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**Global Commodity Chains in the UK Biotechnology Industry:
An Alliance-Driven Governance Model**

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1. INTRODUCTION

An oft repeated comment in economic geography and regional studies is that as the world economy has globalised it has also, paradoxically, regionalised (Scott 2000; Hassink 2005). In this context, economic globalisation refers to the ‘functional integration’ of distributed sites either vertically – as with the organisation of multinational corporations (MNC) – or horizontally – as with global production networks – across a number of geographical scales (see Gereffi 1999; Henderson et al 2002). So, without wishing to accede to the hyperbole of the globalisation discourse as Peter Dicken (2004) warns, it is still important to note how regional economic performance is increasingly bound up with and embedded in a wider set of geographical relations beyond the local, and sometimes national, scale. In particular regional development may be dependent upon the linkages *between* local, national and global production systems within which regional organisations and institutions are embedded (see Dicken et al 2001; Coe et al 2004). Despite this shrinking of time-space as a result of technological changes in transport and telecommunications (Hudson 2002b; Dicken 2003a), the national and regional basis of firms and their capabilities remains a crucial element in the performance of their particular locations, as several authors have continued to stress the importance of the ‘home’ base of globally-oriented companies (Scott 2000; Dicken 2003b; Gertler 2003).

The growing global inter-linkages and inter-dependencies of national and regional economies – promoted and perpetuated through deliberate policy mechanisms at the national and international level – have meant that the global economic performance of those locations has been constructed and constituted as central features of national and regional development (see Rosamond 2002; Brown 2005; The Sapir Group 2005). In part this is a result of the conceptual definition of economic performance as an effect of national, and now regional, competitiveness; in that national and regional economies are considered to be competing for a share of the global markets (Gardiner et al 2004). Thus the danger of poor competitiveness on the part of the European Union appears to be a self-confirming explanation for lower levels of economic growth than the United States because the major global market is the USA. Consequently, any policy drive to secure a

higher share of global markets would, by definition, be aimed at securing a greater share of the US market and therefore sustaining the dominance of US economic hegemony in terms of driving particular technological solutions, product developments or organisational changes to suit the US market (see Harvey 2003, 2005). One example is the global pharmaceutical industry which is dominated by the North America market representing 50 % of world sales, as is the biopharmaceutical market where the North American market makes up 60 % of global sales (Bibby et al 2003; Thayer 2004; see also Dicken 2003a).

Peter Dicken (2004) argues that the concept of 'globalisation' does not offer a useful explanation as to why these processes of internationalisation, and their attendant constitution of regional competitiveness, have occurred. Rather the growing importance of intra-industry and intra-firm global trade represents a series of possibilities for understanding the position of regions within the global economy. For example, (a) the distinct geographical spread of transnational and multinational corporations has tied particular locations into branch-plant 'enclaves' (Hudson 2002a; Dicken 2004); (b) new territorial divisions of labour have been expanded and consolidated (Dunford 2003); or (c) networks of production have been embedded in global systems (Smith et al 2002; Coe et al 2004). In interpreting these changing spatial relations, we have to link the 'local' and the 'global' in meaningful ways that can explain the importance of regional economic performance based on attributes of particular locations. Current research in this area suggests that it is the endogenous knowledge, learning and innovation base of regions that provides particular locations with their 'competitive advantage', building on the earlier work of Joseph Schumpeter, Edith Penrose and others in evolutionary and heterodox economics (e.g. Best 2001; Cooke 2002; Boschma 2004; Fagerberg 2005; Cooke and Leydesdorff 2006). In this work, innovation systems are considered as reliant on the collective and social processes of knowledge production through networks of organisations, institutions and actors that create a spatially-constituted 'virtuous' feedback mechanism and infrastructure (see Asheim and Gertler 2005; Fagerberg 2005; cf Malmberg and Power 2005). There are also questions as to whether global competition itself drives innovation (Simmie 2004), rather than vice versa, although the synthesis

between these two positions suggests that it is the relationship between ‘local buzz’ and ‘global pipelines’, in terms of knowledge and competition, that explains the performance of different regions (see Bathelt et al 2004).

The growing literature on the biotechnology industry provides the means to address all these issues. In many ways it is an exemplar for this very type of explanation, representing a sector highly dependent upon science and technology (McKelvey et al 2004), highly skilled labour (Zucker et al 2002), and high levels of both public and private investment (Cooke 2002). However, the biotechnology industry has been strongly aligned with work on ‘clusters’ in regional studies literature drawing, in particular, on the work of Michael Porter (1990, 2000) as well as subsequent writers in the ‘value chains’ field of business strategy. In the UK at least, this approach has dominated both policy and academic discourse for several years with biotechnology and clusters conceptually linked in the early to mid 1990s in public discussions and then policy (see DTI 1999a, 1999b). However, the cluster literature, because of its concern with local linkages, fails to address the importance of national and global connections to innovation and knowledge production despite research that highlights the importance of these extra-regional ties (Malmberg 2003; Malmberg and Power 2005). It is therefore a limited approach for explaining the innovation process. In contrast sociological and geographical theories around commodity chains (Gereffi 1994, 1996) and production networks (Henderson et al 2002) present a new and, as yet, unutilised approach to understanding the biotechnology industry, particularly its positioning within a global system of innovation and knowledge exchange. Thus in this paper I provide a preliminary analysis of the biotechnology industry from a global commodity chains (GCC) and global production network (GPN) perspective that seeks to synthesise the sociological and geographical work in this research area. In order to do this I first present a discussion of the clusters approach in relation to the biotechnology industry and how the GCC and GPN theories add an extra dimension to this debate. I illustrate these theoretical points with a pilot survey of UK biotechnology firms and secondary data on one commodity (Mylotarg ®) and its ‘developer’ firm (Celltech, now UCB Pharma). Throughout this paper I show how the

UK biotechnology industry is intrinsically tied into a global arrangement of knowledge production and exchange that is driven an alliance oriented governance structure.

