
Article:
Huggins, R., Johnston, A. and Stride, C. orcid.org/0000-0001-9960-2869 (2012) The Knowledge Networks of Higher Education Institutions: An Analysis By Type and Location. Entrepreneurship and Regional Development, 24 (7-8). pp. 475-502. ISSN 0898-5626

https://doi.org/10.1080/08985626.2011.618192

Knowledge Networks and Universities:
Locational and Organisational Aspects of Knowledge Transfer Interactions

Robert Huggins, Andrew Johnston and Chris Stride

Abstract

This paper explores the nature of the significant knowledge networks universities form with external organisations through knowledge transfer activities. Focussing on the UK higher education system, the analysis focuses on examining the extent to which organisational and locational characteristics are associated with the nature of these networks, finding that the nature of the networks universities form through knowledge transfer are related to both characteristics. In particular, we find that the institution's status is important with more established universities are likely to have a more diverse range of organisations with which they interact, as well as a higher number of non-local interactions. In terms of geographic location, we find that universities within lagging regions tend to have more locally focused networks than universities in more leading regions. Overall, the knowledge transfer networking capacity of universities is found to be associated with the regional business environment within which they are situated, with the results going someway to confirming the importance of the role of universities in regional innovation systems, However, it also the case that more established, research focussed, universities are more likely to form part of wider , and possibly even more globalised, knowledge networks. Therefore, both the flow and stock of knowledge within regions is likely to be influenced by the networks formed by its universities, which has implications for both regional innovation capability and regional competitiveness.

1. Introduction

Universities are increasingly portrayed as core knowledge-producing entities that can play an enhanced role in driving innovation and development processes by providing knowledge for business and industry (Foray & Lundvall, 1996; Garlick, 1998; Kitagawa, 2004; Thanki, 1999; Fritsch, 2002; Huggins et al., 2008). Rather than just the knowledge possessed or generated by individual firms and organisations, knowledge sourced from external sources such as universities is considered to be a key factor within modern innovation processes and the formulation of innovation systems (Chesbrough, 2003; Cooke et al., 2004; Freeman, 1987; Freeman, 1995; Lawton Smith & Bagchi-Sen, 2006; Nelson and Rosenberg, 1993). Subsequently, university knowledge transfer practices have come to the fore, especially within UK policy circles but also worldwide as many governments and related agencies are turning their attention to the role of university-generated knowledge and knowledge transfer as a policy solution designed to develop innovative, sustainable and prosperous regional and national economies (Etzkowitz, 2003; Lambert, 2003; Lester, 2005; Drucker & Goldstein, 2007; Sainsbury, 2007; Huggins et al., 2008; Wellings, 2008; Kitson et al. 2009).

Although there is increasing recognition that universities are potentially key players in achieving economic transformation, the underlying perspective is that they are often under-utilized (NCIHE, 1997; Charles, 2003; Goddard & Chatterton, 1999). At the regional level, for instance, an emerging concern is the apparent need to align and match regional knowledge producing networks with regional firms (Uyarra, 2010). However, recent work has also begun to question high policy expectations, with there being little understanding of the actual processes of knowledge flows, and the extent to which regional economic development can be achieved through the utilization of university knowledge (Power and Malmberg, 2008; Huggins, 2008). Economically weak regions may be characterised by insufficient private sector economic activity and a higher-than-average density of small firms perceiving little benefit to be gained from engaging with universities (Siegel et al., 2007).

The discourse on the role of universities as knowledge transfer institutions and key nodes in regional innovation systems is largely reliant on empirical work from exemplar regions, that is, those regions which are among the most competitive in the world in terms of economic growth rates, workforce qualifications, and the number of large, international firms based in new or high-technology sectors (Garnsey and

Heffernan, 2005; Gertler and Wolfe, 2004; Lawton Smith, 2003; Owen-Smith and Powell, 2004; Saxenian, 1994). However, for every successful region there exist many more `ordinary' and uncompetitive regions (Howells, 2005; Tödtling and Trippl, 2005; Doloreux and Dionne, 2008; Huggins and Johnston, 2009).

Universities as knowledge infrastructures may affect the knowledge flows between themselves and a range of organisations at a range of different geographical scales. However, although a growing body of work examining university knowledge transfer demonstrates that many institutions are developing policy initiatives designed to increase such activity (Tornatzky et al., 2002; Paytas et al., 2004; Palmintera, 2005; Abreu et al., 2008; Perkmann & Walsh, 2007), less is known about the nature and pattern of the networks and interactions emerging from such knowledge transfer practices.

In this paper, we seek to explore in more detail the nature and extent to which universities in the UK develop significant knowledge networks in the form of intense interactions with external organisations through knowledge transfer activities. In particular, we are interested in the extent to which both organisational and locational characteristics are associated with the nature of these networks. The paper contributes to the body of literature on university-industry linkages through examining the extent to which these networks vary depending on the regional location of a university, especially in terms of the relative competitiveness of the region (Huggins, 2003; Kitson et al., 2004; Malecki, 2004; Malecki 2007), as well as the status of the institution, in terms of whether it can be classed as 'established' or 'new'.(Braunerhjelm, 2008). In the UK context this classification revolves around whether the institution existed as a university before 1992 or was previously a polytechnic that was granted university status after 1992 when the UK higher education system was changed. Thus, the terms established and newer reflect this distinction between pre-1992 universities and post-1992 universities. Furthermore, we assess how these factors are associated with the type and location of organisations interacting with universities.

The remainder of the paper is structured as follows: sections 2 and 3 present our theoretical and conceptual frameworks as well as outlining the hypotheses we wish to test; section 3 outlines the methodology underlying the empirical analysis and the results, which are presented in section 4. The implications of these results are discussed in more detail in section 5, highlighting the theoretical contribution of the

paper. Finally, section 6 presents our conclusions plus suggestions for further research.

2. Theoretical Background

As innovation comes to be more viewed as a systemic undertaking and an open process involving multiple actors, universities are often described as central nodes of the knowledge-driven economy and key players within in knowledge networks of innovative firms (Wolfe, 2004; Benneworth & Charles, 2005; Wong et al., 2007). Furthermore, university knowledge is increasingly considered as almost a panacea for promoting knowledge-based economic development in terms of encouraging university-industry alliances as a means of exploiting the research being undertaken within the institutions. This provides the starting point for our paper; firms are increasingly encouraged to exploit university knowledge and, accordingly, universities are encouraged to commercialise their research (Lambert, 2003; Markman et al., 2005 SURF et al., 2006). Thus, the creation and maintenance of knowledge networks to support innovation is seen as crucial for development (Lechner & Dowling, 2003).

Knowledge networks can be viewed simply as the interaction of multiple actors, either formally or formally, with the express intention of sharing knowledge in order to develop a new product, production process, or organisational innovation. Most firms face constraints or limits to the amount of resources they can control or exploit for commercial purposes, and are therefore motivated to join, or indeed create, a knowledge network in order to procure external knowledge for innovation (Stuart, 2000; Grant & Baden-Fuller, 2004) The level of formality of the network to some extent depends on the type of knowledge being transferred, more complex codified knowledge tending to involve more formal interaction and tacit knowledge involving more informal interaction (Gulati, 2007).

In general, more outward looking firms are characterised as those being involved with knowledge networks and viewing external organisations such as universities as potential sources of knowledge (Sorenson et al., 2006; Huggins & Johnston, 2009). In addition, absorptive capacity plays an important part; to utilise external knowledge effectively, firms must be able to understand it and utilise similar codebooks, or rules, regulations and language (Cohen & Levinthal, 1990; Lane & Lubatkin, 1998; Cowan et al., 2000). As noted in the introduction, this paper focuses

on the knowledge networks of universities, in particular the types and location of external organisations that comprise these networks. Having broadly outlined the theoretical underpinnings of the paper, Section 3 now develops our conceptual framework in more detail.

3. Conceptual framework

The conceptual framework we employ for this analysis is summarised by Figure 1 and outlined in further detail below. In essence, it is hypothesised that both the particular characteristics of universities and their regional location will be associated with the type of intense interaction undertaken with external organisations through knowledge transfer networks. It is further hypothesised that these factors will be similarly associated with the types of external organisations with which universities interact, as well as their location. Finally, we hypothesise that the nature and pattern of intense interactions through knowledge transfer are associated with university 'performance', measured in terms of research income.

