

Universities, knowledge networks and regional policy

HUGGINS, Robert, JOHNSTON, Andrew and STEFFENSON, Rebecca

Available from Sheffield Hallam University Research Archive (SHURA) at:

<http://shura.shu.ac.uk/6925/>

This document is the author deposited version. You are advised to consult the publisher's version if you wish to cite from it.

Published version

HUGGINS, Robert, JOHNSTON, Andrew and STEFFENSON, Rebecca (2008) Universities, knowledge networks and regional policy. *Cambridge Journal of Regions, Economy and Society*, 1 (2). 321-340. ISSN 1752-1378

Repository use policy

Copyright © and Moral Rights for the papers on this site are retained by the individual authors and/or other copyright owners. Users may download and/or print one copy of any article(s) in SHURA to facilitate their private study or for non-commercial research. You may not engage in further distribution of the material or use it for any profit-making activities or any commercial gain.

Universities, Knowledge Networks and Regional Policy

Abstract

As knowledge becomes an increasingly important part of regional innovation and development processes, the role of universities has come to the fore of regional innovation and economic development policy. The objective of this paper is to critically review and assess the structure and function of knowledge networks and modes of engagement between universities and the business community in regional settings and contexts. It is argued that while regional knowledge networks and modes of engagement between universities and the business community are becoming increasingly prevalent, it is often difficult to ascribe investments in knowledge-based infrastructure to improved regional competitiveness. It is concluded that in a globalised knowledge environment the engagement between universities and regional business communities must be based on a mutual understanding of the role of both network and market-based knowledge interactions.

Key words: Universities, knowledge networks, regional policy

JEL classification: O31, O32, R11, R58

1. Introduction

Growth theory has placed knowledge at the centre of economic development (Romer, 1986; Romer, 1990; Lucas, 1988). Knowledge is viewed not only as the key to the competitiveness of a production unit, i.e. a firm (Nonaka and Takeuchi, 1995), but also territories, i.e. regions (Edmonds, 2003). Regions are increasingly treated as an economic entity, and, in the same way that knowledge is seen as the key to the competitiveness of a firm, knowledge is increasingly viewed as the major element in achieving regional competitiveness (Huggins and Izushi, 2007). One of the outcomes of both theoretical and policy development in this area is that universities and other higher education institutions have come to be regarded as key sources of knowledge utilisable in the pursuit of economic growth, knowledge and technology transfer attaining a more important role within universities (Feldman and Desrochers, 2003).

As knowledge becomes an increasingly important part of regional innovation and development processes, the role of universities has come to the fore as being core knowledge-producing entities that can play an enhanced role in driving innovation and development processes (Cooke, 2004, Fritsch, 2002). In terms of fostering innovation in a knowledge-based economy, universities are seen as potentially key elements of innovation systems through the provision of knowledge for business and industry (Thanki, 1999; Garlick, 1998; Foray and Lundvall, 1996). The transfer and commercialisation of university-generated knowledge is taking an increasingly prevalent role within government policies at a number of levels (Lambert, 2003). Many governments and their agencies are increasingly turning their attention to the role of HEI knowledge commercialisation in developing innovative, sustainable and prosperous regional and national economies (Drucker and Goldstein, 2007). Also, an increasing policy

emphasis is being placed upon developing and growing indigenous SMEs and promoting innovation through regional knowledge networks, as globalisation makes the battle to attract Foreign Direct Investment increasingly competitive (DTI, 2003).

Porter and Ketels (2003) conclude that there is still a lack of understanding of how to create effective impact through knowledge transfer from universities, and the role of regions as part of these processes. Although a number of comparative qualitative studies of university best practices demonstrate that many institutions are developing policy initiatives designed to increase knowledge transfer from universities, but the direct impact of these policies is less documented (Tornatzky, et al., 2002, Paytas, et al., 2004, Palminteri, 2005). This trend has raised alarm with scholars who observe that universities are increasing copying policies based on assumptions about the roles that institutions can or should play (Feller, 2003; Etzkowitz, 2006). In general, at both a policy and theoretical level, the role of the universities in such policies is very much a contested area, and this article seeks to further understand the rationale of regional government and policymakers in endeavouring to establish an environment for such links and commercialisation to be nurtured. The key objective of this paper is to critically review and assess the structure and function of knowledge networks and modes of engagement between universities and the business community in regional settings and contexts. The paper focuses on the increasing attention given to universities as key actors within these regional knowledge networks. The paper illustrates how regional economic development theories are driving policy formulation in this sphere and analyses the extent to which universities are able to stimulate regional innovation activity and economic development.

The paper is structured as follows. The following section presents an overview of regions and knowledge networks, highlighting the role of knowledge and proximity in regional economic development. Section 3 examines the transfer of university knowledge and the policy influences behind this and Sections 4 and 5 explore the various modes of engagement utilised by universities and the success of each type of engagement. Section 6 presents the impacts of university knowledge on regional economic performance and regional innovation levels. Section 7 then examines the extent to which regional policy in lagging regions aims to exploit university knowledge sources and comments on the conditions needed for success. Finally, section 8 offers some conclusions and implications.

2. Regions and Knowledge Networks

Knowledge is now recognised as a key ingredient underlying the competitiveness of regions, nations, sectors and firms. At its most fundamental level, the knowledge-base of an economy can be defined as the capacity and capability to create and innovate new ideas, thoughts, processes and products, and to translate these into economic value and wealth (Huggins and Izushi, 2007). Emerging new theories of the firm, such as the knowledge-based view (Grant, 1996) and extensions of the resource-based view (Lavie, 2006), recognize that knowledge acquisition and creation is increasingly a key reason for engaging in networks with actors external to the firm. The knowledge-based view of the firm focuses on knowledge as the key competitive asset of firms, emphasizing the capacity to integrate tacit knowledge, or ‘knowing how’, as distinct from explicit knowledge, or ‘knowing about’ (Grant, 1996; Mowery, et al., 1998, Huggins, 2000). As part of the process of matching knowledge demand and supply, networks play an important role in controlling access, acting as the

‘pipes and prisms of the market’ (Podolny, 2001; Garmaise and Moskowitz, 2003), and integral to securing resources and obtaining legitimacy, (Lee, et al., 2001; Elfring and Hulsink, 2003). Knowledge networks are considered a crucial element underlying the economic success and competitiveness of regions. Also, universities are often portrayed as forming important actors within networks of local or regional clusters of knowledge-based activities or systems of regional innovation (Saxenian, 1994; Porter, 1998; Cooke, et al., 2004). The most successful knowledge commercialising universities generally possess greater networks with external organisations, although in general are often not particularly strong even in leading universities (Lockett, et al., 2003). Even in a region such as London, which accounts for almost one-quarter of the UK universities, it is found that many of the knowledge transfer involving the region’s universities lack co-ordination and connectivity (Huggins, forthcoming).

Typically, it is argued that the existence of established spatially proximate knowledge networks is one of the key reasons why a number of the most successful localities and regions throughout the world have become or remained more competitive than those that have not adopted a networked approach (Storper, 1997; Lawson and Lorenz, 1999; Huggins, 2000; Bathelt, et al., 2004; Knobben and Oerlemans, 2006). In general, the development of leading advanced regional economies is considered to involve the percolation of knowledge through a highly networked regional business culture rich in ‘untraded interdependencies’ (Castells and Hall, 1994, Storper, 1995; Saxenian, 1994; Porter, 1998; Cooke, et al., 2004; Rutten and Boekema, 2007). It is argued that networks within these leading regional economies are able to mobilise and fully develop the human capital residing within firms, in particular SMEs, through external networks providing feedback loops, ensuring the continuation of high levels of

innovation (Garnsey and Lawton Smith, 1998; Goman, 2000; Bresnahan and Gambardella, 2004).

Within debates concerning knowledge networks, the role of space and place are recognized as increasingly important features of network structure and their operation. Typically, it is argued that strong ties promote the transfer of complex knowledge, while weak ties promote the transfer of simple knowledge, strong ties require the type of face-to-face interaction facilitated by the geographic proximity of network actors (Gertler, 1995; Uzzi, 1997; Cowan, et al., 2003; Bathelt, et al., 2004; Sorenson, et al., 2006). As already highlighted, spatially proximate knowledge networks are considered a key factor underlying the success of the most advanced and successful regional economies (Saxenian, 1994; Storper, 1997; Bathelt, et al., 2004). Many firms, however, do not acquire their knowledge from within geographically proximate areas, particularly those firms based upon innovation-driven growth where knowledge is primarily sourced internationally (Davenport, 2005). If applicable knowledge is available locally, firms and other institutions will attempt to source and acquire it, if not they will look elsewhere (Kingsley and Malecki, 2004). Also, while firms with low levels of absorptive capacity (Cohen and Lenvinthal, 1990) tend to network locally, those with higher absorptive capacity are often more connected to global networks (Drejer and Lund Vinding, 2005). This is perhaps to be expected, and illustrates the importance of internal knowledge absorption capacity on external knowledge network development. It also helps explain why SMEs with relatively low knowledge absorption capacities tend to be reliant on more localised networks.