2. OLD APPROACHES, NEW APPROACHES: CLUSTERS, COMMODITIES AND NETWORKS

Clusters and Value Chains

The United Kingdom government has seized upon the notion that national competitiveness, conceptualised as productivity, and therefore economic growth in Britain are dependent upon the expansion of a 'knowledge economy' (see DTI 1999c for example; also Brown 2005). As a consequence, in the 1998 Competitiveness White Paper (*Our Competitive Future*) the UK government outlined how geographical and social organisation – clusters and networks respectively – promoted regional productivity and regional development (see also HM Treasury 2001). In subsequent policy initiatives they have therefore sought to encourage such organisational forms and capacity. For example, in 2000 they introduced an Innovative Clusters Fund (ICF) to finance incubation and cluster infrastructure by regional development agencies (RDA). A year later they complemented the ICF with a Regional Innovation Fund (RIF) (DTI 2003: 102-3). Across these regional and competitiveness policies the position and importance of biotechnology has been highly pronounced. In 1999 for example there were two Department of Trade and Industry reports concerning biotechnology clusters: *Genome Valley* (DTI 1999a) and *Biotech Clusters* (DTI 1999b). Alongside the DTI, other government departments also produced policy documents that sought to promote cluster developments in Britain, such as the DETR (now ODPM) *Planning for Clusters* report (DETR 2000), the ODPM *Our Towns and Cities* report (ODPM 2000[2004]), and the Treasury's *Lambert Review* (HM Treasury 2003). Consequently the promotion of clusters can be seen as a crucial aspect of regional development policies across multiple government departments as well regional bodies like the RDAs in the UK (HM Treasury 2001; DTI 2003).

Concomitant with the expansion of the policy literature on clusters and competitiveness there has been a growth in academic research on clusters generally (e.g. Breschi and Malerba 2001; Maskell 2001) and ‘biotech’ clusters specifically (Audretsch 2003; Bagchi-Sen, et al. 2004; Casper and Murray 2004; Cooke 2002; Cooke 2004b; Fuchs and Krauss 2003; Lawton-Smith, et al. 2000; McKelvey 2004; Prevezer 2003; Zeller 2001). Whilst research has focused on the national scale, in terms of institutional, national systems and varieties of capitalism approaches,¹ it has also been strongly oriented to a regional scale, with studies of Scotland (Leibovitz 2004), Maryland (Feldman and Francis 2003), Cambridgeshire-UK (Casper and Karamanos 2003), and Lombardy (Breschi et al 2001) amongst the research literature. The two concepts of clusters and competitiveness are derived from the work of Michael Porter who argued that competitive advantage is constituted by ‘home base’ characteristics that impact on innovation capabilities. These characteristics affect a firm’s value chain – “network of activities, connected by linkages” (Porter 1990: 41) – which connects activities within (i.e. production and marketing) and across the firm (i.e. suppliers and customers). The inter-firm linkages form a competitiveness diamond that consists of:

- Firm strategy
- Factor conditions
- Demand conditions
- Related and supporting industries (ibid.: 72).

Porter’s later work focused more on the spatial aspects of this system in contrast to the earlier emphasis on functional aspects (e.g. Porter 2000). As such, Malmberg (2003) argues, the greater clarity in the later work means that the clusters approach highlights the differences between localised (i.e. clustered) and global interactions, which, in turn, strengthens the argument that locational characteristics are central to firm performance. However, there is still limited evidence of localised inter-firm linkages or even inter-organisational collaboration and networks suggesting that the analytical basis of cluster theory is less useful as a spatial explanatory tool (see Malmberg and Power 2005).

There has been a considerable interest in the localised concentration of biotechnology firms with other cognate firms, supply / service companies, and public research institutions, such as universities or public research organisations (PRO). According to Senker (2005) the literature dealing with the biotechnology industry has progressed through three main research fields starting the economics of networks and subsequently covering strategic management and more recently the ‘new economic geography’ of Krugman and others. In her overview however, Senker does not mention the growing body of research in economic geography and regional studies. In this research a stylised representation of the industry has been developed in which successful biotechnology ‘clusters’ comprise certain key features (see McKelvey et al 2004; Ryan and Phillips 2004). These features can be summarised as follows:

- Concentrations of small or medium sized dedicated biotechnology firms (DBFs)
- Concentrations of ‘upstream’ (i.e. universities) and ‘downstream’ (i.e. large pharmaceutical firms) complementary organisations
- Concentrations of venture capital and specialist service firms (i.e. lawyers, consultants)
- Local linkages between the many concentrated organisations
- Local identity produced through trade associations or networking organisations
- Local government policy that encourages a cluster approach to economic development.

Although this policy and academic approach to understanding the biotechnology industry is very popular, there is also a need to recognise that extra-local linkages are as important (if not more so) as local linkages for firms because they provide the stimuli of international demand-pull and knowledge interaction (see Simmie 2003; 2004). Subsequent research has therefore focused on the idea of ‘nodes of excellence’ or ‘megacentres’ that are keyed into a global network of biotechnology capabilities, whilst also benefiting from the local features of clusters (Coenen et al 2004; Cooke 2004a), although more stress is still placed on local interactions rather than global connections.

3. GLOBAL COMMODITY CHAINS AND PRODUCTION NETWORKS

Whilst the cluster approach – of which the value chain is an integral part – promotes the idea of studying the interactions between firms, and other organisation, it largely restricts this to a local or sometimes national scale, especially in its present form. Thus the clarity that this work provided has led to a restrictive application for the clusters approach, even though it could be argued that it has played an important stimulating role in regional studies; illustrated in the plethora of theories and concepts arising since the early 1990s such as national systems of innovation (Lundvall 1992), learning regions (Morgan 1997), and regional innovation systems (Braczyk et al 1998). However, the greater clarity has meant that the analysis of regional economies has been limited to the ‘local milieu’ (Malmberg 2003), despite empirical evidence that localised clusters seldom exhibit “strong internal input-output linkages” (Bathelt et al 2004: 37). Consequently it is useful to consider concepts drawn from the sociological and geographical literature on global commodity chains (GCC) (e.g. Gereffi 1994, 1996) and global production networks (GPN) (e.g. Henderson et al 2002).ⁱⁱ Despite their differences, there are a number of overlaps between these two theories that mean they can be usefully incorporated into an approach that illustrates the spatial embedding and situational interdependence of firms and other organisations in the UK biotechnology industry.