Figure 1 About Here

2.1 University characteristics

As the role of universities in the innovation process has become more widely recognized, engagement with external organisations has become more formalised in university mission statements (Lawton Smith, 2007). Within the UK context, policymakers, both national and regional, have also placed universities at the centre of economic development policies designed to exploit the UK's 'science base', promoting them as key nodes of the knowledge economy (Charles, 2003; Sainsbury, 2007). These developments mirror those taking place elsewhere in the world, reflected in a burgeoning literature that has developed concepts such as 'entrepreneurial universities' (Smilor et al., 1993; Slaughter & Leslie, 1997; Etzkowitz et al., 2000; Powers, 2004;;) and 'academic entrepreneurs' (Meyer, 2003; Shane, 2004), highlighting both institutions and academics that are highly involved in knowledge transfer activities such as the establishment of spin-off firms, and the exploitation of intellectual property rights through the licensing of technology and patent registration (D'Este & Patel, 2007; Huggins, 2008).

However, the higher education sector in the UK, as with the rest of the world, is very diverse with different universities having different objectives and focus as well as differing strengths and weaknesses, not least in terms of their research capability (Higher Education Funding Council for England et al., 2008). Thus, there are often considerable differences in the capability of universities to effectively transfer their knowledge, and of firms to effectively absorb such knowledge (Di Gregorio & Shane, 2003; Lawton Smith & Bagchi-Sen, 2006; Perkmann & Walsh, 2007). The quality and characteristics of university knowledge transfer practices and activities will necessarily be a determining factor of outputs. In the first instance, the knowledge creation capability of a university will be required to be of a quality and type that lends itself to potential transfer (Lee et al., 2001, Friedman & Silberman,2003). Furthermore, the capacity to effectively engage in knowledge transfer forms part of the wider capabilities of the institution, as well as the capabilities of respective knowledge or technology transfer offices (Carlsson & Fridh, 2002, Chapple et al. 2005).

External networking capability may also rely on the prestige and reputation of the institution (Shane & Cable, 2002). More established universities tend to be more research focused, especially in a UK context, and may have a greater attraction for external organisations looking to exploit the knowledge generated by this research for commercial purposes, with newer universities often being weaker in terms of research output (Lambert, 2003; Lockett et al., 2003; Wright et al., 2006; Wellings, 2008). As a result, more established universities may be more likely to interact with external organisations on an intense and enduring basis. In the UK, a government-sponsored review of the role of universities in stimulating innovation performance argues that whilst universities do have a crucial part to play, they cannot all be expected to contribute equally to this goal, with the onus firmly placed on 'curiosity-driven research' universities as the key sources of innovation (Sainsbury, 2007). Other, newer, universities, it is argued, should focus more on economic missions relating to 'user-driven research' and professional teaching.

In general, the diversity of university types has not been readily recognised by scholars or policy makers (Abreu et al., 2008; Kitson et al.., 2009; Lawton Smith, 2007). However, some evidence suggests that leading research-intensive universities tend to be more networked and outward looking (Lockett et al.., 2003; Sainsbury, 2007; Huggins et al., 2008). A study of universities in London found that many of the

resources associated with successful knowledge-based interaction are skewed towards the larger and more prestigious universities in the region, highlighting the existence of a large knowledge network divide across the regional higher education sector (Huggins, 2008). In addition, within the UK mean research income within established universities is significantly higher than newer universities, £3.6 million p.a. compared with £0.55 million p.a. (Mann-Whitney U Test, $Z=7.42$, $p<0.05$) This evidence suggests that more established universities will be members of larger knowledge transfer networks, implying they interact with a more diverse set of organisations than new institutions. This sets out a testable hypothesis:

> **Hypothesis 1**: The status of the institution is important in determining the range of industry links. Established universities are more likely than new universities to intensely interact with a more diverse range of organisations.

2.2 University location

The second factor we examine is university location and the importance of spatial proximity to external organisations wishing to exploit university knowledge. Scholars have long been interested in the effect of location on a range of economic activities, specifically focussing on what makes a region 'competitive' (Kitson et al., 2004). The competitiveness of a region generally refers to the prosperousness of its economy relative to others, specifically in terms of living standards (measured in terms of GDP per capita) or share of a global industry (Storper, 1997). While the idea of competitiveness has been criticised as being 'ill-defined' (Bristow, 2005), the concept has been operationalised in the literature to enable the ranking of regions based on this (see Huggins, 2010). In addition, policy discourse increasingly conceptualises competitiveness in terms of metrics such as the number of knowledge-based firms as well as levels of R&D expenditure (Huggins, 2003; Malecki, 2004; Huggins & Thompson, 2010). Competitive regions, therefore, are those which contain higher levels of knowledge-based activity and where higher levels of R&D and innovative activities are observed. This suggests that organisations located within competitive regions may have a higher demand for knowledge, resulting in higher levels engagement with universities (Huggins et al., 2008).

The existence of established knowledge networks has become viewed as one of the most important factors determining why some localities and regions throughout

the world have become or remained more competitive than others (Storper, 1997; Lawson & Lorenz, 1999; Huggins, 2000; Bathelt et al., 2004; Knobben & Oerlemans, 2006). In general, modern competitive regional economies exhibit a highly networked regional business culture, rich in 'untraded interdependencies' (Castells & Hall, 1994, Storper, 1995; Saxenian, 1994; Porter, 1998; Cooke et al., 2004; Rutten & Boekema, 2007). These networks are important in that they provide feedback loops between actors and, as a result, perpetuate high levels of innovation among members (Garnsey & Lawton Smith, 1998; Goman, 2000; Bresnahan & Gambardella, 2004).

In terms of examining the geography of knowledge networks, it has been established that knowledge spillovers from universities are often spatially constrained, i.e. firm innovation is affected by R&D undertaken by universities located within the same region(Jaffe, 1989). While these studies neglect other forms of university knowledge beyond that protected by patents (Mowery & Sampat, 2005), they do highlight the potential importance of proximity between universities and the organisations with which they interact (Fritsch & Varga, 2003). Spatial proximity to a relevant university knowledge source would therefore appear to be an important factor in accessing knowledge from that source (Davenport, 2005). This is especially important with respect to more tacit forms of knowledge where a shared 'codebook', or language and customs (Cowan et al., 2000), and the existence of a trusting relationship between parties (Wood & Parr, 2005) facilitates the absorption of knowledge from one source to another. The proximity afforded through being located within the same region as the knowledge source can therefore ensure that members of the network do indeed share the same codebook In addition, it must me acknowledged that other types of proximity (e.g. relational, organisational and social) may also have an effect on the ability to source and absorb external knowledge (Boschma, 2005), the focus here is on geographic proximity. Thus, the location of a university, specifically the competitiveness of the region in which it is located in terms of level of knowledge intensive activity, may have a bearing on the extent of its knowledge network. This leads to hypothesis two:

Hypothesis 2: Universities located in more competitive regions are more likely than universities located in less competitive regions to be members of a

wider knowledge network, and will, therefore, intensely interact with a more diverse range of organisations.

Despite the perceived importance of spatial proximity, not all knowledge is acquired from geographically proximate areas. If applicable knowledge is available locally, firms and other institutions will attempt to source and acquire it, if not they will look elsewhere (Davenport, 2005 Kingsley & Malecki, 2004). In addition, firms with higher absorptive capacity are often more connected to global networks (Drejer & Lund Vinding, 2007). The fact that non-proximate actors may be able to transfer complex knowledge across spatial boundaries suggests the constraining effect of distance on knowledge flow and transfer is gradually diminishing (McEvily & Zaheer, 1999; Dunning, 2000; Lissoni, 2001; Tracey & Clark, 2003; Teixeira et al. 2006). For instance, globally sourced knowledge may be superior to that available locally, resulting in improved innovation performance (Davenport, 2005; Zaheer & Bell, 2005; Palazzo, 2005; Johnson et al., 2006). Rising levels of national and transnational academic-industry partnerships demonstrates that neither firms nor universities consider knowledge flows to be necessarily spatially constrained (Huggins et al., 2008). The increased reliance on wider spatial knowledge pipelines is reflected by the growing number of firms choosing to work with the best universities regardless of location in order to take advantage of high talent pools, favourable intellectual property rules and government incentives for joint industry-university research (NSF, 2006; Polenske 2007).

Successful and competitive regional economies are typically populated by research intensive universities that are engaged in world leading research (Drucker and Goldstein, 2007; Lawton Smith, 2007; Sainsbury, 2007). Often these universities have played an important role in the region's innovation and competitiveness culture, for example Cambridge University and the biotechnology cluster in the local area (Cooke, 2002; Cooke & Huggins, 2003) and Stanford University within Silicon Valley (Saxenian, 1994). Whilst a world leading research-intensive university does not necessarily create a high-technology economy (Feldman & Desrochers, 2003), universities undertaking world leading research in competitive regions are also more likely to be members of national or global knowledge pipelines (Bathelt et al., 2004).

Hypothesis 3: Established universities are more likely than newer universities to intensely interact with organisations located outside their own region.

Hypothesis 4: Universities located in more competitive regions are more likely than universities located in less competitive regions to intensely interact with organisations located outside their own region.