Only those firms and located in a contextual geographic environment rich in relevant knowledge sources, such as universities, can take competitive advantage of the co-location of other knowledge actors. However, even in

those locations possessing a university-knowledge rich environment there is evidence of a greater role being played by non-localized networks (Huggins and Izushi, 2007). For example, in the high-technology setting of Cambridge in the UK many actors report global networks as being of greater significance to their operations (Athreye, 2004; Garnsey and Heffernan, 2005). Also, in Canada's high-technology city of Ottawa, known as Silicon Valley North, it is found that although local networks continue to provide mechanisms for transferring knowledge and stimulating innovation within the cluster, for Ottawa's high-tech community global knowledge networks are the most important sources of knowledge and innovation (Doloreux, 2004). In California's Silicon Valley, Saxenian (2005) describes how Asian engineers and entrepreneurs are creating and building networks between the region and regions in China and India, and transferring knowledge from the west to the east.

The key aspect of these developments is that the knowledge base of the world's most advanced local and regional economies is no longer necessarily local, but positioned within global knowledge networks, connecting clusters and their actors (Wolfe and Gertler, 2004; Huggins and Izushi, 2007). There is a growing school of thought that non-proximate actors are often equally, if not better, able to transfer complex knowledge across such spatial boundaries, providing a high performing network structure is in place (McEvily and Zaheer, 1999; Dunning, 2000; Lissoni, 2001; Davenport, 2005; Zaheer and Bell, 2005; Palazzo, 2005; Teixeira, et al. 2006). Therefore, the constraining effect of distance on knowledge flow and transfer is gradually diminishing (Tracey and Clark, 2003; Johnson, et al., 2006). This knowledge is often necessarily superior to that available locally, resulting in improved innovation performance. As Singh (2005) finds, simply being in the same locality is often of little benefit for diffusing

knowledge from creators to other actors in the locality, with there being a need for networked interaction between these actors.

3. University Knowledge Transfer

As universities potentially form part of both regional and globally connected knowledge networks and systems of innovation, the means by which the knowledge they generate flows, or not as may be the case, as well as their characteristics and capabilities, the types of knowledge they generate, and the constituency of their networks and modes of engagement are of clear importance. In general, the transfer and commercialisation of the knowledge and research residing and undertaken in universities has come to be viewed as an increasingly important stimulant of economic growth (Etzkowitz, 1998; Bok 2003), particularly for improving the development capabilities and economic performance of regions (Kukliński, 2001; Lawton Smith, 2003; Feldman and Desrochers, 2003; Goldstein and Renault, 2004; Wolfe, 2004; Shane, 2004; Braunerhjelm, 2005). This has occurred as regional variations in underlying levels of knowledge and creative-based entrepreneurship are further understood to be important aspects of future regional economic development potential (Dill, 1995; Nijkamp, 2003; Audretsch, 2004). These developments have been coupled with notions of ‘entrepreneurial universities’ (Smilor, et al., 1993; Slaughter and Leslie, 1997; Etzkowitz, et al., 2000; Powers, 2004) and ‘academic entrepreneurs’ (Meyer, 2003; Shane, 2004) that are highly involved in venturing and commercialisation 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 and Patel, 2005).

The potential regional development impact of university knowledge is shaped by a number of core factors. These include the entrepreneurial orientation and attitude of particular universities, which may be shaped by the underlying national and regional policy environment relating to the knowledge commercialisation activities of the higher education sector (Smilor, et al., 1993; Etzkowitz, 1998; Etzkowitz, et al., 2000). For instance, it is argued that the US has a more vibrant and decentralized system of university knowledge commercialisation than Europe due to the introduction in the US of 1980 Bayh-Dole Act, which gave universities, rather than individual researchers, title to innovations established in their confines (Goldfarb and Henrekson, 2003). While leading universities in the US annually spinout 2.8 new companies per institution, universities in the UK achieve an average of only 1.3 spinouts per institution. Also, the mean average licenses granted to the US universities is 23.2 per annum, compared with only 3.8 per annum in the UK, resulting in average annual license income of US\$6.6m per US institution and US\$365,000 per UK institution. Comparing license income as a percentage of total research expenditure, US universities generate 2.8 per cent compared with 1.1 per cent in the (HEBI, 2004). In a study of the US–Swedish knowledge transfer and commercialization gap, Goldfarb and Henrekson (2003) argue that despite the seeming success of Sweden’s university system, the commercialization rate of academic results is low when compared with the US. They conclude that this is at least partly due to top-down national policies in Sweden stifling and discouraging universities from actively commercialising their knowledge and research (a situation not dissimilar to that found in the UK).

The Swedish model, which in many respects is similar to that in the rest of Europe, creates strong disincentives toward academics to undertake knowledge transfer activities aimed at the commercial sector, especially the establishment of spin-out companies. Despite the implementation by the

Swedish government of numerous technology-transfer initiatives aimed at universities, the key barometer of success for universities has continued to be academic results, with a lack of incentives for universities to become involved in the commercialization of their ideas. Therefore, there are little upside gains to be made and considerable downside risks in terms of the esteem which government funding bodies hold for particular institutions (Goldfard and Henrekson, 2003). Within a UK context, it is argued that government has failed to fully realise the significant direct and indirect contribution universities make to its local, regional and national economies (Kelly, et al., 2002). On the other hand, it is also argued that the performance of many universities in the area of knowledge transfer and commercialisation activities has not matched their overall potential, partly due to the relatively low level of internal financial and human resources that are being devoted to such activities (Charles and Conway, 2001; Charles, 2003; Wright, et al., 2006).

A lack of supply-side resources has been coupled with issues concerning the constraining characteristics of HEI knowledge-based venturing, particularly the creation of spin-off firms, whereby their value is primarily linked to the longer-term growth potential derived from scientific knowledge and intellectual property. In their early stages, such ventures lack tangible assets to use as collateral, while their products initially have little or no track record, and are largely untested in markets or subject to high rates of obsolescence (Bank of England, 2002). Furthermore, the demand-side is considered a significant constraint in stimulating wider processes of knowledge transfer, especially engaging the business sector with higher education sector (Lambert, 2003).

Even if a facilitating policy environment is in place, the quality and characteristics of university knowledge transfer practices and activities will

necessarily be a determining factor of commercialisation outputs. In the first instance, the knowledge creation capability will be required to be of a quality and type that lends itself to potential commercialisation and industrial utilisation (Lee, et al., 2001; Friedman and Silberman, 2003). Also, the ability of the institution to protect its research and ideas may be necessary for successful commercialisation (Powers and McDougall, 2005). The relative success of knowledge commercialisation activities in the US compared with most parts of Europe has relied far more on the development of strong networks facilitated through a rich infrastructure of intermediary organisations (Sapienza 1992; Prevezer, 2001; Çetindamar and LaageHellman, 2003). In general, the US system of knowledge transfer is more bottom-up due to the experimentation it has facilitated in the way university policy can best exploit IP.

The Bayh-Dole Act has furthered the role of US universities as drivers of their regional business communities, many of which have traditionally been key actors in forming part of knowledge clusters in the US. Indeed, the clusters of Silicon Valley in California, Route 128 in Boston, and the Research Triangle in North Carolina have evolved around the universities of Stanford, MIT, and Chapel Hill respectively (Huggins and Izushi, 2007). Regulatory reforms in Europe and Japan have been introduced to try and increase technology commercialisation from HEIs by eliminating the ‘professor privilege’ and shifting intellectual property rights to research institutions (OECD, 2004). International policy emulation of the Bayh-Dole Act has resulted from the belief that university patenting is essential for effective technology transfer from universities to industry, but critics argue that these policy transfer models overlook more economically important channels through which universities contribute to innovation and economic growth (Mowery and Sampat, 2004).

4. The ‘Engaged’ University

As the role of universities in bolstering technology communities and shaping innovation cultures has become more widely recognized, regional engagement and innovation capacity have become core themes in university mission statements. The triple helix model role formalises this role and views universities as increasingly ‘entrepreneurial’ or ‘generative’ institutions where the spillover of knowledge is the result of strategic internal re-organization which facilitates the development of incubators or science parks and human capital development programs (Etzkowitz, 2006; Etzkowitz and Zhou, 2006; Gunasekara, 2006). Scholars have also identified a new type a university which is even more entrenched in regional economic and social development. They argue that the ‘engaged’ university is one that is not only entrepreneurial in technology development but that is also adaptive and responsive to the needs of the region and plays a wider role in building social and civic capital through community service and leadership in regional social and civic structures (Chatterton and Goddard, 2000). These engaged universities play a ‘developmental’ role in learning regions by establishing programmes, building institutions and facilitating networks which are tailored to the needs of the regions they serve (Gunasekara, 2006).