The GCC approach was defined by Hopkins and Wallerstein (1994: 17) as “a network of labor and production processes whose end result is a finished commodity”, and has its origins in their earlier work on world systems theory. It is mainly associated with the work of Gary Gereffi (1994, 1996) who identified two governance forms of GCC – producer-driven and buyer-driven – each focused on different manufacturing sectors – consumer durables (i.e. automobiles) and non-durables (i.e. apparel) respectively. The main reason to use a GCC approach is that it enables the analysis of global linkages across localities and therefore it provides a contrasting perspective on the biotechnology industry to the more commonly used cluster perspective (e.g. Breschi et al 2001; Cooke 2001; Coenen et al 2004). It also avoids the limitations of the ‘varieties of capitalism’

approach (i.e. Kettler and Casper 2000), by emphasising a non-state analysis of firm activities. According to Gereffi (1996), there are main foci to the GCC approach:

- The organisational aspects of chains and the linkages between different economic networks;
- The cross-national nature of organisations;
- The spatial dispersal of governance; and
- Inter and intra-sectoral variations.

These foci provide the approach with several advantages over conceptualising specific industrial sectors / commodities in cluster or value chain terms. The first is that GCC recognise the interplay between different institutional systems in production, rather than assuming that one system represents a dominant form or dominates production. Second, GCC allow the analysis of linkages across local, national and global scales, rather than being limited to the localised interactions of cluster theory (see Malmberg and Power 2005). Third, the GCC focus on governance enables research to consider the power relations between actors in the chain, rather than ignore such aspects of commodity production. Finally, GCC enables research to focus on the variations within and between different industrial sectors by focusing on a particular commodity, rather than focusing on a specific sector or locality (see Gereffi 1994, 1996, 1999; Raikes et al 2000; Bair 2005).

The GPN approach also seeks to avoid a state-centric analysis, although, unlike the GCC, it avoids the spatial disembedding implicit in the GCC characterisation of production and organisational activity as a linear rather than geographically bounded process (Whitley 1996; Smith et al 2000). Although there have been attempts to link the dispersed organisation of global commodity chains with the concentrated organisation of localised production (e.g. Bair and Gereffi 2001; Sturgeon 2001), it has been predominantly through the adoption of the 'value chain' concept (e.g. Gereffi et al 2005), which has meant that there is an increased emphasis on the "internal logics of sectors" rather than on the external linkages between sectors, different organisations and different institutions

(see Bair 2005: 164). This perspective ignores the processes of knowledge exchange and integration that occur across different sectoral, organisational and institutional networks at different spatial scales embedded in processes of geographical concentration and dispersal (see Ernst 2002; Ernst and Kim 2002), which can be addressed through the adoption of aspects of the global production network (GPN) approach. In her article on 'sticky places', Ann Markusen (1996) outlines a number of different types of industrial district (e.g. Marshallian, Hub-and-spoke, Satellite) that all involve such local or regional embedding of firms alongside an important orientation to externalised linkages. The GPN concept incorporates these issues in "an explicitly relational, network-focused approach" that "promises to offer a better understanding of production systems" (Henderson et al 2002: 442). It is both spatial, addressing the differences between actors at different scales, and relational, addressing the relationships between those actors within and across the different scales.

4. ALLIANCE-DRIVEN GOVERNANCE: A NEW GLOBAL COMMODITY CHAIN?

By incorporating aspects of the global production networks into the global commodity chains approach I can develop a new governance model alongside the ones outlined by Gereffi (1994, 1996, 2001a). These are split between two main commodity chain types, with another emergent one that I will not consider here, one being producer-driven (PDGCC) and the other consumer-driven (CDGCC). Gereffi (1994, 1996, 2001a) presents the first of these (PDGCC) as arising during a period in which import substitution industrialisation (ISI) was a dominant development paradigm. This coincided with a period of investment-based globalisation roughly spanning the 1950s until the 1970s, although in this case there was also a gradual shift from an ISI model to an intra-firm trade system. The producer-driven governance model was concerned with the vertical integration of transnational firms across national borders producing consumer durables, and intermediate and capital goods, which created strong barriers to entry from economies of scale (see **Table 1** below). The second (CDGCC) model was associated with an export-substitution industrialisation (ESI) development model that grew

alongside a trade-based period of globalisation from the 1970s until, at least, the mid 1990s. The consumer-driven model was characterised by the horizontal integration of firms across national borders that produce consumer nondurables such as apparel or footwear, and where the barriers to entry are largely derived from economies of scope (i.e. linkages between suppliers, producers and retailers). In this model the role of retailers and marketers is crucial as they are the firms that provide the have the competencies to compete.

The new governance type, which I have termed the alliance-driven GCC (ADGCC) and incorporates the spatial features of the global production network, can be positioned alongside these two models outlined by Gary Gereffi (see **Table 1** for comparison). The reason to introduce this new model is that the previous two governance types are essentially development models designed to understand the role of trans-border linkages for developing economies (see Bair 2005). As such they do not really focus on the role of trans-border linkages for developed economies, especially in relation to the growing importance of knowledge-based economic development (see OECD 1996; DTI 1998; although also see Sokol 2004 for a critique).