2.3 Type and location of interacting organisation

A broader outlook and a willingness to collaborate make firms more likely to engage in interaction with universities (Motohashi, 2005). However, the utilisation of university knowledge is not uniform across all organisations, with not all benefiting equally. There are differences between the objectives of larger and smaller firms, with larger firms tending to focus on building on non-core competences, whereas smaller firms focus on solving problems in their core areas (Santoro & Chakrabarti, 2002). There may also be sectoral differences, with a significant correlation existing between the concentration of high-technology industries and university research relevant fields within a region (Nagle, 2007).

Intense interactions between universities and external organisations are clearly not confined to one single type of organisation but span a number of actors and processes (Huggins et al., 2008). Larger and smaller firms both utilise knowledge generated within universities for innovation, but in smaller firms this knowledge may be of greater importance due to the fact they possess fewer knowledge resources internally (Acs et al., 1994). How larger firms are likely to possess more resources – in the form of human, research, and financial capital – as well the capability to engage in wider spatial knowledge networks. Therefore intense interactions with larger organisations, which are always spatially proximate to the universities with which they interact, are likely to be of greater benefit to the universities with which they are interacting.

Hypothesis 5: Higher levels of research income are associated with those universities intensely interacting with organisations that are: (a) large domestic or multinational firms; (b) located outside their own region; and (c) are large domestic or multinational firms located outside their own region.

3. Methodology

The data analysed in this paper was gathered via a postal survey sent to all UK universities (159 institutions) covering all 12 UK NUTS 1 (i.e. Government Office) regions. In total, 59 usable responses were received, giving a response rate of 37%. The 59 responses included both established (i.e. pre-1992) institutions, and new (i.e. post-1992) institutions. The responding institutions accounted for 71% of total research income for all universities in the UK, and at least 50% of the university research income within each UK region. Paper questionnaires were posted to knowledge transfer officers within all universities, contact details for which were obtained from a HEFCE (the Higher Education Funding Council for England) database (which also held details of institutions in Scotland, Wales, and Northern Ireland). These individuals were targeted because of their natural overview of their institution's external relationships. Postal administration was followed up with an electronic version of the questionnaire, as well as telephone calls to encourage a prompt return.

Whilst we acknowledge that the external networks universities are extremely complex and encompass more than will be known to the respective knowledge transfer office, the purpose of this survey was to obtain an overview of the most important external knowledge networks in terms of the type and geographic location of organisations interacting intensely with universities in a knowledge transfer capacity. Hence the primary question in the survey asked respondents to provide, for each of eight knowledge transfer areas, the type and location of three external companies or organisations – in no particular order - which they considered their institution to have *'most intensely interacted with over the last three years'*. As guidance, we defined 'intense interaction' as referring to 'collaboration or cooperation that has involved strong relationships and networks developing between *institutions (and relevant staff) and firms or other organisations'*.

The eight areas of knowledge transfer listed consists of the following categories: (1) collaborative research - activities which involve undertaking a project in partnership with a firm or other organisation; (2) contract research with SMEs - activities which involve undertaking a project for a small or medium sized firm (less than 250 employees); (3) contract research with non-SMEs - activities which involve undertaking a project for a large firm (more than 250 employees); (4) consultancy contracts - activities which involve the provision of a specific service, facility or piece

of equipment to another organisation; (5) courses for businesses - activities which involve creating or providing education for the business community; (6) patents - activities which resulted in the application or granting of a patent; (7) licences - activities where the interaction involved the granting of licences; (8) spin-outs - activities which involved interaction with any firm which is: a spin-out with some ownership by a university; a spin-out not owned by the institution; a staff start-up; or a graduate start-up.

This approach provides a broad overview of the most important external knowledge-based network relationships for each university, from which we were able to build-up a comprehensive list of the types of organisations universities intensely interact with, and also their location. Having reviewed the responses provided by each university, we categorised the interacting organisations as follows: (1) Multinational Enterprise - company with plants/units located in more than one nation; (2) Large Domestic Enterprise - UK company with more than 250 employees; (3) SME - company with less than 250 employees; (4) Public Sector Research Establishments - e.g. Defence Evaluation Research Agency, Forensic Science Service, Institute of Food Research, Meteorological Office; (5) Other Public Sector/Government Departments, Authorities or Agencies; (6) University or Higher Education Institute; (7) Funding Council or Other Funding Body; (8) Private Sector Research Establishments, and (9) other organisations. Interactions were also classified geographically, initially by region (or nation if outside UK, and then grouped as follow (1) Local - network actor located in same region as the university, (2) UK, non-Local (other region of the UK), (3) European, and (4) the rest of the World. From these classifications of each interaction, summary variables were created.

Further variables were collected on the characteristics of each university and relevant financial data, in particular research income. University characteristics included the status of the institution and the relative competitiveness of region in which it was located. Status was coded as a binary variable: established universities were defined as those awarded university status before 1992, and new universities defined as those established during and after 1992, when the UK higher education

system was modified to allow former polytechnics and higher education colleges to obtain their own degree awarding powers[1].

Likewise, the location measure of regional competitiveness was represented by aggregating the regions into competitive versus less-competitive regions. As previously noted, in this case the 'region' is taken to be one of the 12 UK NUTS 1 regions as it is these spatial units which form the basis of sub-national policymaking within the UK. Whilst we acknowledge that the spatial scale over which knowledge spillovers between universities and industry are measured does vary widely, covering a region, a metropolitan area or travel to work areas (Feldman, 1999; D'Este & Iammarino, 2010) Based on the UK Competitiveness Index (Huggins, 2003; Huggins and Thompson, 2010), of the twelve UK NUTS 1 regions, the competitive regions consisted of Eastern England, London, and South East England, as these are the only ones performing above the UK average in terms of a broad number of economic indicators, such as GVA per capita, productivity, R&D expenditure and unemployment. The remaining nine regions were classed as relatively uncompetitive as they lag behind the UK average in terms of the same economic indicators, as well as knowledge-based indicators such as innovation, patenting, and densities of knowledge-intensive firms.

Of the 59 responding universities, 34 (58%) were established (pre-1992) establishments (cf. 46% for the total population of universities). All 12 regions were represented, with the highest proportion of respondents (11; 19%) from London, and the lowest, just 1, from Northern Ireland (which only has 2 universities). Using the classification highlighted above, 22 respondents (37%) were located within competitive regions (cf. 41% for the total population of universities).

The total number of interactions reported across the knowledge transfer areas had an approximately normal distribution, with a mean of 17.85 links and a median of 18 links. Of the 59 universities, only 7 were able to name a full set of 24 links over the 8 knowledge transfer areas, with 5 reporting less than 10 links. Universities were most likely (over 90%) to name the maximum of three for consultancy contracts and

[1] It was decided to include status as a dichotomous rather than continuous variable for a number of reasons. Firstly, many UK universities have been involved in a number of mergers; therefore establishing a date of founding does not necessarily reflect the longevity of an institution. Secondly, the UK higher education system has two distinct periods of expansion, the 1960s and 1990s and including age as a continuous variable would result in many institutions having similar ages. We feel that a dichotomous variable best reflects the peculiarities of the UK system where universities are generally viewed as 'established' (founded before 1992) or 'new' (gained university status in 1992 or later).

for collaborative research; in contrast, only 17 universities were able to name three organisations with whom they interacted with respect to patenting activity.

The data analysis performed was initially exploratory, describing the characteristics of the universities within our sample, and then providing an overview of the types and locations of organisations with which universities intensely interact through knowledge transfer. This was followed by a series of inferential statistical analyses to examine the hypotheses indicated above. For hypotheses 1 and 2, we first tested for the impact of status (established versus newer) and region (competitive versus non-competitive) upon the types of interactions possessed by the universities. We achieved this using a two-way analysis of variance to assess the unique impact of each of these variables. The main effects tested by this analysis were also examined by using a pair of (non-parametric) Mann-Whitney U-tests. We then tested the associations of both status and competitiveness of region against the predominant type of organisation with which universities interact via a pair of chi-square tests.

Hypotheses 3 and 4 were assessed by examining the differences in the average percentage of non-local interactions by university age and regional competitiveness. Since the distribution of the percentage of interactions that were non-local is approximately normally distributed, a two-way analysis of variance was used to simultaneously determine the unique impact of status and location (regional competitiveness). Again, a pair of Mann-Whitney U-tests - one for each predictor in turn - were also run as a supplementary analysis. The relationships between the location of an interacting organisation and university age and location were also assessed by a pair of cross-tabulations and accompanying chi-square tests.

Finally, to test the relative 'value' to universities of their knowledge transfer with interacting organisations, we examined whether the predominant type and geographical location of these organisations was related to research income[2], using a two-way analysis of variance. For all of the inferential statistical tests described above we used the $p < 0.05$ level of statistical significance, employing one-tailed tests where the proposition was directional. Measures of effect size are quoted where appropriate.