Both of these perceptions acknowledge that universities can serve as key sources of knowledge for industry, and that policy initiatives designed to build new niches of knowledge and develop more effective mechanisms for transferring university-based knowledge to regional partners can potentially bolster technology communities and shape innovation cultures. Universities have traditionally provided *know how* (skills and capability) and *know why* (general principles and laws), but the focus on commercialising knowledge, offering consultancy services and entering into collaborative relationships

all demonstrate academic expansion into *know what* (facts) and *know who* (establishing collaborative relationships) (Charles, 2006). The balance between creating and diffusing knowledge illustrates an emerging ‘third mission’ of universities where new commitments to service compliment existing teaching and research missions (Etzkowitz and Zhou, 2006). It is not universally accepted that universities should invest in the third mission. Some scholars such as Feller (2003) argue that universities should focus on building research capacity (knowledge creation) if they want to increase technology commercialization, while others argue the importance of developing more effective mechanisms for transferring knowledge to both private and public sectors (knowledge diffusion) (see for example Stoneman and Diederer, 1994).

Since the creation of ‘steeples of excellence’ was identified as a key strategy in Stanford’s entrepreneurial development, other universities have been seeking to strengthen and expand into new knowledge niches (Etzkowitz, 2006). These niches increasingly fall within the scope of Mode 2 research which is interdisciplinary and collaborative (Etzkowitz and Martin, 2000). This interdisciplinary research agenda has spilled over into new curricula programs designed to provide graduates with the new skills required by industries in the knowledge economy. These include programs that emphasize interdisciplinary teamwork between science, engineering, business and law students; the creation of technology commercialization degrees across academic disciplines and new degrees in ‘Creativity Studies’ (Tornatzky, et al., 2002).

5. Modes of Engagement

The increased interest in universities as knowledge creators has been mirrored by an apparent increase in the amount of knowledge that universities create, as measured by the number of patents universities are generating (Hegde, 2005). In the US, academic patents quadrupled between 1988 and 2003, licenses and options increased by 40%, and income from licenses doubled from 1997-2003 (NSF, 2006). The growing number of patents, licenses and new firms generated from university-based research are indicators that HEIs are increasing their efforts to commercialise technology (Nelson, 2001; Thursby, et al., 2001; Hall and MacGarvie, 2006). The observed increases in patents and willingness to commercialise knowledge may merely reflect the increased propensity to patent or licence knowledge rather than an increase in knowledge (Thursby and Thursby, 2000). An increase in patenting activity does not necessarily indicate a rise in the quality of knowledge, i.e. more knowledge is not necessarily better knowledge. Also, an increase in the patenting activity does not necessarily mean a university is creating the type of knowledge local firms require. The mismatch between knowledge creation and regional diffusions is demonstrated by Johns Hopkins University, which despite being one of the highest federally funded research schools in the US has failed to transform Baltimore into a high technology centre (Feldman and Desrochers, 2004).

Most universities do not profit from license revenue, and many of the highest yielding revenues come from a limited number of blockbuster inventions. In general, licensing income has been highly concentrated among relatively few universities, with technology transfer failing to be financially lucrative for most universities (Powers, 2004). Although gaining equity in start-ups is generally perceived as more financially lucrative and of higher regional significance, few universities generate more than 1-2 spin offs annually, with six institutions accounting for about one-quarter of all the start-ups in the US in 2002 (NSF, 2006). Only four US universities spin

off more than 10 companies annually, and all of them spent more than a half billion dollars in annual R&D (NSF, 2006).

Three of the most prevalent policies for promoting engagement between universities and firms are the establishment of technology transfer offices, establishing science parks and outreach programmes. The main function of technology transfer offices is to assist faculty with the legal processes of disclosing and patenting intellectual property, establishing start up companies and arranging sales of licenses. Technology transfer offices are increasingly involved in promoting spin-offs, which can also extend to university provided venture capital (Steffensen, et al., 1999). The success of these technology transfer offices is linked to a number of organizational, cultural and environmental factors including the professionalism of the agents, style of management and leadership, the compensation of the agents and the existence of a clear strategy for creating spin-out companies (Markman, et al., 2005a; Markman, et al., 2005b Debackere and Veugelers, 2005; Lockett, et al., 2003, Carlsson and Fridh, 2002; Chapple, et al., 2005). One of the key explanations for this UK-US differential in knowledge transfer is experience and accumulated knowledge, since the US has been involved in public sector knowledge transfer activities significantly longer than the UK (Franklin, et al., 2001). Historical and embedded university attitudes towards industry are also important as the most entrepreneurial universities, including MIT, Stanford and Carnegie Mellon, have long histories of working with industry. Newer institutions such as Sunderland University and Oxford Brookes have made major contribution to regional development due to their ability to quickly adapt to new climates (Glasson, 2003).

The creation of science parks is central to most universities' strategies to increase knowledge spillover (Storey and Tether, 1998; Vedovello, 1997).

These spaces range from small business incubators to large science and technology research parks. In addition to providing companies with subsidized laboratory space, science and technology parks often provide consulting services, networks and connections to university faculty, other companies and venture capitalists (AURP, 2006). Science parks aim to enable rapid technology transfer, offer improved funding for academic programs, help to attract research faculty, sponsored research agreements, student placements, and create opportunities to commercialise intellectual property (AURP, 2006; Chatziioanou and Sullivan, 2004).

Gauging the success or failure of research parks is a normative process than hinges on weighing their relative costs versus benefits. Increases in technology commercialisation, employment in high technology clusters, and firm graduation from the park are positive indicators. While the population of research parks has increased and parks that mature out of incubation stages have the potential to generate economic benefits to regions, there is a high mortality rate and there is a higher probability of parks failing to meet objectives (Luger and Goldstein, 1991). The developmental strategies of research parks are also linked to their success. For example that the overemphasis of the Penn State Innovation Park's real estate potential undermined its capacity to create innovative climates (Etzkowitz, 2006). On the other hand, some have been able to successfully focus on niche technology areas. Examples cited by the AURP (2006) include Cornell University's 'Technology Farm' which focuses on agriculture and food; the UCSF's Mission Bay, North Carolina State's Centennial Campus and MIT's University Park which have been strategically planned for mixed use development; and a new wave of parks, such as Wake Forest's Piedmont Triad Research Park, which are linked to urban re-development.

Science parks also have a wider impact on a region, for example the Iowa State University Research Park found that the park employed 900 employees and had a total impact of \$1.34 billion on the local economy (AURP, 2006). From 2003-2004, the University of Arizona Science and Technology Park reported employing 13,300 workers and with an economic impact of US\$1.9 billion on the economies of Tucson and Pima County (AURP, 2006). The University of North Carolina Industrial Energy Program provided 6,000 free services from 1999-2000, and recipients reported \$129 million in economic benefits. Clients of the Pennsylvania Technical Assistance Program (PENNTAP) have reported US\$180 million in economic benefits in the past five years and the creation or retention of 3,670 jobs. Since 1986 the Purdue Technical Assistance programs and services have assisted over 4,700 organizations, trained over 4,600 employees, boosted sales by US\$339 million, increased capital investments by \$69 million, contributed cost savings of US\$34 million, and saved or added over 4,700 jobs in the state.

Universities increasingly provide services to smaller firms through extension services, business assistance and accelerator programs, and outreach programs. Business assistance programs focus on knowledge diffusion through awareness building and technology demonstration, information search and referral services and education and training (Shapira and Rosenfeld, 1997). These programs are designed to transfer university expertise in new technologies and business practices to improved product performance and quality and process efficiency. Executive education and training programs assist regions by targeting human capital development and upgrading the skills of workforce through on-the job training and classroom training. These courses are not limited to technology professionals or business managers. Training programs also build civic and social capital through continuing education for non-profit managers and

local governments. The most regionally developmental universities provide assistance to community and economic development through applied research and consulting projects (Tornatzky, et al., 2002; Paytas, et al., 2004).

[Table 1 about here]

6. The Impact of University Knowledge Transfer

One method for examining the innovativeness of regions is through patenting activity (Acs, et al., 2002). A major finding of patent activity studies is that the diffusion of university knowledge is spatially constrained, i.e. firm innovation is affected by R&D undertaken by universities *within the same region* (Jaffe, 1989; Henderson, et al., 1998). This result holds for regions in both Europe and the US (Fritsch and Varga, 2003), with knowledge generated within regions being key to their economic development. A firm's geographic proximity to a knowledge source would therefore appear to be important (Davenport, 2005), although 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).