Table 1: Global Commodity Chain Types

	PRODUCER-DRIVEN	BUYER-DRIVEN	ALLIANCE-DRIVEN
Drivers of GCC	Industrial capital	Commercial capital	Public and venture capital
Core Competencies	R&D, production	Design, marketing	Allies, Regulations
Barriers to Entry	Economies of scale	Economies of scope	Economies of complexity
Economic Sectors	Consumer durables, intermediate goods, capital goods	Consumer nondurables	Intangibles, hi-tech, services
Typical Industries	Automobiles, computers, aircraft	Apparel, footwear, toys	Hi-tech, services
Ownership of Manufacturing Firms	Transnational firms	Local firms, predominantly in developing countries	Mixture
Main Network Links	Investment-based	Trade-based	Alliance-based
Predominant Network Structure	Vertical	Horizontal	Matrix

Source: Adapted from Gereffi 2001b

Thus the ADGCC seeks to present these trans-border linkages in terms of relationships along the commodity chain of high technology or knowledge-based (i.e. services) products like those developed by the biotechnology industry; i.e. biopharmaceuticals, platform technologies, diagnostics, bioremediation. This new governance model is based on a matrix of alliance relationships between firms and other organisations that requires core competency in coordinating interaction, especially across multiple spatial scales, so that firms can absorb often disparate and dispersed knowledge alongside the internal production of and combination with existing knowledge (see Ernst and Kim 2002). This includes the ability to comply with regulatory and institutional features of multiple spatial locations. Firms need to do this because of (a) the high complexity and sophistication of the technologies involved in their industries, which rely upon access to both the latest codified (i.e. scientific findings) and tacit (i.e. scientific expertise) knowledge (Senker

2005), and (b) the iterative process of knowledge production through feedback between knowledge sources, again spatially distributed across different geographical scales (Gertler and Levitte 2005). Consequently the ADGCC is reliant upon both public and venture capital because other forms of capital are risk-averse and unwilling to operate under the high degree of uncertainty, engendered by the economies of complexity (i.e. the need to operate within a series of alliance relationships) that present strong barriers to entry.

5. BIOTECHNOLOGY COMMODITY CHAINS

To illustrate the alliance-driven global commodity chain I next look at how the UK biotechnology industry, although it is organisationally concentrated in specific locations, it is also relationally tied into a number of local, national and global linkages. To do this I first map out Celltech plc's alliance network between 1997 and 2004 to show the importance of extra-local linkages, before exploring a case study of a biotechnology commodity chain in which Celltech was involved; the biopharmaceutical Mylotarg ®. Finally I examine primary data from a small pilot survey of UK biotechnology firms that broadens the findings of the secondary data.

Methodological Note

To start with I constructed an alliance network for the first UK biotechnology company Celltech plc (now UCB Pharma) from secondary data derived from the *Bioworld* database (see **Figure 3**).ⁱⁱⁱ Although this mapping exercise clearly illustrated the importance of extra-local linkages, I also produced a case study of a biopharmaceutical commodity, co-developed by Celltech, from secondary data and one survey response (see below). The main secondary data sources were the *Biopharma* product database (Rader 2003),^{iv} company websites (e.g. Celltech, now UCB Pharma) and other organisational websites (e.g. PhRMA). From this data I constructed a brief commodity chain of the biopharmaceutical product Mylotarg ® (gemtuzumab ozogamicin), which was marketed worldwide by Wyeth Corporation and approved by the USA Food and Drug Administration (FDA) in May 2000 (see **Table 2**). Finally, alongside this secondary data

and as a follow-up to my doctoral research, I emailed a commodity history survey to all the biotechnology company respondents from an earlier survey carried out in 2004. I approached a total of 56 informants in July 2005 and after two email follow-ups, 15 people were found to have moved or deemed not relevant, another 10 turned down the request and 12 (21%) completed the survey although only 11 of these were useable. The remaining 19 people did not respond to the email requests. All respondents were asked to complete a product history survey which contained a stylised timeline of a particular product's development from basic science funding through to customer base. At each stage the respondents were asked for data on the organisations involved and the location of those organisations in relation to the firm (see **Table 3**).