[2] Research income was included as proxy for total research activity for each university. Consideration was given to normalising this by FTE for each institution; however we felt that this did not necessarily reflect the total number of academics within a university. In addition as the value of individual grants varies widely we felt it was not appropriate to attempt to control for this. Therefore total research income is included as a measure for total research activity.

4. Results

Table 1 provides a full breakdown of the types of organisations universities intensely interact with by knowledge transfer area. Classifying broadly, private sector actors, i.e. multinationals, large domestic firms and SMEs, are overwhelmingly regarded by universities as the organisations with which they most intensely interact across all knowledge transfer areas, accounting for over three-quarters of the average number of interactions. Specifically, over all transfer areas the most common types of firms and organisations with which there are intense interactions are SMEs. On average, SMEs account for almost 40% of interactions, and were the most frequently recorded type for five of the eight knowledge transfer areas. Multinationals account for, on average, 20% of interactions, and large domestic firms 18%.

Table 1 about here

Table 2 provides a similar breakdown by the geographical location of interacting organisations. The most common location of organisations across all interaction types is local (i.e. within the same region as the university), although this varies between knowledge transfer areas, with contract research for SMEs and spin-outs the most likely to be undertaken with locally-based organisations (on average, over 80% in each case), compared to collaborative research, contract research for non-SMEs, patents, and licensing, all of which were almost as likely to be undertaken with non-local organisations including organisations from outside the UK.

Calculating the predominant organisational type and location across the knowledge transfer areas for each university, SMEs are found to be the predominant type in 64% of universities, with a further 17% more likely to interact with multinationals. The other type of organisations with which there is frequent interaction is the public sector and large domestic firms. In terms of the location of interacting organisations, 76% of universities are most likely to interact with locally-based organisations, with the rest most frequently interacting with non-local UK based organisations.

Table 2 about here

This leads us to examine hypotheses 1 and 2, which postulated the existence of differences in the diversity of interactions across older and newer universities, as well as between those located in competitive or less competitive regions. A significant relationship is found between the total number of interactions and university status (Cohen's D = 0.61 indicating a medium effect size, $F = 5.54$, $p < 0.05$), but not with location. Results from a pair of non-parametric tests investigating the main effects of university age and location separately give the same pattern of effects. Sample means (reported in Table 3) indicate that older universities record significantly more links. This indicates a difference in breadth of scope – diversity - since universities were limited to recording three interactions within each area.

A chi-square test of predominant interacting organisation type by age provides evidence that these constructs are not independent (chi-sq = 13.24 on 10df, $p < 0.05$), with 72% of newer universities most likely to interact with domestic SMEs, compared to 59% of older universities, which are more likely to interact with multinationals (27% of older universities list this as their predominant interacting organisation type). However, there is no evidence to reject the assumption of independence between interacting organisation type and the regional competitiveness of a university's location. For instance, in both competitive and less competitive regions, approximately 65% of universities primarily interact with SMEs. Together these results offer support for hypothesis 1, though not for hypothesis 2. Therefore it appears that the types of organisations universities intensely interact with are more likely to be determined by the type of institution rather than its location.

The percentage of interactions with organisations outside a university's own region (i.e. non-local interactions) is found to vary across older and newer universities, as well as between those situated within more or less competitive regions (Table 4 for a summary). Specifically, older universities are more likely to intensely interact with organisations outside their own region, with a median percentage of interactions that were non-local of 40%, compared to 31% for older universities (Cohen's D = 0.44, $F = 3.28$ $p < 0.05$). Interestingly, we find that organisations in South East England and London account for more than one-half of the inter-regional interactions of universities in other regions (22% and 30% respectively). This result is unsurprising as London and South East England are the UK's most competitive locations, possessing the highest densities of knowledge-based firms and a higher proportion of the UK's public sector R&D activity (Huggins & Thompson, 2010).

These factors clearly heighten the propensity for universities in other regions to interact with organisations from these two regions.

Table 3 About Here

Universities located in competitive locations are more likely to intensely interact with organisations outside of these regions, with a median percentage of non-local interactions of 42%, compared to 32% for universities in less competitive regions (Cohen's $D = 0.51$, $F = 4.07$, $p < 0.05$). Universities in London report 35% of their intense interactions to be with organisations located in South East England, with universities in South East England reporting 26% intense interactions to be with London-based organisations. Clearly, issues of geographic proximity may to some extent account for these flows, but none of the universities in other regions possess such a cross-flow of knowledge.

When the predominant location of interacting organisations is examined, there is evidence (though not statistically significant at the $p < 0.05$ level) that this is not independent of either university age or location. In total, 71% of older universities report the location of their predominant interacting organisations as being local, compared to 84% of newer universities. Furthermore, 64% of universities in competitive regions reported the location of their predominant interacting organisations as being local, compared to 84% of universities based in the less competitive regions. Together, these results offer support for hypotheses 3 and 4, i.e. more established universities and those located in more competitive regions are more likely to report intense interactions with organisations from outside their home region.

Table 4 about here

In terms of assessing the relative university income value of the various interactions, a statistically significant relationship is found between university research income and both the predominant type and location of interacting organisations. Specifically, the main effects indicate that those universities interacting with non-locally-based organisations, and those interacting with multinationals and large domestic companies, are more likely to report higher levels of research income ($F = 3.304$, $p < 0.05$; $F = 6.145$, $p < 0.05$ respectively). However, when breaking down universities by

a combination of predominant interacting organisation type and location, the subgroup with the highest research income are those universities interacting with locally-based large domestic firms, as illustrated by Figure 2, lending support to hypothesis 5.

Whilst the analysis cannot put an actual value on each type of interaction it does illustrate the types of interactions that are associated with the highest levels of research income across universities. The evidence suggests that universities with higher levels of research income report that they predominantly have intense interactions with large domestic firms based within the same region. In addition, intense interaction with multinational firms and domestic SMEs located outside the region are associated with higher levels of research income. By contrast, universities that are predominantly involved in intense interactions with SMEs and public sector organisations within their own region tend to have lower levels of research income. Overall, the evidence suggests there is not a strict dichotomy of local interactions being more associated with a higher level of research income than non-local interactions or vice versa, but a more complex relationships based on the type of institution and interacting organisation, as well as the location of each.

Figure 2 about here

5. Discussion

The findings presented in the previous section highlight some interesting results. Firstly, the status of the university is important in terms of influencing the size of its knowledge network. Therefore, hypothesis 1, that established universities are more likely to have a more diverse range of organisations with which they intensely interact, is confirmed, In addition to this, we find that a university's status is also important in determining the level of non-local interactions within its knowledge network, i.e. the extent to which an institution participates in global knowledge pipelines. These findings suggest that the organisational aspects of a university's knowledge transfer network are more likely to be based on the status of university rather than the competitiveness of its location. Therefore, the status of an institution determines the size of its knowledge transfer network; those institutions that have higher levels of research income and are more established tend to participate in larger networks than newer institutions that with lower levels of research income.

With respect to the location of a university and its non-local interactions, we find that both hypotheses 3 and 4 are confirmed; established universities have a higher number of non-local interactions, as do universities located in more competitive regions. In general, all universities - in less competitive regions are more introverted than their counterparts in more competitive regions. However, we find that universities in more competitive regions are not more likely to have a more diverse range of organisations with which they intensely interact than their counterparts in less competitive regions (hypothesis 2). Therefore, the location of a university only has an effect on the scope of its links not the type of links.

These results suggest that more established universities are more likely to belong to globalised knowledge networks that transcend the region in which they are located. The fact that universities located in more competitive regions have a larger number of non-local links suggests that the knowledge networks of universities within these regions reflects those of the firms in the region. This hints at the influence of the institutional setting of the university in that it reflects the norms of the entire region (North, 1990), although further research is clearly required in this area in order to assess this in greater depth. This finding reinforces the contention that regional contexts are an important influencing factor on universities and the composition of their knowledge networks, with universities in lagging regions focussing more on local firms - usually SMEs -which may not result in the creation of the type of reputation effects associated with larger firms (Howells, 2005; Todtling & Trippl, 2005; Benneworth & Hospers, 2007; Drucker & Goldstein, 2007; Huggins et al., 2008). Interaction with organisations in London and the South East of England, i.e. the most competitive UK regions home to the largest number of knowledge-based firms and highest levels of innovation and R&D expenditure, represents a significant link for many universities located in other regions. This suggests a bias exists in terms of the location of external partners towards the more competitive regions, in line with the results reported by D'Este & Iammarino (2010). We suggest this may result from higher regional absorptive capacity, that is the organisations within these regions simply possess a greater absorptive capacity for external knowledge and, thus, have a higher propensity for sourcing university knowledge (Azagra-Caro et al., 2006). What has not been established, however, is the direction of causation for this relationship, therefore further research is required in order to establish whether it is universities

that seek to develop links with strong firms regardless of their location or is it competitive firms seek out the specific knowledge they need whether it is proximate or distant?