While university knowledge may be spatially constrained, the level of patenting within a region is not just related to the knowledge created by universities (Greunz, 2005). Patenting activity is dependent on both private sector and university R&D. Gruenz (2005) estimates elasticities of business and university R&D of 0.76 and 0.14 respectively, i.e. a 1% increase in business R&D expenditure creates a 0.76% rise in patents, where as a 1% rise in university R&D creates a 0.14% increase in patents. Importantly, the results also suggest that one affects the other, i.e. a 1% increase in university

R&D stimulates a 0.3% increase in business R&D and, conversely, a 1% increase in business R&D stimulates a 0.24% increase in university R&D. The R&D activities of universities and firms, therefore, are inter-related, and while universities do not develop all inventions, university knowledge still plays a part in their development (Mansfield, 1995). It is also argued that it is not the R&D undertaken by universities that is the most important regional development factor but the number of degrees the university produces, i.e. the output of graduates (Riddel and Schwer, 2003). Human capital creation may then be of greater importance, with the role of universities in building human capital not limited to creating technical and scientific knowledge. Florida (1995) argues that a key function of universities is to produce creative workers that drive the knowledge economy. Many factors may influence the effect of university knowledge on economic development. For example, the level of agglomeration in a region influences how effectively university knowledge is utilised, based on the densities of the networks and the frequency of the interaction between firms in the region (Varga, 2000). Thus, the structure of the regional economy may be important in determining the effectiveness of university knowledge in influencing regional development.

The utilisation of university knowledge is not uniform across all firms, with not all firms benefiting equally. It has been suggested that smaller firms in a region benefit from spillovers of university knowledge as they have fewer resources with which to generate their own knowledge (Acs, et al., 1994). Also, regional high-technology firms tend to benefit from university knowledge (Audretsch, et al., 2005), with there being a significant correlation between the concentration of high-tech industries and university research in high-tech fields within a region (Nagle, 2007). Universities also play a role in the formation of new firms. Kirchoff, et al. (2007) argue that university R&D has the third most significant effect on new firm formation,

behind market size and the size of the foreign population. Therefore, entrepreneurs are attracted to regions with significant knowledge creating infrastructure and high levels of knowledge which to tap.

[Table 2 about here]

The evidence that universities contribute to regional economic development in a number of ways does not necessarily suggest which of the activities have the biggest effect on development. Perkmann and Walsh (2007) rank the various university activities in terms of their impacts on regional economic development (see Table x), with research partnerships between firms and universities being among those activities which have the highest impact. In order to harness the benefits of this type of collaboration many firms and universities in the US have formed industry-university cooperative research centres (IUCRCs), which involve formal collaboration between the two. Involvement in an IUCRC increases industrial patenting activity by 4% (Adams, et al., 2001). Through formal consulting practices, joint research and collaboration and providing graduate students an IUCRC enables firms to access a number of factors that contribute to the competitiveness of a firm. Firms with a broader outlook and a greater willingness to collaborate are more likely to engage in university/industry collaboration (Motohashi, 2005). These firms are likely to be younger firms, i.e. those with less time to develop their own knowledge resources (Motohashi, 2005). Larger firms tend to focus on building on non-core competences, where as smaller firms focus on solving problems in their core areas (Santoro and Chakrabarti, 2002). Firms and academics engage in IUCRCs for differing reasons. For academics the priority is to secure funding, for firms the priority is obtaining knowledge for product development (Lee, 2000). However, IUCRCs can also restrict the 'academic' output of universities, i.e. the resulting outputs are focussed on

industrial products and processes (Cohen, et al., 1998), with it further found that participation in a IUCRC does not necessarily facilitate knowledge transfer (Adams, et al., 2001).

7. Regional Policy

As a means of stimulating increased interaction across and knowledge generating actors, particularly universities, public policy intervention in recent years has drawn on the ‘triple helix’ model of economic development, which seeks to promote such increased interaction across three broad institutional spheres, namely: government; business/industry; and higher education (Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2003). Triple helix approaches to development are considered as capable of producing new forms of collaboration and partnerships capable of driving forward regional development. Such approaches operate through a range of regimes and basic tendencies in their formation, which have the capacity to evolve over time (Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2003). Most prominence has been given to the triple helix regime based on overlapping spheres of state-industry-academia through the establishment of hybrid organisations discussed above, such as intermediaries, innovation and incubation centres, and science parks, allowing each sphere to undertake activities from which they were previously excluded. Such overlapping triple helix forms are manifested by government operating through its industrial policy, an industrial structure whereby by firms engage in inter-organisational alliances and networks with universities (Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2003).

Of course, many of the globe’s leading regions, such as Silicon Valley, have implicitly operated a successful overlapping triple helix development model for many years. However, the triple helix formulation has also gained

significant currency as an approach for improving the fortunes of economically lagging regions. The adoption of the triple helix model bears a strong resemblance to regional adoption of cluster policy models, which have mainly focused on seeking to develop key sectors of the economy, often knowledge-based sectors, with a focus on hard infrastructure, such as science parks, business incubators, laboratories (Massey, et al., 1992; Castells and Hall, 1994; Martin and Sunley, 2003; Rosenfeld, 2005). In reality both cluster and triple helix development models have focused more on building hardware rather than the networks, value and supply-chains, underlying successful growth (Boschma, 2004; *Hospers*, 2006; Huggins and Izushi, 2007).

The push to an overlapping sphere triple helix model by government is leading to what Etzkowitz (2003) has found to be a ‘conflict of interest’ state among the university sector in relation to its new roles. A recent triple helix-based analysis of knowledge flow in the relatively uncompetitive region of Yorkshire in the UK found significant deficiencies in its underlying framework (Huggins, et al., 2007). As Figure 1 illustrates, there is little evidence of direct knowledge transfer between the higher education and business communities or regional knowledge spillovers. Also, large-scale knowledge creation appears mainly restricted to a small number of higher education institutions, with the key linkages between higher education and government are largely national rather than regional. This confirms broader evidence which finds that the limited research bases of many institutions significantly reduces their ability and propensity to engage in these activities, although they often contribute to regional development in other ways, such as through cultural activities and the promotion of social inclusion which can lead to wider, organic links between business and HEIs (Lockett, et al., 2003; Chapple, et al., 2005).

While there has been a rapid increase in number of knowledge transfer intermediaries, many with strong or direct links with the region's universities, many intermediaries appear focused or facing either the business community or the higher education community rather than both (Huggins, et al., 2007). With regard to those regional knowledge networks involving universities, it was found that while universities engage in collaborative knowledge networks with universities, large firms and other public sector research establishments, the interaction and knowledge exchange universities engage in with SMEs in the region is likely to be far more market-based. It is market-based to the extent that the universities are either directly seeking an economic return from SMEs or are receiving it indirectly from the government funding they receive – through initiatives such as the Higher Education Innovation Fund – as means of attempting to stimulate their knowledge transfer and engagement levels with business and industry. Therefore, if such funding were removed it is probable that universities would be less inclined to seek to transfer their knowledge to SMEs, particularly as they would be less likely to receive potentially useful knowledge in return from SMEs. This raises the important issue of whether regional policy intervention is catalysing knowledge networks or knowledge markets (Huggins, et al., 2007).

[Figure 1 about here]

As uncompetitive regions continues to struggle to achieve improvements in its competitiveness, despite large investments in infrastructure, the role of policy in stimulating a networked environment must clearly return as a key focus of future intervention. More emphasis should be given to the formation of knowledge markets, which may act as the stimulus for the later formation of networks (Figure 2). It is often the case that a market-based relationship is first required before more collaborative knowledge sourcing

and transfer is undertaken, such is the case customers and suppliers become key sources of knowledge for many firms (Todtling and Kaufmann, 2001; Freel, 2002; Maskell, 2004). On the hand, universities must be careful that they do not end up merely imitating the knowledge provision services of the private sector. The diversity of SMEs means that they require diverse flows of knowledge from an equally diverse range of sources (Brüderl and Preisendörfer, 1998; Rickne, 2006). The ‘pre-packaged’ knowledge from knowledge providers such as consultants is often of less use to SMEs. In general, the requirement for SMEs is access to ‘non-standardized’ and highly specific forms of knowledge.