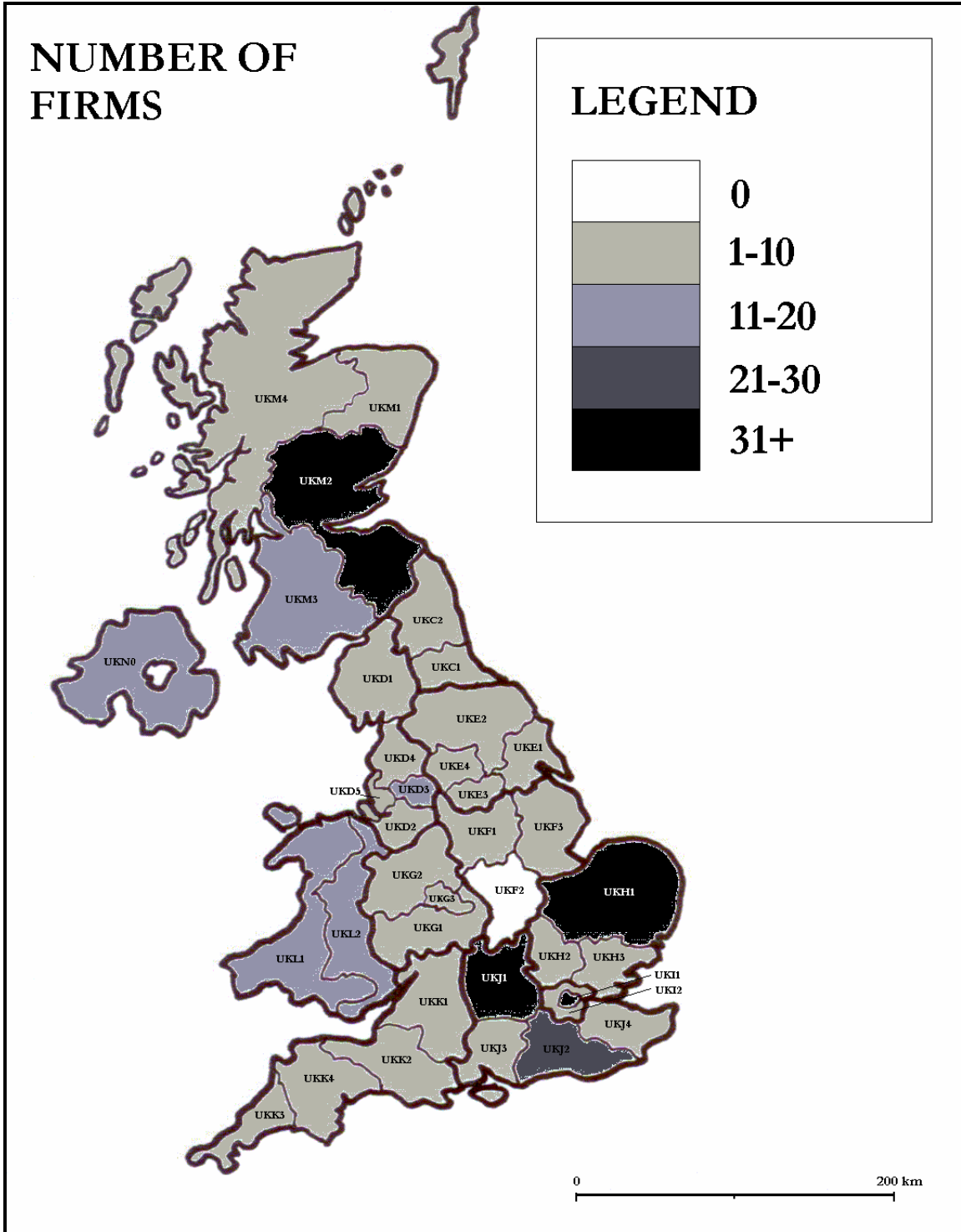
6. BACKGROUND: BIOTECHNOLOGY IN THE UK

The location of the UK biotechnology industry in specific Porterian clusters can be represented as concentrations of several complementary organisations; (a) biotechnology firms, (b) service providers, (c) public research organisations, and (d) university departments. Although the two DTI biotechnology reports (DTI 1999a, 1999b) highlight the main concentration of the biotechnology sector as Cambridge, Oxfordshire, London, South-east England and Central Scotland, secondary data on the geographical spread of the biotechnology industry indicate that, although they represent the strongest concentrations of biotechnology in the UK, these 'clusters' are not as large as the two reports indicate (see Birch n.d.). Because I have described the UK biotechnology industry in more detail elsewhere (ibid.), I only provide a map of biotechnology firms that carry out research here in order to highlight the location of those firms that engage in knowledge production, and would therefore need to draw upon local and extra-local sources of knowledge, and the extent of their concentration in the UK. There were a total of 436 biotechnology firms in 2003, with a mean average of 11.78 firms and median of 6 firms per NUTS2 region (see **Figure 1**). Only four regions had more than twice the mean average and they represented over half of all biotechnology firms in the UK:

- Berkshire, Buckinghamshire and Oxfordshire (68 firms)
- East Anglia (65)

- Inner London (62)
- Eastern Scotland (39)

Figure 1: Location of UK Biotechnology Firms 2003



In historical terms, only 42 of these firms were founded in 1983 or before (including Celltech) with, once again the two largest concentrations in East Anglia (9 firms) and Berkshire, Buckinghamshire and Oxfordshire (5 firms). These two regions represented a third of all firms in 1983; a position only slightly less than their current position with 30.5 % of the totla. The data above illustrates the concentration of the biotechnology sector in the four regions previously identified as clusters by the government (DTI 1999a, 1999b). However, each concentration differs from the others across a range of indicators that can be used to show the differences between the regional knowledge *base* (i.e. capacity) and the regional economic *driver* (i.e. source of firms) of each of these locations possibly indicating that they are either at different stages of maturity or consist of different biotechnology sector types (see Cooke 2004e).

7. POSITIONING A COMPANY WITHIN A GLOBAL COMMODITY CHAIN: CELLTECH PLC

The first UK biotechnology firm was Celltech plc, founded in 1980 as a state-owned company (although also with private investors) by the UK government as a response to the recommendations contained in the *Spinks Report* (ACARD 1980). Originally it had exclusive rights to commercialise genetic engineering research funded by the Medical Research Council (MRC) – a right it retained until 1985 – as a response to the perceived failure by the MRC to protect the monoclonal antibody research of Milstein and Köhler at Cambridge University (Sharp 1985; Bud 1993). In 1993 Celltech was listed on the London Stock Exchange and six years later it merged with Chiroscience plc, another public company which had been formed in 1992 by Christopher Evans and listed in 1994. In 2000 Celltech Chiroscience acquired Medeva plc (a pharmaceutical company) and changed its name to Celltech Group plc. Finally, in July 2004 Celltech Group was acquired by the Belgium firm UCB Pharma.^v

A map of Celltech's formal alliances and collaborations can be mapped out using secondary data from the *Bioworld* database for the years between 1997 and mid-2004 (see **Figure 2**). Initially these alliances distinguish between the three main companies that

formed Celltech Group in 2000; Celltech, Chiroscience and Medeva. It is possible to illustrate the direction of the knowledge or technology transfers between Celltech and the organisations that Celltech collaborated with, plus map out these relationships (see **Figure 3** for a key to **Figure 2**). The mapping of Celltech's alliances provides a clear indication that the company does not rely upon local, regional or even national collaborations, at least in regards to formal arrangements. Across all three initial companies there are a total of two collaborations with UK based firms and several purchases of (e.g. Oxford Glycosciences in 2003) or divestments to (e.g. Evans Vaccines to Powderject in 2000) such nationally-based companies. This means that a significant proportion (93%) of all their alliances are with foreign based firms; usually US based (81%).