The overall level of university research income is associated with both the type and location of the predominant interacting organisation. Hypotheses 5a and 5b are confirmed, as there is evidence that higher levels of research income are associated with a focus on intense interaction with non-local organisations or larger organisations. However, hypothesis 5c cannot be confirmed, as not all non-local interactions with larger organisations are associated with higher levels of research income.

In terms of research income generation, there are clear differences between the predominant type of external organisation a university interacts with and overall research income. This is an important finding as it shows that intense interactions with some types of external organisation are more valuable to universities than others. This may have an important bearing on the choice of interacting organisations across universities, with knowledge transfer officers keen to maximise research income at a time when the overall budget for higher education is facing reductions (Sainsbury, 2007). The geography of the network is also linked to overall research income, with non-local interactions generally being more valuable. Therefore, although universities are increasingly viewed by as important sources of local knowledge and encouraged to interact with local businesses (Lawton Smith, 2007), the reality is that it is interactions with non-local organisations which is most associated with higher levels of research income.

From a theoretical perspective, these findings appear to support the discourse that global knowledge pipelines are important mechanisms for the transmission of knowledge (Bathelt et al., 2004; Owen-Smith and Powell, 2004). Those organisations engaged in knowledge transfer networks with universities appear to be inclined to seek out a specific institution regardless of location, rather than 'plump' for a local institution. We can infer from this that inter-regional knowledge networks between firms and universities are not hindered by the lack of a shared 'code-book' **(**Cowan et al., 2000; Breschi & Lissoni, 2001). More practically, this has implications for the policymakers, especially in terms of the spatial scale at which the demand and supply for university knowledge can be best mediated (Lambert, 2003; Paytas et al., 2004; Lawton Smith, 2007). Firms and other organisations do not necessarily cluster around

universities best equipped with knowledge they require, but instead source the best knowledge regardless of location limitations. Clearly, interactions between universities and external organisations are often based on reputation effects, where academic excellence in specific research areas attracts such organisations regardless of location.

As noted previously, this study represents an overview of university-industry linkages within the UK and, as such, poses a number of questions for further research. Fristly, a clear issue within the relevant research is the lack, with some notable exceptions (for example Dill, 1995; Feldman & Desrochers, 2004; Youtie & Shapira, 2008) of the type of qualitative research that allows us to better understand the processes by which knowledge networks involving universities develop and evolve. Such networks will inevitably go beyond those on the radar of a university knowledge or technology transfer office. Indeed, a potential limitation of our own analysis is that it is based on data provided by such offices. I. Therefore this paper provides an aggregated overview of university-industry links within the UK, with the unit of analysis being the individual university, we have not included any metrics for research quality as these are collected at the department level, and therefore aggregating them for a whole university does not give offer a clear picture of research quality. Thus, there is scope for using individual departments as the unit of analysis in order to assess the effects of the quality of research undertaken within the departments on the number of significant knowledge links with external organisations, as D'Este & Iammarino (2010) did in terms of engineering and science based research grants.

In addition to the change in the organisational unit of analysis there is also scope for altering the geographic unit of analysis from reasonably large NUTS 1 regions covering multiple cities to a use a smaller geographic unit such as a county (NUTS 2) or city (NUTS 3). Whilst the paper highlights the significance of links in more competitive regions of the UK, further research could be directed towards understanding which sub-regions are the most important in terms of significant interactions with external organisations.

6. Conclusion

This paper has shown that the nature of the significant knowledge networks universities form through knowledge transfer vary are according to both institutional status and the location of the institution. At the outset of the paper, we indicated the apparent importance of universities as key actors and nodes within regional knowledge networks. The results produced here go someway to confirming the importance of the role of universities in such networks. However, it clearly the case that the knowledge networks of established universities are more likely to be of greater scope and more globalised.

In terms of regional development policy implications, universities need to be seen as part of the 'co-evolution' process between 'global and national structures' and 'global-national-regional interactions' (Sotarauta & Kautonen, 2007). All universities to some extent aim to be part of a global knowledge network, but in order for regions to operate through global network nodes the business communities surrounding universities need to have the capability to absorb and exploit the science, innovation, and the technologies generated by the universities (Florida, 1999; Feller, 2004; Doloreux & Dionne, 2008). However, even the most prestigious universities often look to their region and locality for support, as well as claiming credit for adding to the area's economic and social strength (Lawton Smith, 2007; Kitson et al., 2009; Huggins et al., 2008). In the vein, we should not overlook the fact that universities also have important roles to play in preserving local jobs, diversifying the local economy and attracting inward investors. Furthermore, regions in economic 'catch-up' positions, without multiple nodes of knowledge generation, tend to hope that their universities will serve as an 'anchor tenant' (Agrawal & Cockburn, 2003) to attract other private-sector knowledge-based facilities.

More widely, universities alone cannot be expected to shoulder the burden for transforming the innovation capabilities and knowledge economies of their regions. Universities are far from a homogeneous grouping, and policymaking may be better served by embracing such diversity. To an extent economic development and innovation policy in the UK has increasingly recognised the need to account for regional diversity. However, the Further and Higher Education Act of 1992 (HMSO, 1992), which established polytechnics as universities, has implicitly pushed an agenda of homogenisation across the higher education sector. Although in itself this has brought certain benefits, it has meant that the breadth of differentiated aims and

activities across UK institutions has become somewhat opaque from a policy-making perspective.

References

Abreu, M., Grinevich, V., Hughes, A., Kitson, M., & Ternouth, P. (2008). Universities, business and knowledge exchange. London: The Council for Industry and Higher Education.

Acs, Z., Auderetsch, D. B., & Feldman, M. P. (1994). R&D spillovers and recipient firm size. Review of Economics and Statistics, 76(2), 336-340.

Agrawal, A., & Cockburn, I. (2003). The anchor tenant hypothesis: Exploring the role of large, local, R&D-intensive firms in regional innovation systems. International Journal of Industrial Organization, 21(9), 1227-1253.

Azagra-Caro, J., Archontakis, F., Gutierrez-Gracia, A., & Fernandez-de-Lucio, I. (2006). Faculty support for the objectives of university-industry relations versus degree of R&D cooperation: The importance of regional absorptive capacity. Research Policy, 35(1), 37-55.

Bathelt, H., Malmberg, A., & Maskell, P. (2004). Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. Progress in Human Geography, 28(1), 31-56.

Benneworth, P., & Charles, D. (2005). University spin-off policies and economic development in less successful regions: Learning from two decades of policy practice. European Planning Studies, 13(4), 537-557.

Benneworth, P., & Hospers, G.-J. (2007). The new economic geography of old industrial regions: universities as global-local pipelines. Environment and Planning C: Government and Policy, 25(6).

Boschma, R. A. (2005). Proximity and innovation: A critical assessment. Regional Studies, 39(1), 61-74.

Braunerhjelm, P. (2005). New Universities, New Industries and Regional Performance, *Paper presented at the 'DRUID Tenth Anniversary Summer* Conference. Copenhagen, Denmark.

Breschi, S., & Lissoni, F. (2001). Knowledge spillovers and local innovation systems: A critical survey. Industrial and Corporate Change, 10(4), 975-1005.

Bresnahan, T., & Gambardella, A. (Eds.). (2004). Building high-tech clusters: Silicon Valley and beyond. Cambridge: Cambridge University Press.

Bristow, G. (2005). Everyone's a 'winner': problematising the discourse of regional competitiveness. Journal of Economic Geography, 5(3), 285-304.

Carlsson, B., & Fridh, A. C. (2002). Technology transfer in United States universities: A survey and statistical analysis. Journal of Evolutionary Economics, 12(1-2), 199-232.

Castells, M., & Hall, P. (1994). Technopoles of the world: The making of the twenty-first century industrial complexes. London: Routledge.

Chapple, W., Lockett, A., Siegel, D. S., & Wright, M. (2005). Assessing the relative performance of U.K. technology transfer offices: Parametric and non-parametric evidence. Research Policy, 34(3), 369-384.

Charles, D. (2003). Universities and territorial development: Reshaping the regional role of UK universites. Local Economy, 18(1), 7-20.