Knowledge suppliers will not always be willing, or in a position, to transfer knowledge across networks, where there is a low expectancy of a reciprocal return, as has been argued is often the case with university-SME networks with regions, whereby the flow of knowledge, and subsequent value added, tends to be one directional (Meyer-Krahmer and Schmoch, 1998). Universities are often wary of engaging with a business community dominated by SMEs, which they often regard as inferior and less lucrative collaborators and partners in comparison to larger and more internationally focused firms. This potentially has an impact on the ability of those SMEs demanding knowledge to absorb and infuse it. For instance, a simple market transaction of knowledge may lead to significant information asymmetries as to how such knowledge is effectively applied or utilised (Cohen and Levinthal, 1990; Mackun and MacPherson, 1997). In other words, effective knowledge absorption is more likely to be effective through collaborative networks than it is through market transactions (Arrow, 1971; Maskell, 2000). Therefore, there is a clear policy role in ensuring that knowledge transfer opportunities are not lost through the lack of a knowledge market; and secondly, where knowledge markets are developed their transformation to networked forms of interaction must be encouraged and

facilitated. Networks in knowledge-intensive markets tend to be highly heterogeneous, requiring additional network management resources, in order to convey complex ideas across these markets and their audiences (Darr and Talmud, 2003; Reagans and McEvily, 2003). Furthermore, many universities lack the requisite number of knowledge brokers and gatekeepers to enable and moderate the flow of knowledge both into and from each institution, and translate this into terms that are meaningful within the institution as well as to other network members as appropriate (Tushman and Katz, 1980; Harada, 2003). As Zaheer and Bell (2005) note, there is a requirement to focus on the dual necessity of forming and managing external contact networks that produce value, as well as possessing the internal capabilities to profitably exploit this knowledge.

Although universities should and do play a role in regional economic development through knowledge transfer, such is the diversity of the roles that the higher education sector has to undertake, universities alone cannot shoulder the burden for transforming the region's innovation capability and knowledge economy. If universities are to continue to play a role it is vital that knowledge transfer and networks initiatives are fully supported to ensure sustainability. Often business support systems are not well linked with the higher system and bespoke policies are required to fulfil this role, ensuring that there is a suitable balance between supporting networked and market oriented transfers of knowledge. However, as networks of knowledge becoming increasingly globally oriented, the capability to strategically develop and influence regionally oriented networks may diminish.

[Figure 2 about here]

8. Conclusions

This paper has shown that regional knowledge networks and modes of engagement between universities and the business community are becoming increasingly prevalent. However, while the impact on regional development of university knowledge transfer is generally positive, there is considerable variability in the capability of universities to effectively transfer their knowledge and of regional businesses to effectively absorb such knowledge. While public policy intervention aimed at stimulating more effective knowledge networks has often been the focus of attention in relatively lagging regions, it is not clear that such regions are either creating (through their universities) the type of knowledge that is applicable or absorbable by firms, especially SMEs. As a result policy has sought to establish intermediary brokers and intermediary institutions such as science parks, cooperative research centres and incubators, as a means of improving the linkage and interface between regional knowledge supply and demand. In some regions, such efforts appear to be reaping reward through acknowledged contributions to regional development. However, this is not always with the case, with it being too difficult to ascribe investments in knowledge-based infrastructure to improved regional competitiveness. Policymakers need to further understand the extent to which these investments are alleviating market failure or stimulating new channels of knowledge flow resulting in improved economic performance. As this paper highlights, appropriate knowledge sources are now less likely to be local and future investments must be placed within a globalised knowledge

environment. In many ways, universities are the ‘multinationals’ of this environment, and their engagement with SME communities must be based on a mutual understanding of the role of both network and market-based knowledge interactions.

Future developments, therefore, must be able to account for a range of potential barriers and issues, e.g. do firms and universities share similar timescales over which work could be carried out? Do practitioners from both sides share a common language, i.e. do they share a common vocabulary, or codebook, for working on similar projects? In addition, internal cultural barriers to building more effective knowledge transfer mechanisms may exist. Shifting to more entrepreneurial and engaged strategies places more emphasis on the third mission. This requires clarification of university missions which may be identified through strategic planning processes and executed through strong university leadership. Also shifting to Mode 2 research requires the creation of cross disciplinary research programmes and collaborative research partnerships.

Even if universities improve their knowledge transfer efforts, the impact on regional development is unclear, 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, although the level of latent demand may be significantly higher. While the potential of universities and their knowledge can be further harnessed to catalyse new knowledge-based economic activity, it is unlikely they can achieve this alone. The onus being placed on universities to become the bases of commercialisable knowledge in many regions is probably too heavy, particularly given their continuing teaching and research remits. Even a cursory analysis of leading regions from around the world, indicates that while universities can play an important role they are often supported by a system of publicly-funded

research institutes and laboratories dedicated only to applied research, much of which has transfer potential.

References

- Acs, Z., Anselin, L. and Varga, A. 2002. Patents and innovation counts as measures of regional production of new knowledge, *Research Policy*, vol. 21, no. 7
- Acs, Z., Auderetsch, D. B. and Feldman, M. P. 1994. R&D spillovers and recipient firm size, *Review of Economics and Statistics*, vol. 76, no. 2
- Adams, H. and Jaffe, A. 1996. Bounding the effects of R&D: An investigation using matched establishment-firm data, *The RAND Journal of Economics*, vol. 27, no. 4
- Adams, J. D., Chiang, E. P. and Starkey, K. 2001. Industry-University cooperative research centres, *Journal of Technology Transfer*, vol. 24, no. 1
- Arrow, K. 1971. *Essays in the Theory of Risk- Bearing*, Chicago, Markum
- Athreye, S. 2004. Agglomeration and growth: a study of the Cambridge hi-tech cluster, in: Bresnahan, T. and Gambardella, A. (Eds.), *Building High-Tech Clusters Silicon Valley and Beyond*, Cambridge and New York: Cambridge University Press
- Audretsch, D. B. 2004 *Entrepreneurship and the Strategic Management of Places*, Paper presented to conference on 'Knowledge Clusters and Entrepreneurship in Regional Economic Development, Humphrey Institute of Public Affairs, University of Minnesota, Minnesota,
- Audretsch, D. B., Lehmann, E. E. and Warning, S. 2005. University spillovers and new firm location, *Research Policy*, vol. 34, no. 7
- AURP. 2007. *Characteristics and trends in North American research parks: 21st century directions*, Columbus, Ohio, Report published by the Association of University Research Parks and Battelle
- Bank of England. 2002. *Finance for Small Firms – Ninth Report*, London, Bank of England
- Bathelt, H., Malmberg, A. and Maskell, P. 2004. Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation, *Progress in Human Geography*, vol. 28, no. 1
- Bok, D. 2003. *Universities in the Marketplace: The Commercialization of Higher Education*, Princeton, Princeton University Press

- Boschma, R. A. 2004. Competitiveness of regions from an evolutionary perspective, *Regional Studies*, vol. 38, no. 9
- Boschma, R. A. 2005. Proximity and innovation: A critical assessment, *Regional Studies*, vol. 39, no. 1
- Braunerhjelm, P. 2005 New Universities, New Industries and Regional Performance, Paper presented at the 'DRUID Tenth Anniversary Summer Conference, Copenhagen, Denmark, June 2005
- Bresnahan, T. and Gambardella, A. 2004. Building high-tech clusters: Silicon Valley and beyond, Cambridge, Cambridge University Press
- Brüderl, J. and Preisendörfer, P. 1997. Network Support and the Success of Newly Founded Businesses. *Small Business Economics* 10: 213-225, *Small Business Economics*, vol. 10, no. 2
- Carlsson, B. and Fridh, A. C. 2002. Technology transfer in United States universities: A survey and statistical analysis, *Journal of Evolutionary Economics*, vol. 12, no. 1-2
- Castells, M. and Hall, P. 1994. Technopoles of the world: The making of the twenty-first century industrial complexes, London, Routledge
- Çetindamar, D. and LaageHellman, J. 2003. Growth Dynamics in the Biomedical/Biotechnology System, *Small Business Economics*, vol. 20, no. 4
- Chapple, W., Lockett, A., Siegel, D. S. and Wright, M. 2005. Assessing the relative performance of U.K. technology transfer offices: Parametric and non-parametric evidence, *Research Policy*, vol. 34, no. 3
- Charles, D. 2003. Universities and territorial development: Reshaping the regional role of UK universities, *Local Economy*, vol. 18, no. 1
- Charles, D. 2006. Universities as key knowledge infrastructures in Regional Innovation Systems, *Innovation*, vol. 19, no. 1
- Charles, D. and Conway, C. 2001. Higher education business interaction survey, Bristol, HEFCE
- Chatterton, P. and Goddard, J. B. 2000. The response of higher education institutions to regional needs, *European Journal of Education*, vol. 35, no. 4