Figure 2: Company Alliance Chain: Celltech

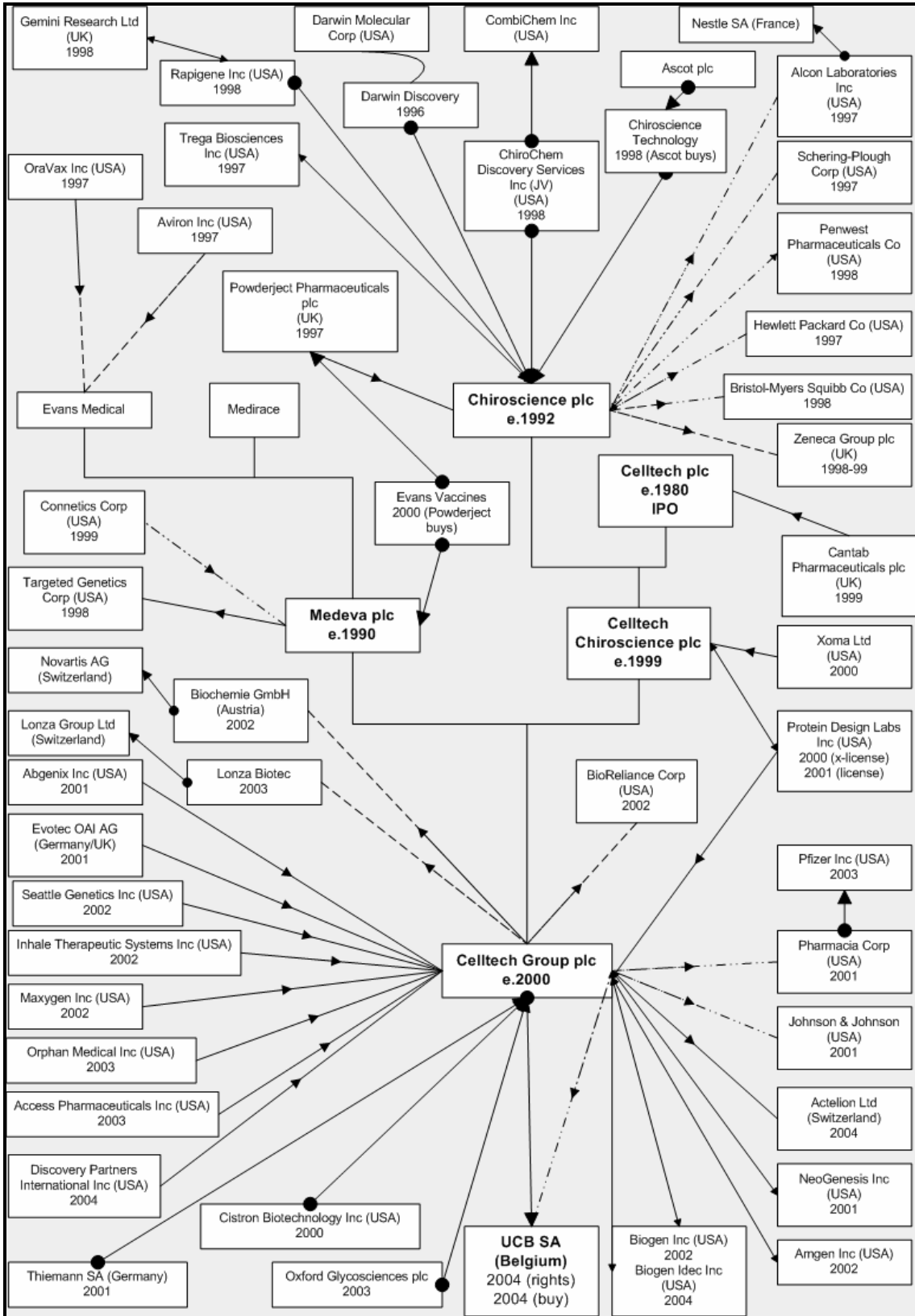
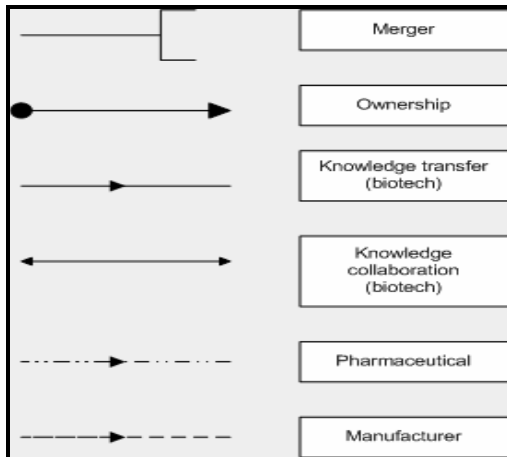


Figure 4: Key to Figure 3



Prior to merger, most of Chiroscience's alliances between 1997 and 1999 were outbound to US pharmaceutical or large companies (i.e. the knowledge or technology was transferred to the other organisation); including Zeneca Group (1998-99), Bristol-Myers Squibb (1998), and Schering-Plough (1997). Only one was a biotechnology joint-collaboration and one an inbound alliance (i.e. knowledge transferred into Chiroscience). The data on Celltech (1997-1999) prior to merging with Chiroscience is limited, only covering one inbound biotechnology alliance. In the case of Medeva (1997-2000) there were also few alliances; two manufacturing inbound alliances (i.e. products manufactured by Medeva), one inbound pharmaceutical alliance and an outbound biotechnology alliance. All were with US companies.

After the 2000 merger of all three companies and up until mid-2004 there were a significant number of formal alliances and collaborations. About half of these were inbound biotechnology alliances, largely with US companies, whilst the other half were mostly collaborations or outbound pharmaceutical and biotechnology alliances, again with US companies. There were also three manufacturing alliances with two European firms and one US firm. Finally, there were two multi-stage alliances, one with Protein Design Labs (USA) that included licensing and cross-licensing deals for antibody humanisation technologies. It is evident that the original collaboration between the two firms that occurred during the development of Mylotarg (see later) has continued. The

second dual alliance is with Biogen Idec (USA/Switzerland) and covers two collaborative alliances. This secondary data on Celltech's alliance structure illustrates the extent to which it was tied into a global system of knowledge and technology exchange. In the later stages of its existence, after the 2000 merger with Medeva, it appeared that Celltech drew upon the knowledge capabilities of biotechnology companies, mostly based in the USA, and provided or jointly produced knowledge capabilities with pharmaceutical companies, again, mostly US based. However, this does not mean that it existed within either a vertical or horizontal network structure, but rather it operated within a complex matrix of inter-related technological and knowledge systems that were spatially embedded in a number of different, dispersed locations and networks.