Chesbrough, H. W. (2003). Open Innovation: The New Imperative for Creating and Profiting from Technology. Cambridge, MA: Harvard Business School Press.
Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. Administrative Science Quarterly, 35(1), 128-152.
Cooke, P. (2002). Regional innovation systems: General findings and some new evidence from biotechnology clusters. Journal of Technology Transfer, 27(1), 133-145.
Cooke, P., Heidenreich, M., & Braczyk, H. (Eds.). (2004). Regional innovation systems: The role of governance in a globalised world. London: Routledge.
Cooke, P., & Huggins, R. (2003). High-technology clustering in Cambridge. In Sforzi (Ed.), The Institutions of Local Development (pp. 51-74). Aldershot: Ashgate.
Cowan, R., David, P., & Foray, D. (2000). The explicit economics of knowledge codification and tacitness. Industrial and Corporate Change, 9(2), 211-253.
D'Este, P., & Iammarino, S. (2010). The spatial profile of university-business research partnerships. Papers in Regional Science, 89(2), 335-350.
D'Este, P., & Patel, P. (2007). University-industry linkages in the UK: What are the factors underlying the variety of interactions with industry? Research Policy, 36(9), 1295-1313.
Davenport, S. (2005). Exploring the role of proximity in SME knowledge-acquisition. Research Policy, 34(5), 683-701.
Di Gregorio, D., & Shane, S. (2003). Why do some universities generate more start-ups than others? Research Policy, 32(2).
Dill, D. D. (1995). University-Industry Entrepreneurship – The Organization and Management of American-University Technology Transfer Units. Higher Education, 29(4), 369-384.
Doloreux, D., & Dionne, S. (2008). Is regional innovation system development possible in peripheral regions? Some evidence from the case of La Pocatière, Canada Entrepreneurship and Regional Development, 20(3), 259-283.
Drejer, I., & Lund Vinding, A. (2005). Searching Near and Far: Determinants of Innovative Firms' Propensities to Collaborate across Geographical Distances, Paper presented at the DRUID Tenth Anniversary Summer Conference 2005 on the Dynamics of Industry and Innovation: Organizations, Networks and Systems. Copenhagen: June 27-29.
Drucker, J., & Goldstein, H. (2007). Assessing the regional economic development impacts of universites: A review of current approaches. International Regional Science Review, 30(1), 20-46.
Dunning, J. H. (2000). Regions, Globalization, and the Knowledge Economy: The Issues Stated. In Dunning (Ed.), Regions, Globalization, and the Knowledge-Based Economy. Oxford: Oxford University Press.
Etzkowitz, H. (2003). Innovation in innovation: The triple helix of university-industry-government relations. Social Science Information, 42(3), 293-337.
Etzkowitz, H., Websterb, A., Gebhardt, C., Regina, B., & Terra, C. (2000). The Future of the University and the University of the Future: Evolution of Ivory Tower to Entrepreneurial Paradigm. Research Policy, 29(2), 313-330.
Feldman, M. P. (1999). The economics of innovation, spillovers and agglomeration: A review of empirical studies. Economics of Innovation and New Technology, 8, 5-25.
Feldman, M. P., & Desrochers, P. (2003). Research universities and local economic development: Lessons from the history of the John Hopkins University. Industry and Innovation, 10(1), 5-24.

Feller, I. (2004). Virtuous and vicious cycles in the contributions of public research universities to state economic development objectives. Economic Development Quarterly, 18(2), 138-150

Florida, R. (1999). The role of the university: Leveraging talent, not technology. Issues in Science and Technology, 15(1), 67-73.

Foray, D., & Lundvall, B. (1996). The knowledge-based economy: From the economics of knowledge to the learning economy. In OECD (Ed.), Employment and growth in the knowledge-based economy (pp. 3-28). Paris: OECD.

Freeman, C. (1987). Technology policy and economic performance : lessons from Japan. London: Pinter.

Freeman, C. (1995). The' national system of innovation' in historical perspective. Cambridge Journal of Economics, 19(1), 5-24.

Friedman, J., & Silberman, J. (2003). University Technology Transfer: Do Incentives, Management, and Location Matter? Journal of Technology Transfer, 28(1), 17-30.

Fritsch, M. (2002). Measuring the quality of regional innovation systems: A knowledge production function approach. International Regional Science Review, 25(1), 86-101.

Fritsch, M., & Varga, A. (2003). Spatial knowledge spillovers and university research: Evidence from Austria. Annals of Regional Science, 37(2), 303-322.

Garlick, S. (1998). Creative associations in special places: Enhancing the role of universities in building competitive regional economies. Canberra.

Garnsey, E., & Lawton Smith, H. (1998). Proximity and complexity in the emergence of high technoogy industry: The Oxbridge comparison. Geoforum, 29(4), 433-450.

Goddard, J., & Chatterton, P. (1999). Regional development agencies and the knowledge economy: Harnessing the potential of universities. Environment and Planning C: Government and Policy, 17(6), 685-699.

Goman, C. K. (2000). The human side of high-tech: Lessons from the technology frontier. New York: John Wiley & Sons.

Grant, R., & Baden-Fuller, C. (2004). A knowledge accessing theory of strategic alliances. Journal of Management Studies, 41(1), 61-84.

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

Higher Education Funding Council for England, Scottish Funding Council, Higher Education Funding Council for Wales, & Department for Employment and Learning. (2008). Research assessment exercise 2008: The outcome: available at http://www.rae.ac.uk/results/outstore/RAEOutcomeAE.pdf - downloaded April 2011.

HMSO. (1992). 1992 Further and Higher Education Act, 1992 Public General Acts - Elizabeth II chapter 13. London: HMSO.

Huggins, R. (2000). The Business of Networks: Inter-firm Interaction, Institutional Policy and the TEC Experiment. Aldershot: Ashgate.

Huggins, R. (2003). Creating a UK Competitiveness Index: Regional and Local Benchmarking. Regional Studies, 37(1), 89-96.

Huggins, R. (2008). Universities and knowledge-based venturing: Finance, management and networks in London. Entrepreneurship and Regional Development, 20(2).

Huggins, R., & Johnston, A. (2007). The Knowledge Networks of SMEs: Findings from an Uncompetitive Region. Growth and Change, 40(2), 227-259.
Huggins, R., Johnston, A., & Steffenson, R. (2008). Universities, knowledge networks and regional policy. Cambridge Journal of Regions, Economy and Society, 2(1), 321-340.
Huggins, R., & Thompson, P. (2010). UK Competitiveness Index 2010. Centre for International Competitiveness: University of Wales Institute, Cardiff.
Jaffe, A. B. (1989). Real effects of academic research. American Economic Review, 79(5), 957-970.
Johnson, D. K. N., Siripong, A., & Brown, A. S. (2006). The Demise of Distance? The Declining Role of Physical Proximity for Knowledge Transmission. Growth and Change. Growth and Change, 37(1), 19-33.
Kingsley, G., & Malecki, E. J. (2004). Networking for Competitiveness Small Business Economics, 23(1), 71-84.
Kitagawa, F. (2004). Universities and Regional Advantage: Higher Education and Innovation Policies in English Regions. European Planning Studies, 12(6).
Kitson, M., Howells, J., Braham, R., & Westlake, S. (2009). The connected university: Driving recovery and growth in the UK economy. London: NESTA.
Kitson, M., Martin, R., & Tyler, P. (2004). Regional Competitiveness: An Elusive yet Key Concept? Regional Studies, 38(9), 991-999.
Knobben, J., & Oerlemans, L. (2006). Proximity and inter-organizational collaboration: A literature review. International Journal of Management Reviews, 8(2), 71-89.
Lambert, R. (2003). Lambert review of business university collaboration. Norwich: HMSO.
Lane, P., & Lubatkin, M. (1998). Relative absorptive capacity and interorganisational learning. Strategic Management Journal, 19, 461-477.
Lawson, C., & Lorenz, E. (1999). Collective learning, tacit knowledge and regional innovative capacity. Regional Studies, 33(4), 305-317.
Lawton Smith, H. (2007). Universities, innovation, and territorial development: a review of the evidence. Environment and Planning C: Government and Policy, 25(1).
Lawton Smith, H., & Bagchi-Sen, S. (2006). University-industry interactions: The case of the UK biotech industry. Industry and Innovation, 13(4), 371-392.
Lechner, C., & Dowling, M. (2003). Firm networks: external relationships as sources for the growth and competitiveness of entrepreneurial firms. Entrepreneurship and Regional Development, 15(1), 1-26.
Lee, C., Lee, K., & Pennings, J. M. (2001). Internal Capabilities, External Networks, and performance: A study on Technology-Based Ventures. Strategic Management Journal, 22(6-7), 615-640.
Lester, R. K. (2005). Universities, innovation, and the competitiveness of local economies: Summary report from the local innovation systems project - phase I. WP 05-010, Industrial Performance Center, Massachusetts Institute of Technology, MA: http://web.mit.edu/ipc/publications/pdf/05-010.pdf.
Lissoni, F. (2001). Knowledge codification and the geography of innovation: The case of Brescia mechanical cluster. Research Policy, 30(9), 1481-1500.
Lockett, A., Murray, G., & Wright, M. (2002). Do UK Venture Capitalists Still Have a Bias Against Investment in New Technology Firms. Research Policy, 31(6).