- Chatziioanou, A. and Sullivan, E. 2004. University Technology and Research Parks: Panacea or Menace for Engineering Students?, *Industry and Higher Education*, vol. 18, no. 2
- Cohen, W. M., Florida, R., Randazzese, L. P. and Walsh, J. 1998. Industry and the academy: Uneasy partners in the cause of technological advance, in: Noll, R. (Eds.), *Challenges to research universities*, Washington D.C., Brookings Institution Press
- Cohen, W. M. and Lenvinthal, D. A. 1990. Absorptive capacity: A new perspective on learning and innovation, *Administrative Science Quarterly*, vol. 35, no. 1
- Cooke, P. 2004. Regional innovation systems - an evolutionary approach, in: Cooke, P., Heidenreich, M. and Braczyk, H. (Eds.), *Regional innovation systems: the role of governance in a globalized world*, London, Routledge
- Cooke, P., Heidenreich, M. and Braczyk, H. 2004. *Regional innovation systems: The role of governance in a globalised world*, London, Routledge
- Cowan, R., Jonard, N. and Özman, M. 2003. *Knowledge Dynamics in a Network Industry*, Maastricht, Maastricht Economic Research Institute on Innovation and Technology.
- D'Este, P. and Patel, P. 2005 *University-Industry Linkages in the UK: What are the Factors Determining the Variety of University Researchers' Interactions with Industry?*, Paper presented at the DRUID Tenth Anniversary Summer Conference, Copenhagen, Denmark, June 2005
- Darr, A. and Talmud, I. 2003. The structure of knowledge and seller-buyer networks in markets for emergent technologies, *Organization Studies*, vol. 24, no. 3
- Davenport, S. 2005. Exploring the role of proximity in SME knowledge-acquisition, *Research Policy*, vol. 34, no. 5
- Debackere, K. and Veugelers, R. 2005. The role of academic technology transfer organizations in improving industry science links, *Research Policy*, vol. 34, no. 3
- Dill, D. D. 1995. University-Industry Entrepreneurship – The Organization and Management of American-University Technology Transfer Units, *Higher Education*, vol. 29, no. 4

- Doloreux, D. 2004. Regional Innovation Systems in Canada: A Comparative Study *Regional Studies*, vol. 38, no. 5
- Drejer, I. and 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,
- Drucker, J. and Goldstein, H. 2007. Assessing the regional economic development impacts of universities: A review of current approaches, *International Regional Science Review*, vol. 30, no. 1
- DTI. 2003. Innovation report - Competing in the global economy: The innovation challenge, London, HMSO
- Dunning, J. H. 2000. Regions, Globalization, and the Knowledge Economy: The Issues Stated, in: Dunning, J. (Eds.), *Regions, Globalization, and the Knowledge-Based Economy*, Oxford, Oxford University Press.
- Edmonds, T. 2003. Regional competitiveness and the role of the knowledge economy, House of Commons Library: London, Research Paper 00/73
- Elfring, T. and Hulsink, W. 2003. Networks in Entrepreneurship: the Case of High-Technology Firms *Small Business Economics*, vol. 21, no. 4
- Etzkowitz, H. 1998. The Norms of Entrepreneurial Science: Cognitive Effects of the New University-Industry Linkages, *Research Policy*, vol. 27, no. 8
- Etzkowitz, H. 2003. Innovation in Innovation: the Triple Helix of University-Industry-Government Relations, *Social Science Information*, vol. 42, no. 3
- Etzkowitz, H. 2006. The New Visible Hand: an assisted linear model of science and innovation policy, *Science and Public Policy*, vol. 33, no. 5
- Etzkowitz, H. and Leydesdorff, L. 2000. The Dynamics of Innovation: from National Systems and "Mode 2" to a Triple Helix of University-Industry-Government Relations *Research Policy*, vol. 29, no. 2
- Etzkowitz, H. and Martin, B. 2000. The origin and evolution of the university species, *VEST*, vol. 13, no. 1

- Etzkowitz, H., Webster, A., Gebhardt, C., Regina, B. and Terra, C. 2000. The Future of the University and the University of the Future: Evolution of Ivory Tower to Entrepreneurial Paradigm, *Research Policy*, vol. 29, no. 2
- Etzkowitz, H. and Zhou, C. 2006. Triple Helix twins: innovation and sustainability *Science and Public Policy*, vol. 33, no. 1
- Etzkowitz, H. and Zhou, C. 2006. Triple Helix Twins: Innovation and Sustainability, *Science and Public Policy*, vol. 33, no. 1
- Feldman, M. P. and Desrochers, P. 2003. Research universities and local economic development: Lessons from the history of the John Hopkins University, *Industry and Innovation*, vol. 10, no. 1
- Feller, I. 2004. Virtuous and vicious cycles in the contributions of public research universities to state economic development objectives, *Economic Development Quarterly*, vol. 18, no. 2
- Foray, D. and Lundvall, B. 1996. The knowledge-based economy: From the economics of knowledge to the learning economy, in: OECD (Eds.), *Employment and growth in the knowledge-based economy*, Paris, OECD
- Franklin, S., Wright, M. and Lockett, A. 2001. Academic and surrogate entrepreneurs in university spin-out companies, *Journal of Technology Transfer*, vol. 26, no. 1-2
- Freel, M. 2002. On regional systems of innovation: illustrations from the West Midlands, *Environment and Planning C: Government and Policy*, vol. 20, no. 5
- Friedman, J. and Silberman, J. 2003. University Technology Transfer: Do Incentives, Management, and Location Matter?, *Journal of Technology Transfer*, vol. 28, no. 1
- Fritsch, M. 2002. Measuring the quality of regional innovation systems: A knowledge production function approach, *International Regional Science Review*, vol. 25, no. 1
- Fritsch, M. and Varga, A. 2003. Spatial knowledge spillovers and university research: Evidence from Austria, *Annals of Regional Science*, vol. 37, no.
- Garlick, S., 1998. Creative associations in special places: Enhancing the role of universities in building competitive regional economies, DEETYA Canberra

- Garmaise, M. J. and Moskowitz, T. J. 2003. Informal Financial Networks: Theory and Evidence, *Review of Financial Studies*, vol. 16, no. 4
- Garnsey, E. and Heffernan, P. 2005. High-technology Clustering through Spin-out and Attraction: The Cambridge Case, *Regional Studies*, vol. 39, no. 8
- Garnsey, E. and Lawton Smith, H. 1998. Proximity and complexity in the emergence of high technology industry: The oxbridge comparison, *Geoforum*, vol. 29, no. 4
- Gertler, M. 1995. "Being there": Proximity, Organization, and Culture in the Development and Adoption of Advanced Manufacturing Technologies, *Economic Geography*, vol. 71, no. 1
- Glasson, J. 2003. The Widening Local and Regional Development Impacts of the Modern Universities- A Tale of Two Cities (and North-South Perspectives), *Local Economy*, vol. 18, no. 1
- Goldfard, B. and Henrekson, M. 2003. Bottom-Up Versus Top-Down Policies Towards the Commercialization of University Intellectual Property, *Research Policy*, vol. 32, no. 4
- Goldstein, H. A. and Renault, C. S. 2004. Contributions of Universities to Regional Economic Development: A Quasi-Experimental Approach, *Regional Studies*, vol. 38, no. 7
- Goman, C. K. 2000. *The human side of high-tech: Lessons from the technology frontier*, New York, John Wiley & Sons
- Grant, R. 1996. Towards a knowledge based theory of the firm, *Strategic Management Journal*, vol. 17, no. Winter special issue
- Greunz, L. 2005. Intra- and inter-regional knowledge spillovers: Evidence from European regions, *European Planning Studies*, vol. 13, no. 3
- Gunasekara, C. 2006. The generative and developmental roles of universities in Regional Innovation Systems, *Science and Policy*, vol. 33, no. 2
- Hall, B. H. and MacGarvie, M., 2006. The Private Value of Software Patents, NBER Working Paper 12195 (April 2006)

- Harada, T. 2003. Three steps in knowledge communication: the emergence of knowledge transformers, *Research Policy*, vol. 32, no. 10
- Harmon, B., Cardozo, A., Elder, R., Leuthold, T., Parshall, J., Raghisan, J. and Smith, M. 1997. Mapping the university technology transfer program, *Journal of Business Venturing*, vol. 2, no. 6
- HEBI. 2004. Higher Education-Business Interaction Survey 2001-02, . London, Department for Employment and Learning, Higher Education Funding Council for England, Higher Education Funding Council for Wales, Scottish Higher Education Funding Council, Office of Science and Technology
- Hegde, D. 2005. Public and private universities: Unequal sources of regional innovation, *Economic Development Quarterly*, vol. 19, no. 4
- Henderson, J. V., Kuncoro, A. and Turner, M. 1995. Industrial development in cities, *Journal of Political Economy*, vol. 103, no. 5
- Huggins, R. 2000. *The Business of Networks: Inter-firm Interaction, Institutional Policy and the TEC Experiment*, Aldershot, Ashgate
- Huggins, R. and Izushi, H. 2007. *Competing for Knowledge: Creating, Connecting and Growing*, London, Routledge
- Huggins, R., Johnston, A. and Strakova, L., 2007. *Yorkshire and Humber Knowledge Investment Strategy*, University of Sheffield
- Jaffe, A. B. 1989. Real effects of academic research, *American Economic Review*, vol. 79, no. 5
- Johnson, D. K. N., Siripong, A. and Brown, A. S. 2006. The Demise of Distance? The Declining Role of Physical Proximity for Knowledge Transmission. *Growth and Change*, vol. 37, no. 1
- Kelly, U., Marsh, R. and McNicoll, I. 2002. *The Impact of Higher Education Institutions on the UK Economy*, London, UK Universities
- Kingsley, G. and Malecki, E. J. 2004. Networking for Competitiveness *Small Business Economics*, vol. 23, no. 1
- Kirchhoff, B. A., Newbert, S. L., Hasan, I. and Armington, C. 2007. The influence of university R & D expenditures on new business formations and employment growth, *Entrepreneurship Theory and Practice*, vol. 31, no. 4