8. GLOBAL COMMODITY CHAIN CASE STUDY: MYLOTARG ®

Whilst the Celltech's alliance network illustrates the spatial embedding of one firm's formal relationships in multi-scalar and dispersed locations, it does not provide evidence of the importance of such spatial dimensions in commodity development. Celltech co-developed a biopharmaceutical called Mylotarg ®, which represents a useful case study to explore the extra-local connections necessary in biotechnology commodity chains. Mylotarg is formed from the conjugation of a recombinant humanised antibody (specific to receptors on leukaemia cells) with calicheamicin, a bacterial toxin. The conjugation of these two elements forms gemtuzumab ozogamicin, an immunotoxin that targets leukaemia cells.^{vi} Mylotarg was the first such antibody-immunotoxin (i.e. antibody-targeted chemotherapy) to be approved by the Food and Drug Administration (FDA), which happened in 2000.^{vii} The product consists of three main elements:

- Calicheamicin; an anti-cancer agent isolated from a caliche clay sample collected in Kerrville, Texas by Lederle (now Wyeth) researchers in 1981.
- Murine CD33 antigen: an antigen originally developed by Fred Hutchison Cancer Research Center in Seattle, Washington and licensed by Lederle (now Wyeth) in 1990.

- **Humanisation technology:** this involved inserting the murine antigen into a human monoclonal antibody and was developed by Celltech in Berkshire, UK using their own technology and technology licensed from Protein Design Labs Inc (Fremont, California) in 1990.

As the description of the three constitutive parts shows, the research and development of Mylotarg was a complex process incorporating a number of scientific discoveries, technologies, and development activities over a 20 year period between the identification of the anti-cancer agent and approval by the FDA. Its development also reveals the importance of national and global inter-linkages throughout the production process from basic science through to manufacture and packaging (see **Table 3**). Within the commodity chain one actor coordinated the activity of the others; in this case Lederle Labs, a division of American Cyanamid which was later bought by American Home Products (renamed Wyeth Corporation in 2002) in 1994.^{viii} By 1994 the coordinating company had filed an investigational new drug (IND) application for Mylotarg with the FDA.^{ix}

Table 3: Global Commodity Chain: Mylotarg

PRODUCTION PROCESS	LOCATION and ORGANISATION
Basic Research	1. New York, pharmaceutical company (calicheamicin), 2. Washington state, public research organisation (murine antigen)
Development	1. Berkshire (UK), biotechnology company 1 (humanisation technology) 2. California, biotechnology company (humanisation technology) 3. New York, pharmaceutical company and Berkshire, biotechnology company 1 (humanised monoclonal antibody)
Trials (Phase I & II)	USA and Europe
Approval	Maryland, FDA
Manufacture	1. New York, pharmaceutical company 2. Berkshire, biotechnology company 1 (licensed technology)

	3. Berkshire, biotechnology company 2 – spin-out from biotechnology company 1 (licensed technology)
Packaging	Puerto Rico, pharmaceutical company

Source: Rader 2003; PhRMA website; survey response.

Following the development trajectory of this one commodity usefully illustrates the importance of such inter-linkages. Subsequent to the initial research and development outlined above, the various elements had to be combined to produce a final commodity. Thus after the original discovery of calicheamicin as an anti-cancer agent it was necessary to develop a delivery system because the agent was such a powerful toxic. This necessitated the combination of the agent with a CD33 antigen-binding antibody that, because it was derived from a rodent, needed to be humanised as a monoclonal antibody.

9. ALLIANCE-DRIVEN GLOBAL COMMODITY CHAINS: PILOT SURVEY

After outlining the importance of extra-local linkages to one UK biotechnology firm (Celltech) and one of its commodities (Mylotarg), here I report on a pilot survey that should broaden the relevance of using the global commodity chains approach to research the UK biotechnology industry. Primary data on a series of commodity chains was collected using a pilot survey which, although limited to only 11 useable responses, provides an initial indication of the spatial and organisational interaction and orientation of biotechnology commodity production. Each production stage (i.e. research and development, marketing) was stylised as independent and isolated from the other stages enabling respondents to indicate firstly which organisations were involved and secondly where those organisations were located. Where the stage was considered to be internal, respondents were asked to indicate accordingly. The geographical location of the stages differentiated between ‘local’, ‘national’, ‘international’ and ‘all’ scales (see **Figure 2**).

Figure 2: Scale Colour Code

LOCAL	NATIONAL	INTERNATIONAL	ALL
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For the early production phases, starting with *basic science funder* and ending with *research & development*, it appears as though the majority of activity occurs internally and nationally. *Basic science research* and *research & development* are performed internally, as well as externally; locally and internationally for the former, and across all the geographic spaces for the latter (although proportionately less). In contrast *basic science funder* and *initial investor* activity is strongly located at a national level, indicating the importance of public science funding bodies such as the Research Councils and the Department for Trade and Industry (DTI). What this indicates is that the national public funding of biological sciences is a crucial element in the commodity chain and a key driver in the new typology. The equal split between local and international external basic science also partially corroborates the arguments about the importance of extra-local linkages (i.e. Bathelt et al 2004; Simmie 2004). However, it also shows that there is relatively little cross-over between territorial sources of knowledge (only one incidence) at this stage of the chain, although the difference between basic science and R&D illustrates the importance of both the same and alternative sources of knowledge during the 'scientific' phase of the innovation process.

Table 2: Biotechnology Global Commodity Chain Survey Results

	BASIC SCIENCE FUNDER	BASIC SCIENCE RESEARCH	INITIAL INVESTOR	RESEARCH & DEVELOPMENT	BUSINESS SERVICES/CONSULTANT	SUPPLIER	LATE INVESTOR	MANUFACTURER	REGULATOR	MARKETER	CUSTOMER
A	DTI	Internal	Internal	Internal	Internal	External	VC	Internal External	Internal	Internal	Drug clinic, Police, Work
B	Head office	Head office	Internal	Internal	-	-	-	Internal	MHRA, FOD EMEA	-	Surgeons Surgeons
C	Pharma	University	Pharma	University Pharma	Pharma	Pharma Pharma	Internal	Pharma	EMEA, FDA	Pharma	Public
D	PRO	PRO	PRO	PRO	-	-	Internal	JV Biotech	SDA	JV Biotech	Private hospitals
E	-	-	Angels VC	Internal	-	-	VC	-	-	-	University, Biotech, Pharma
F	HEI grant bodies	University	Internal External	Internal University	-	University	-	Internal External	Internal	Internal External	Universities, Vets, Feed Companies, Labs, etc
G	DTI, MRC, SERC	University University	VC	Internal Pharma	Small and large firms	Many firms	Public market	Contract manufacturers	FDA and European	Pharma plc	Physicians