Lockett, A., Wright, M., & Franklin, S. (2003). Technology Transfer and Universities' Spin-out Strategies. Small Business Economics, 20(2), 185-200.

Malecki, E. J. (2004). Jockeying for Position: What It Means and Why It Matters to Regional Development Policy When Places Compete. Regional Studies, 38(9), 1101-1120.

Malecki, E. J. (2007). Cities and regions competing in the global economy: knowledge and local development policies. Environment and Planning C: Government and Policy, 25(5).

Markman, G., Phan, P., Balkin, D., & Gianiodis, P. (2005). Innovation speed: transferring university technology to market Research Policy, 34(7), 1058-1075.

McEvily, B., & Zaheer, A. (1999). Bridging ties: A source of firm heterogeneity in competitive capabilities. Strategic Management Journal, 20(12), 1133-1156.

Meyer, M. (2003). Academic Entrepreneurs or Entrepreneurial Academics? Research-based Ventures and Public Support Mechanisms

R&D Management, 33(2), 107-115.

Motohashi, K. (2005). University-industry collaborations in Japan: The role of new technology-based firms in transforming the National Innovation System. Research Policy, 34(5), 583-594.

Mowery, D., & Sampat, B. (2004). The Bayh-Dole Act of 1980 and University–Industry Technology Transfer: A Model for Other OECD Governments? . Journal of Technology Transfer, 30(1).

Nagle, M. (2007). Canonical analysis of university presence and industrial comparative advantage. Economic Development Quarterly, 21(4), 325-338.

NCIHE. (1997). Higher education in the learning society: Report of the national committee, of inquiry into higher education (Dearing Committee). London: HMSO.

North, D. (1990). Institutions, institutional change and economic performance. Cambridge: Cambridge University Press.

NSF. (2006). Science and Technology Indicators. Arlington, VA: National Science Foundation.

Palazzo, G. (2005). Postnational constellations of innovativeness: a cosmopolitan approach. Technology Analysis & Strategic Management, 17(1), 55-72.

Palmintera, D. (2005). Accelerating ED through University Technology Transfer: Report to the Connecticut Tech Transfer and Commercialization Advisory Board. Washington, D.C.: Innovation Associates.

Paytas, J., Gradeck, R., & Andrews, L. (2004). Universities and the Development of Industry Clusters: Report Prepared for the Economic Development Administration and U.S. Department of Commerce. Pittsburgh, PA: Carnegie Mellon University, Center for Economic Development.

Paytas, J., Gradeck, R., & Andrews, L. (2004). Universities and the Development of Industry Clusters: Report Prepared for the Economic Development Administration and

U.S. Department of Commerce. Carnegie Mellon University: Center for Economic Development.

Perkmann, M., & Walsh, K. (2007). University-industry relationships and open innovation: Towards a research agenda. International Journal of Management Reviews, 9(4), 259-280.

Porter, M. (1998). Clusters and competition: New agendas for companies, governments and institutions. In Porter (Ed.), On Competition. Boston: HBS Press.

Powers, J. B. (2004). R&D Funding Sources and University Technology Transfer: What is Stimulating Universities to be more Entrepreneurial? Research in Higher Education, 45(1), 1-23.

Rutten, R., & Boekema, F. (2007). The Learning Region: Foundations, State of the Art, Future. Cheltenham: Edward Elgar.

Sainsbury, D. (2007). *The race to the top: A review of government's science and* innovation policies. London: HMSO.

Santoro, M. D., & Chakrabarti, A. K. (2002). Firm size and technology centrality in industry-university interactions. Research Policy, 31, 1163-1180.

Saxenian, A. (1994). Regional advantage: culture and competition in Silicon Valley and Route 128. Cambridge, Massachusetts: Harvard University Press.

Shane, S. (2004). Academic Entrepreneurship: University Spinoffs and Wealth Creation. Cheltenham, UK and Northampton, MA, USA: Edward Elgar.

Shane, S., & Cable, D. (2002). Network ties, reputation, and the financing of new ventures. Management Science, 48(3), 364-381.

Slaughter, S., & Leslie, L. L. (1997). Academic Capitalism: Politics, Policies, and the Entrepreneurial University. Baltimore MD: Johns Hopkins University Press.

Smilor, R. W., Dietrich, G. B., & Gibson, D. V. (1993). The Entrepreneurial University: The Role of Higher Education in the United States in Technology Commercialization and Economic Development. International Social Science Journal, 135(1), 1-11.

Sorenson, O., Rivkin, J. W., & Fleming, L. (2006). Complexity, networks and knowledge flow. Research Policy, 35(994-1017).

Sotarauta, M., & Kautonen, M. (2007). Co-evolution of the Finnish national and local innovation and science arenas: Towards a dynamic understanding of multilevel governance. Regional Studies, 41(8), 1085-1098.

Storper, M. (1995). The resurgence of regional economics, ten years later. European Urban and Regional Studies, 2(2), 191-221.

Storper, M. (1997). The Regional World: Territorial Development in a Global Economy. New York: Guildford Press.

Stuart, T. E. (2000). Interorganizational alliances and the performance of firms: A study of growth and innovation rates in a high-technology industry. Strategic Management Journal, 21(8), 791-811.

SURF, IPP, CURDS, PREST, & CRIC. (2006). The Embedded University in the *'Science Economy': Capacities, Contexts and Expectations* – A Research Agenda, A Report to the ESRC. Swindon: ESRC.

Teixeira, A., Santos, P., & Oliveira Brochado, A. (2006). Does proximity really matter in international R&D cooperative projects?, Paper presented at European Network on Industrial Policy (EUNIP) 9th International Conference. Limerick, Ireland.

Thanki, R. (1999). How do we know the value of higher education to regional development? Regional Studies, 33(1), 84-89.

Todtling, F., & Trippl, M. (2005). One size fits all? Towards a differential regional innovation policy approach. Research Policy, 34(8), 1203-1219.

Tornatzky, L., Waugaman, P., & O'Gray, D. (2002). Innovation U: New University Roles in a Knowledge Economy, Research Triangle Park, N.C Southern Technology Council : Southern Growth Policies Board.

Tracey, P., & Clark, G. L. (2003). Alliances, networks and competitive strategy: Rethinking clusters of innovation. Growth and Change, 34(1), 1-16.
Uyarra, E. (2010). Conceptualizing the regional roles of universities, implications and contradictions. European Planning Studies, 18(8), 1227-1246.
Wellings, P. (2008). Intellectual property and research benefits. Lancaster: Lancaster University.
Wolfe, D. (2004). The Role of Universities in Regional Development and Cluster Formation. Toronto: Centre for International Studies, University of Toronto.
Wong, P.-K., Ho, Y.-P., & Singh, A. (2007). Towards an "Entrepreneurial University" model to support knowledge-based economic development: The case of the National University of Singapore. World Development, 35(6).
Wood, G. A., & Parr, J. B. (2005). Transaction Costs, Agglomeration Economies, and Industrial Location. Growth and Change, 36(1), 1-15.
Wright, M., Lockett, A., Clarysse, B., & Binks, M. (2006). University Spin-Out Companies and Venture Capital. Research Policy, 35(4), 481-501.
Youtie, J., & Shapira, P. (2008). Building an innovation hub: A case study of the transformation of university roles in regional technological and economic development. Research Policy, 37(8), 1188-1204.
Zaheer, A., & Bell, G. (2005). Benefiting from network position: firm capabilities, structural holes, and performance. Strategic Management Journal 26(9), 809 – 825.