- Knobben, J. and Oerlemans, L. 2006. Proximity and inter-organizational collaboration: A literature review, *International Journal of Management Reviews*, vol. 8, no. 2
- Kukliński, A. 2001. The Role of Universities in Stimulating Regional Development and Educating Global Elites, *Higher Education in Europe* vol. 26, no. 3
- Lambert, R. 2003. Lambert review of business university collaboration, Norwich, HMSO
- Lavie, D. 2006. The competitive advantage of interconnected firm: an expansion of the resource-based view, *Academy of Management Review*, vol. 31, no. 3
- Lawson, C. and Lorenz, E. 1999. Collective learning, tacit knowledge and regional innovative capacity, *Regional Studies*, vol. 33, no. 4
- Lawton Smith, H. 2003. Knowledge Organizations and Local Economic Development: The Cases of Oxford and Grenoble, *Regional Studies*, vol. 37, no. 9
- Lee, C., Lee, K. and Pennings, J. M. 2001. Internal Capabilities, External Networks, and performance: A study on Technology-Based Ventures, *Strategic Management Journal*, vol. 22, no. 6-7
- Lee, Y. 2000. The sustainability of university-industry collaboration: An empirical assessment, *Journal of Technology Transfer*, vol. 25, no. 1
- Lissoni, F. 2001. Knowledge codification and the geogralhy of innovation: The case of Brescia mechanical cluster, *Research Policy*, vol. 30, no. 9
- Lockett, A., Wright, M. and Franklin, S. 2003. Technology Transfer and Universities' Spin-out Strategies, *Small Business Economics*, vol. 20, no. 2
- Lucas, R. E. 1988. On the Mechanics of Economic Development, *Journal of Monetary Economics*, vol. 22, no. 1
- Luger, M. and Goldstein, A. 1991. *Technology in the Garden*, Chapel Hill, The University of North Carolina Press
- Mackun, P. and MacPherson, A. D. 1997. Externally-assisted product innovation in the manufacturing sector: The role of location, in-house R&D and outside technical support, *Regional Studies*, vol. 31, no. 7

- Mansfield, E. 1995. Academic research underlying industrial innovations: Sources, characteristics, and financing, *The Review of Economics and Statistics*, vol. 77, no. 1
- Markman, G., Phan, P., Balkin, D. and Gianiodis, P. 2005. Entrepreneurship and university-based technology transfer, *Journal of Business Venturing*, vol. 20, no. 2
- Markman, G., Phan, P., Balkin, D. and Gianiodis, P. 2005. Innovation speed: transferring university technology to market *Research Policy*, vol. 34, no. 7
- Martin, R. and Sunley, P. 2003. Deconstructing clusters: Chaotic concept or policy panacea, *Journal of Economic Geography*, vol. 3, no. 1
- Maskell, P. 2000. Social capital, innovation and competitiveness, in: Baron, S., Field, J. and Schuller, T. (Eds.), *Social capital: Critical perspectives*, Oxford, Oxford University Press
- Maskell, P. 2004. Learning in the village economy of Denmark: The role of institutions and policy in sustaining competitiveness, in: Cooke, P., Heidenreich, M. and Braczyk, H. (Eds.), *Regional innovation systems: The role of governances in a globalized world*, London, Routledge
- Massey, D., Quintas, P. and Wield, D. 1992. *High-tech fantasies: Science parks in society, science and space*, London, Routledge
- McEvily, B. and Zaheer, A. 1999. Bridging ties: A source of firm heterogeneity in competitive capabilities, *Strategic Management Journal*, vol. 20, no. 12
- Meyer-Krahmer, F. and Schmoch, U. 1998. Science-based technologies: university-industry interactions in four fields, *Research Policy*, vol. 27, no. 8
- Meyer, M. 2003. Academic Entrepreneurs or Entrepreneurial Academics? Research-based Ventures and Public Support Mechanisms *R&D Management*, vol. 33, no. 2
- Motohashi, K. 2005. University-industry collaborations in Japan: The role of new technology-based firms in transforming the National Innovation System, *Research Policy*, vol. 34, no. 5

- Mowery, D. and Sampat, B. 2004. The Bayh-Dole Act of 1980 and University-Industry Technology Transfer: A Model for Other OECD Governments? , *Journal of Technology Transfer*, vol. 30, no. 1
- Mowery, D. C., Oxley, J. E. and Silverman, B. S. 1998. Technological overlap and interfirm cooperation: Implications for the resource-based view of the firm, *Research Policy*, vol. 27, no. 5
- Nagle, M. 2007. Canonical analysis of university presence and industrial comparative advantage, *Economic Development Quarterly*, vol. 21, no. 4
- Nelson, R. 2001. Observations on the post-Bayh-Dole rise of patenting at American universities, *Journal of Technology Transfer*, vol. 26, no. 1-2
- Nijkamp, P. 2003. Entrepreneurship in a Modern Network Economy, *Regional Studies*, vol. 37, no. 4
- Nonaka, I. and Takeuchi, H. 1995. *The Knowledge-Creating Company*, Oxford, Oxford University Press
- NSF. 2006. *Science and Technology Indicators*, Arlington, VA, National Science Foundation
- OECD. 2004. *Patents and innovation: Trends and policy changes*, Paris, OECD
- Palazzo, G. 2005. Postnational constellations of innovativeness: a cosmopolitan approach, *Technology Analysis & Strategic Management*, vol. 17, no. 1
- Palmintera, D., 2005. *Accelerating ED through University Technology Transfer: Report to the Connecticut Tech Transfer and Commercialization Advisory Board*, Washington, D.C.
- Paytas, J., Gradeck, R. and 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
- Perkmann, M. and Walsh, K. 2007. University-industry relationships and open innovation: Towards a research agenda, *International Journal of Management Reviews*, vol. 9, no. 4
- Phan, P., Siegel, D. and Wright, M. 2005. Science parks and incubators: observations, synthesis and future research, *Journal of Business Venturing*, vol. 20, no. 2

- Podolny, J. M. 2001. Networks as the Pipes and Prisms of the Market, *American Journal of Sociology*, vol. 107, no. 1
- Porter, M. 1998. Clusters and competition: New agendas for companies, governments and institutions, in: Porter, M. (Eds.), *On Competition*, Boston, HBS Press
- Porter, M. E. and Ketels, C. H. M. 2003. *UK Competitiveness: moving to the next stage.* , London, Department of Trade and Industry
- Powers, J. B. 2004. R&D Funding Sources and University Technology Transfer: What is Stimulating Universities to be more Entrepreneurial?, *Research in Higher Education*, vol. 45, no. 1
- Powers, J. B. and McDougall, P. P. 2005. University Start-Up Formation and Technology Licensing with Firms that Go Public: A Resource-Based View of Academic Entrepreneurship, *Journal of Business Venturing*, vol. 20, no. 3
- Prevezer, M. 2001. Ingredients in the Early Development of the US Biotechnology Industry, *Small Business Economics*, vol. 17, no. 1-2
- Reagans, R. and McEvily, B. 2003. Network structure and knowledge transfer: The effects of cohesion and range, *Administrative Science Quarterly*, vol. 48, no. 2
- Rickne, A. 2006. Connectivity and Performance of Science-based Firms, *Small Business Economics*, vol. 26, no. 4
- Riddel, M. and Schwer, R. K. 2003. Regional innovative capacity with endogenous employment: Empirical evidence from the U.S., *The Review of Regional Studies*, vol. 33, no. 1
- Romer, P. 1986. Increasing returns and long-run growth, *Journal of Political Economy*, vol. 94, no. 5
- Romer, P. M. 1990. Endogenous Technological-Change, *Journal of Political Economy*, vol. 98, no. 5
- Rosenfeld, S. A. 2005. *Rosenfeld Industry clusters: business choice, policy outcome, or branding strategy.* , Carrboro, NC, *Regional Technology Strategies*
- Rutten, R. and Boekema, F. 2007. *The Learning Region: Foundations, State of the Art, Future*, Cheltenham, Edward Elgar

