; technology transfer; consultancy support; contracts/legal support; patenting/IP advice; corporate relations; press/communications; investment funds, such as seed and proof of concept; external fundraising for research. - **Skills and human capital development**: continuing professional development/short courses; joint curriculum development; lifelong learning; careers services; work placement/project experience; knowledge sharing and diffusion. - **Knowledge sharing and diffusion**: provision of public space; alumni networks; KE professional networks;

(*Continued*)

Appendix 1. (*Continued*)

	staff exchanges; academic–external organisation networks. - **Supporting the community/public engagement**: outreach; volunteering; widening participation; awareness-raising/knowledge diffusion; involving the public in research; social cohesion/community regeneration. - **Social enterprise/entrepreneurship**: social enterprise; enterprise and entrepreneurship training. - **Exploiting the HEI's physical assets**: science parks; incubators; facilities/ equipment. *Source*: http://www.hefce.ac.uk/whatwedo/kes/
Research Councils (RC)	In addition to the support for world-class research, RC have developed a large portfolio of knowledge transfer activities, offering funding for: - **Collaborative training**: CASE/ Collaborative Doctoral Awards, Training for Industry, Dorothy Hodgkins' Postgraduate Awards. - **People and information flows**: networking, research dissemination, research brokering, placements, secondments, exchanges, collaborative research fellowships. - **Collaborative R&D**: responsive and directive mode research projects, schemes to encourage collaborative research projects through responsive mode, collaborative programmes of research, creation of shared space for collaborative R&D, TSB Collaborative R&D Programme, LINK Collaborative R&D Programme. - **Commercialisation**: promoting an entrepreneurial culture; buying-out time for commercialisation activities; proof of concept funding. *Source*: http://www.rcuk.ac.uk/
Technology Strategy Board (TSB)	The UK Innovation Agency supports and co-funds partnerships between business and academia in various forms, e.g.: - **Catapult Centres** are physical centres where the best of the UK's businesses, scientists and engineers work side by side on late-stage research and development – transforming 'high

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Appendix 1. (*Continued*)

	potential' ideas into new products and services to generate economic growth. - **Knowledge Transfer Partnerships (KTPs)** are meant to help UK businesses to improve competitiveness, productivity and performance by accessing the knowledge, technology and skills that are available within universities, colleges and research organisations, through the development of collaborative partnerships. - **Collaborative R&D initiatives** encourage businesses and researchers to work together on innovative projects in strategically important areas of science, engineering and technology – from which successful new products, processes and services can emerge, contributing to business and economic growth. - **Innovation vouchers** are meant to encourage start-ups and medium-sized businesses from across the UK to look outside their current network for new knowledge that can help them to grow and develop. - **The Small Business Research Initiative (SBRI)** is a well-established process to connect public sector challenges with innovative ideas from industry, supporting companies to generate economic growth and enabling improvement in achieving government objectives. SBRI enables the development of innovative products and services through the public procurement of research and development (R&D). *Source*: https://www.innovateuk.org/funding-support
The National Centre for Universities and Business (NCUB)	NCUB is an independent non-profit business, successor of the UK's Council for Industry and Higher Education (CIHE). It focuses on strengthening the strategic partnership between universities and business and offers performance measurement, brokerage and different practical projects (e.g. Food Economy Task Force, London Creative & Digital Fusion, Student Employability Index etc.). *Source*: http://www.ncub.co.uk/
The Association for University Research and Industry Links (AURIL)	AURIL is the largest professional association representing all practitioners involved in knowledge creation development and exchange in the UK and Ireland. It has more than 1600

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	members from universities and public sector research establishments. In partnership with other different bodies, AURIL has produced many publications on knowledge exchange, such as the *Continuing Professional Development Framework for Knowledge Transfer Practitioners* (AURIL, 2006), which has turned into the AURIL-Jisc *Professional Development Tool.* Source: http://www.auril.org.uk/Home/tabid/1130/Default.aspx
The Institute for Knowledge Transfer (IKT)	The IKT is an accredited professional body devoted to supporting and promoting the knowledge professional, improving the standards of competency knowledge transfer and stimulating the quality and provision of training. The IKT hosts and organises several events (e.g. The IKT Innovation Tours, InnovationKT Annual Conference, regional networking events etc.), offers mentoring and continuous professional development accreditations (e.g. The Certificate of Innovation, Knowledge Exchange and Transfer Cert.IKT) and manages the *Journal of Innovation Impact,* an international peer-reviewed journal that publishes fundamental and applied research on the impact of innovation, knowledge exchange and entrepreneurship, from around the world. Source: http://institutekt.com/index.html
The Intellectual Property Office (IPO)	The IPO produces resources that cover all aspects of intellectual property (IP), which is a key part of the knowledge transfer environment, e.g.: - *Intellectual asset management for universities* (IPO, 2011) is a guide that aims to help senior university managers to set strategies to optimise the benefits from the intellectual assets created by their staff and students; - *Lambert ToolKit for Collaborative Research* includes a decision guide, model agreements and guidance materials to facilitate contract negotiations involving publicly-funded research organisations (universities) and companies etc. Source: http://www.ipo.gov.uk/whyuse/research.htm
PRAXIS–UNICO	Praxis–Unico is an educational not-for-profit organisation set up to support innovation and commercialisation of public sector and charity

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	research for social and economic impact. Praxis–Unico facilitates the interaction between the public sector research base, business and government and provides a forum for best practice exchange, underpinned by training and development programmes. Source: http://www.praxisunico.org.uk/
University Enterprise Zones (UEZ)	In 2014, the government launched a pilot scheme – **University Enterprise Zones (UEZ)** – which is meant to encourage universities to strengthen their roles as strategic partners in local growth, to engage with Local Enterprise Partnerships (LEPs) and to stimulate development of incubator and/or grow on space for small businesses in locations that encourage businesses to interact with universities and to innovate. *Source*: https://www.gov.uk/government/policies/investing-in-research-development-and-innovation/supporting-pages/university-enterprise-zones