Figure 1: Conceptual framework

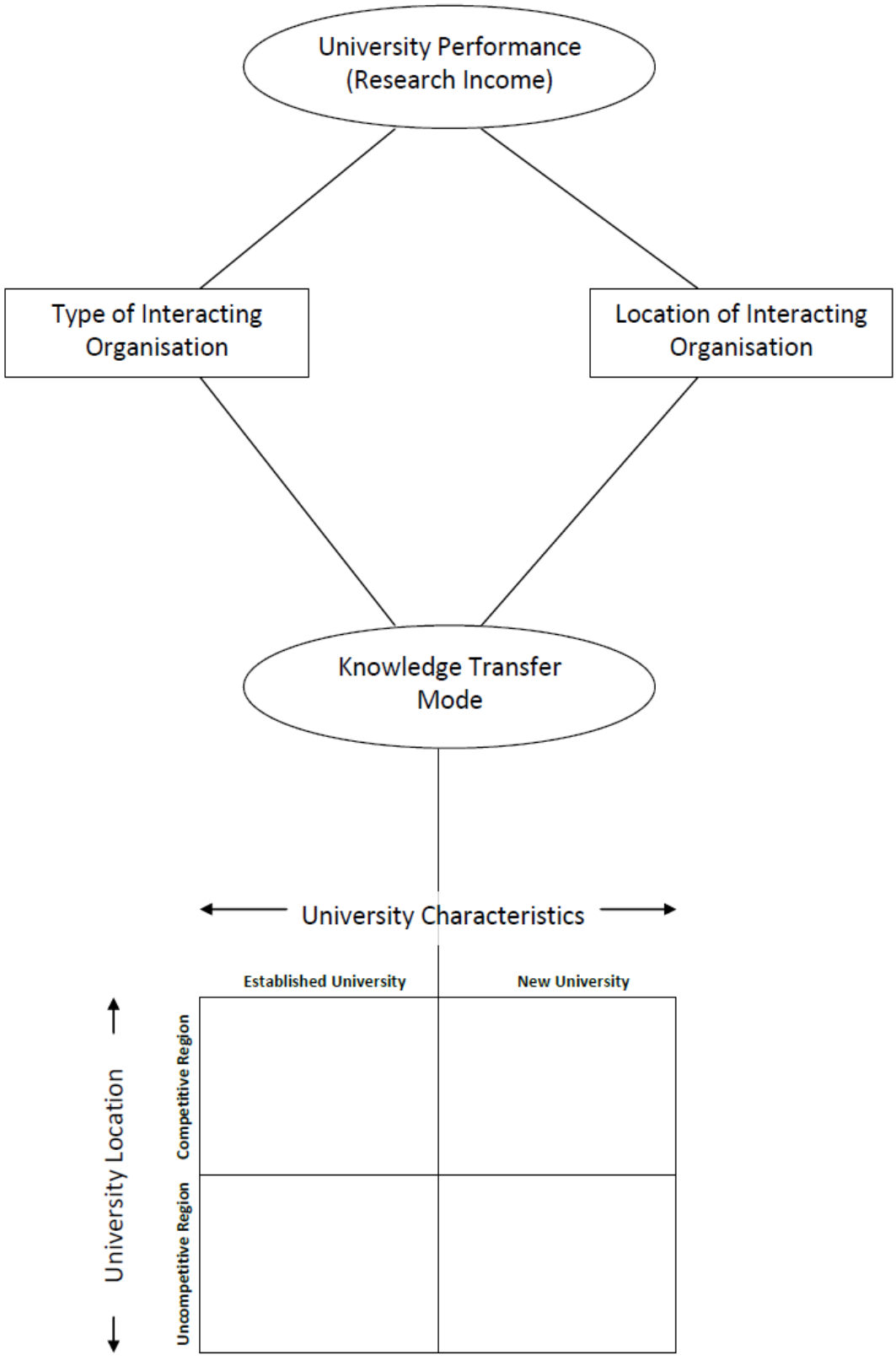

Table 1: Mean number of intense interaction s by knowledge transfer type and type of interacting organisation (N = 59 universities)

	MNE	Large Domestic Firm	SME	Public Sector Research Establishment	Other Public Sector Body	University	Funding Council / Body	Private Sector Research Establishment	Other
Collaborative research	0.90 (32.16%)	0.66 (23.39%)	0.76 (26.32%)	0.02 (0.58%)	0.15 (5.26%)	0.05 (1.75%)	0.00 (0.00%)	0.00 (0.00%)	0.27 (10.53%)
Contract research – SME	0.02 (0.62%)	0.15 (6.79%)	2.39 (90.12%)	0.00 (0.00%)	0.03 (1.23%)	0.00 (0.00%)	0.00 (0.00%)	0.00 (0.00%)	0.03 (1.23%)
Contract research - non-SME	1.00 (36.61%)	0.76 (27.08%)	0.29 (10.42%)	0.12 (4.17%)	0.29 (12.50%)	0.00 (0.00%)	0.07 (2.38%)	0.05 (1.79%)	0.14 (5.06%)
Consultancy contracts	0.56 (19.30%)	0.64 (22.81%)	0.68 (23.39%)	0.03 (1.17%)	0.49 (17.25%)	0.00 (0.00%)	0.08 (2.92%)	0.08 (2.92%)	0.29 (10.23%)
Courses for businesses	0.56 (22.02%)	0.61 (21.43%)	0.63 (22.02%)	0.03 (1.19%)	0.51 (20.54%)	0.00 (0.00%)	0.00 (0.00%)	0.02 (0.60%)	0.27 (12.20%)
Patents	0.37 (40.48%)	0.19 (19.05%)	0.36 (33.33%)	0.02 (1.59%)	0.02 (1.59%)	0.00 (0.00%)	0.00 (0.00%)	0.02 (1.59%)	0.02 (2.38%)
Licences	0.25 (25.36%)	0.27 (23.19%)	0.37 (38.41%)	0.02 (1.45%)	0.02 (1.45%)	0.00 (0.00%)	0.03 (2.90%)	0.05 (7.25%)	0.00 (0.00%)
Spin-outs	0.00 (0.00%)	0.07 (2.84%)	1.95 (89.36%)	0.00 (0.00%)	0.05 (2.13%)	0.07 (2.84%)	0.00 (0.00%)	0.02 (0.71%)	0.05 (2.13%)
Total	3.66 (19.54%)	3.36 (18.11%)	7.42 (39.59%)	0.24 (1.63%)	1.56 (10.71%)	0.12 (0.59%)	0.19 (0.91%)	0.24 (1.15%)	1.07 (7.77%)

Table 2: Mean number of intense interaction s by knowledge transfer type and location of interacting organisation (N = 59 universities)

	Local (i.e. Within Region)	Non-local: Other UK Region	Non-local: Europe	Non-local: Rest of the world
Collaborative research	1.49 (52.05%)	1.12 (39.77%)	0.15 (6.43%)	0.05 (1.75%)
Contract research – SME	2.12 (80.86%)	0.51 (19.14%)	0.00 (0.00%)	0.00 (0.00%)
Contract research - non-SME	1.25 (46.73%)	1.15 (42.56%)	0.14 (4.76%)	0.17 (5.95%)
Consultancy contracts	1.61 (56.43%)	1.07 (37.13%)	0.10 (3.51%)	0.08 (2.92%)
Courses for businesses	1.81 (69.94%)	0.73 (27.08%)	0.05 (1.79%)	0.03 (1.19%)
Patents	0.54 (52.38%)	0.39 (38.89%)	0.00 (0.00%)	0.05 (8.73%)
Licences	0.63 (55.07%)	0.31 (34.78%)	0.02 (1.45%)	0.07 (8.70%)
Spin-outs	1.88 (85.11%)	0.31 (14.18%)	0.00 (0.00%)	0.02 (0.71%)
Total	11.34 (63.94%)	5.58 (30.45%)	0.46 (2.92%)	0.47 (2.69%)

Table 3: Number of intense interactions by university type, university location, and predominant type of interacting organisation

	Age of University			Competitiveness of region in which university is located		
	Old (pre-1992)	New (post-1992)	F-statistic, df (effect size)	Competitive	Uncompetitive	F-statistic, df (effect size)
Number of interactions across 8 knowledge transfer areas (min = 0, max = 24)	Mean = 19.06 Median = 18.50	Mean = 16.20 Median = 17.00	5.54* (Cohen's D = 0.61)	Mean = 17.77 Median = 19.00	Mean = 17.89 Median = 18.00	< 0.01 (Cohen's D = 0.02)
Predominant type of interacting organisations (percent of sample)	Domestic SME (58.80%)	Domestic SME (72.00%)	NA	Domestic SME (63.64%)	Domestic SME (64.86%)	NA
Percentage of interactions which are with non-local organisations	Mean = 39.75 Median = 36.36	Mean = 31.04 Median = 33.33	3.28* (Cohen's D = 0.44)	Mean = 42.33 Median = 40.83	Mean = 32.33 Median = 33.33	4.07* (Cohen's D = 0.51)
Predominant location of interacting organisations (percent of sample)	Local (70.59%)	Local (84.00%)	NA	Local (63.63%)	Local (83.78%)	

* indicates effect of predictor is statistically significant at 5% level

Table 4: % of interactions by university type, university location, and location of interacting organisation

	Competitive Regions		Uncompetitive Regions		Old Universities		New Universities	
	Old Universities	New Universities	Old Universities	New Universities	Competitive Regions	Uncompetitive Regions	Competitive Regions	Uncompetitive Regions
Local (within region)	49.8	64.6	64.0	74.2	49.7	64.1	64.6	74.3
Other UK region	44.6	29.8	29.1	21.4	44.5	29.1	29.8	21.4
Europe	4.1	4.4	2.0	3.0	4.0	1.9	4.4	3.0
International - Other	1.5	1.2	4.9	1.4	1.8	4.9	1.2	1.3
Total	100%	100%	100%	100%	100%	100%	100%	100%

Figure 2: Mean university research Income by predominant type and location of interacting organisation