- Santoro, M. D. and Chakrabarti, A. K. 2002. Firm size and technology centrality in industry-university interactions, *Research Policy*, vol. 31, no.
- Sapienza, H. J. 1992. When Do Venture Capitalists Add Value, *Journal of Business Venturing*, vol. 7, no. 1
- Saxenian, A. 1994. *Regional advantage: culture and competition in Silicon Valley and Route 128, Cambridge, Massachusetts*, Harvard University Press
- Saxenian, A. 2005. From brain drain to brain circulation: Transnational communities and regional upgrading in India and China, *Studies in Comparative International Development*, vol. 40, no. 1
- Shane, S. 2004. *Academic Entrepreneurship: University Spinoffs and Wealth Creation*, Cheltenham, UK and Northampton, MA, USA, Edward Elgar
- Shapira, P. and Rosenfeld, S. A., 1997. An overview of technology diffusion policies and programs to enhance the technological absorptive capabilities of Small and Medium Enterprises, Background paper prepared for the Organization for Economic Cooperation and Development Directorate for Science, Technology and Industry
<http://www.ciber.gatech.edu/workingpaper/1997/shapira2.pdf>
- Singh, J. 2005. Collaborative networks as determinants of knowledge diffusion patterns, *Management Science*, vol. 51, no. 5
- Slaughter, S. and Leslie, L. L. 1997. *Academic Capitalism: Politics, Policies, and the Entrepreneurial University*, Baltimore MD, Johns Hopkins University Press
- Smilor, R. W., Dietrich, G. B. and 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*, vol. 135, no. 1
- Sorenson, O., Rivkin, J. W. and Fleming, L. 2006. Complexity, networks and knowledge flow, *Research Policy*, vol. 35, no. 994-1017
- Steffensen, M., Rogers, E. and Speakman, K. 2000. Spin-offs from research centers at a research university, *Journal of Business Venturing*, vol. 15, no. 1

- Stoneman, P. and Diederer, P. 1994. Technology Diffusion and Public Policy, *The Economic Journal*, vol. 104, no.
- Storey, D. J. and Tether, B. S. 1998. Public policy measures to support new technology based firms in the European Union, *Research Policy*, vol. 26, no.
- Storper, M. 1995. The resurgence of regional economics, ten years later, *European Urban and Regional Studies*, vol. 2, no. 2
- Storper, M. 1997. *The Regional World: Territorial Development in a Global Economy*, New York, Guildford Press
- Teixeira, A., Santos, P. and 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, 20-22 June 2006
- Thanki, R. 1999. How do we know the value of higher education to regional development?, *Regional Studies*, vol. 33, no. 1
- Thursby, J. G., Jensen, R. A. and Thursby, M. C. 2001. Objectives, characteristics and outcomes of university licensing: a survey of major U.S. universities, *Journal of Technology Transfer*, vol. 26, no. 1-2
- Thursby, J. G. and Thursby, M. C. 2002. Who is selling the ivory tower? Sources of growth in university licensing, *Management Science*, vol. 48, no. 1
- Todtling, F. and Kaufmann, A. 2001. The role of the region for innovation activities of SMEs, *European Urban and Regional Studies*, vol. 8, no. 3
- Tornatzky, L., Waugaman, P. and 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. and Clark, G. L. 2003. Alliances, networks and competitive strategy: Rethinking clusters of innovation, *Growth and Change*, vol. 34, no. 1
- Tushman, M. L. and Katz, R. 1980. External communication and project performance: an investigation into the role of gatekeepers, *Management Science*, vol. 26, no.

- Uzzi, B. 1997. Social structure and competition in interfirm networks: The paradox of embeddedness, *Administrative Science Quarterly*, vol. 42, no. 1
- Varga, A. 2000. Local academic knowledge transfers and the concentration of economic activity, *Journal of Regional Science*, vol. 40, no. 2
- Vedovello, C. 1997. Science parks and university-industry interaction: Geographical proximity between the agents as a driving force, *Technovation*, vol. 17, no. 9
- Wolfe, D. 2004. *The Role of Universities in Regional Development and Cluster Formation*, Toronto, Centre for International Studies, University of Toronto
- Wolfe, D. and Gertler, M. 2004. Clusters from the Inside and Out: Local Dynamics and Global Linkages, *Urban Studies*, vol. 41, no. 5-6
- Wright, M., Lockett, A., Clarysse, B. and Binks, M. 2006. University Spin-Out Companies and Venture Capital, *Research Policy*, vol. 35, no. 4
- Zaheer, A. and Bell, G. 2005. Benefiting from network position: firm capabilities, structural holes, and performance, *Strategic Management Journal* vol. 26, no. 9

Table 1: Modes of University Engagement

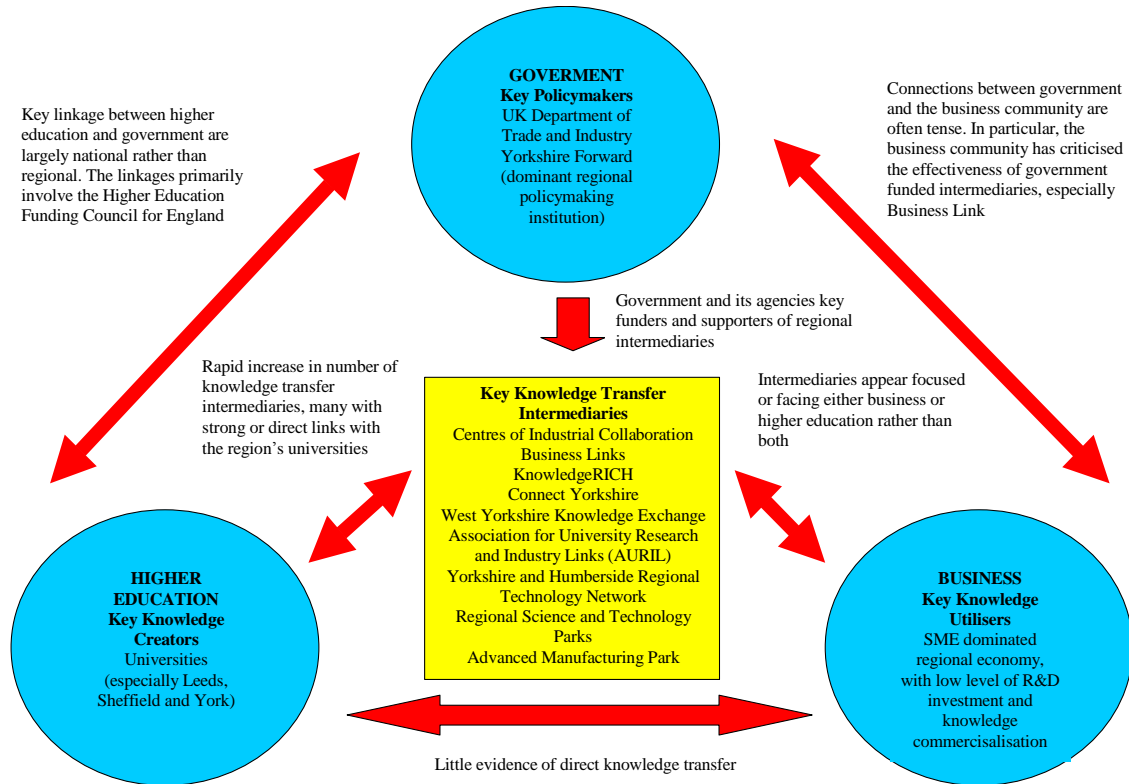
Factor	Role(s) in knowledge transfer	Factors affecting success
Formation of technology transfer offices	Administer legal processes with respect to patenting and licensing intellectual property Establish and promote spin-off companies Monitor research to decide on commercialisation strategy	Level of professionalism of technology transfer officers (Markman, et al., 2005a) Decentralised management (Debackere and Veugelers, 2005) Financial incentives for technology transfer officers (Markman, et al., 2005a) Clear vision and leadership (Lockett et al., 2003) Existing relationships with external actors (Harmon, et al., 1997)
Creation of science parks	Subsidised laboratory space/workspace Consultancy services Proximity and connections to university faculty Proximity to other high technology firms Rapid technology transfer Student/graduate placements Opportunities to commercialise university knowledge and intellectual property	Ability to recruit tenants (AURP, 2006) Close proximity to universities to facilitate the flow of knowledge (Adams and Jaffe, 1996; Phan, et al., 2006) Faculty open to working with firms based in the science park (Etzkowitz, 2006) The presence of multinational companies' research labs
Development of outreach programmes/education	Awareness building Technology demonstration Search and referral services Executive education programmes Workforce skill development	More efficient operations and higher skilled workforce (Shapira and Rosenfeld, 1997) Developing applied research projects (Tornatzky, et al., 2002)

Table 2: University Policies and Regional Economic Development Impact

High Impact	Medium Impact	Low Impact
Research partnerships Research services and publications Networking	Academic entrepreneurship Human resources transfer	Technology commercialization (transfers of IP)

Source: Perkmann and Walsh (2007)

Figure 1: Triple Helix Representation of Yorkshire's Knowledge Flow Model



Source: Huggins, et al.(2007)

Figure 2: Regional Knowledge Flow Across Networks and Markets