H	University	Internal	VC	Internal	-	External	VC, public market	Outsourced	FDA	-	-
	VC	University					VC, public market				
I	-	-	-	Internal	-	External	-	Internal	External	Internal	External
J	VC	Internal	VC	Internal	Internal	External	VC	Internal	Internal	Internal	External
K	Seed fund	Internal	Business angels	University, firms	External	External	-	-	-	-	-
				University, firms	External						

The intermediary production phase, starting with *business services* and ending with *manufacturer* is largely dominated by internationally-based production activity, although with internal and nationally-based activity as well. *Business services* and, especially, *supplier* activity is internationally located (where relevant), illustrating the importance of global knowledge and technologies, whereas *late investor* activity is national and *manufacturing* internal. There is also both national and international located *manufacturing*, as well as some limited internal and international *late investment*. The predominance of internationally-based services (i.e. suppliers and business services) indicates that the innovating firms are drawing upon specific types of international knowledge (i.e. non-scientific) during innovation that local actors simply cannot provide because of its specificity (i.e. global market conditions). The importance of national *later investment* seems to illustrate the continuing role that national venture capital plays in late stage innovation, whereas the split between internal and external (both national and international) *manufacturing* shows divergent strategies by different firms; one type pursue vertical consolidation whilst the other externalise their production needs.

In the final production phase, starting with *regulator* and ending with *customer*, there is a total dominance of international-based activity. *Regulation* and *consumers* are predominantly internationally located, although in the latter case there is also a significant national base. *Marketing* is also international, although there is a significant internal proportion as well. These findings confirm research on the importance of both institutional context (i.e. Kettler and Casper 2000) and international demand (i.e. Simmie 2003). There is a pronounced global (and national) dimension to regulation and sales that precludes any significant localised effects from concentrations.

9. CONCLUSION

Although the biotechnology industry has been lauded as an example of a cluster based sector, one that will transform our economy and society (e.g. BIGT 2003), there are a number of recent voices raising concerns about the emphasis placed on this one industry and its claims to revolutionary innovation (e.g. Arundel and Mintzes 2004; Nightingale

and Martin 2004; Joppi et al 2005). Another element to these concerns is the policy emphasis, and academic support for that emphasis, on biotechnology clusters as a source of regional, or national, competitiveness. The concentrations of biotechnology firms mapped out in this paper illustrate just how small the UK biotechnology industry is – less than 450 firms – despite the enormous public and private investment in this field previously and currently. What this also illustrates is that these UK concentrations cannot hope to achieve innovative success, and subsequent economic development, without linkages to other sites of knowledge. This means that, at least in relation to the UK, another approach to understanding the biotechnology industry, aside from one based on cluster theory, is necessary. The work on global commodity chains (GCC) and global production networks (GPN) provides the necessary conceptual tools to do just that as demonstrated in this paper.

Incorporating the geographical features of the GPN approach into the more sociological GCC perspective provides the means to analyse the embedding of the crucial local, national and global linkages at these multiple scales. The importance of extra-local linkages to biotechnology firms in particular is illustrated in the alliance network of the company Celltech plc; both prior to merger and afterwards. Celltech is positioned within a series of alliances that connect it to US-based biotechnology firms, especially as sources of knowledge, and to large, US-based pharmaceutical companies, mostly as demand for Celltech's knowledge. These relationships show how knowledge production and exchange are spatially dependent in that Celltech drew on dispersed knowledge sources and, in turn, was a 'dispersed' knowledge source for other, often larger, companies. Because these relationships were all formal there was a possibility that Celltech drew upon more localised informal knowledge sources, although the number of co-located firms (i.e. Berkshire based) was only 15 suggesting a limited source for such interaction as well as motivation for seeking external linkages.

Further evidence of the extra-local orientation of the biotechnology industry, in the UK and the USA at least, is provided by the Mylotarg global commodity chain. The collaborative linkages that facilitated the development of this product were embedded in

a number of distinct global locations from Washington state and California through New York to Berkshire, UK. None of these represented a clear linear set of activities that naturally followed on from each other, as implied in the global commodity chains literature (see Whitley 1996). In contrast, the development of this one commodity illustrates the importance of global production networks (GPN) where activity in one organisation in a particular location is dependent upon the activity of another organisation in another location, although it is coordinated by another organisation (i.e. Lederle, now Wyeth). To engage in this GPN these organisations, particularly the coordinating one, need the capability to work outside of their own institutional, spatially embedded (whether regional or national) innovation system, as well as across and within other similarly institutional, spatially embedded systems; especially (supra)national regulatory rules. This implies that the focus on embedding organisations, especially biotechnology firms, in such systems may be detrimental to the product development, which relies upon an alliance-based, collaborative system stretching across multiple scales.

These conclusions are reinforced in the results of the pilot survey. No single respondent claimed that only internal and/or local actors were involved in product development, indicating that biotechnology innovation depends on capabilities embedded across multiple scales; i.e. national-based basic science funding, local-based R&D, international-based marketing and customers. The expanding role of collaboration across organisations and space has already been commented on in the literature (e.g. Gertler and Levitte 2005), but here the data shows that focusing on the endogenous capabilities of regional organisations, to the exclusion of their extra-local counterparts, can be a detrimental policy orientation that ignores the all too common possibility of regional path dependency and lock-in (see Boschma 2004; Hassink 2005). So, although the UK has several regions that represent sites of bioscience excellence (e.g. East Anglia, Oxfordshire) these are not necessarily going to produce the high sources of value-added growth expected from biotechnology. Policy-makers might therefore benefit from shifting their emphasis from the pursuit of productivity as the source of regional economic development towards a more nuanced approach that can account for the inter-linkages and inter-dependencies

between regions that have been emphasised in economic geography and regional studies for several decades now (e.g. Massey 1995; see also Fothergill 2005).

Of course, the likelihood of such a reorientation is unlikely with the pursuit of neoliberal policies at the regional, national and supranational scale as actors across all these spatialised governance systems promote policies designed to benefit the accumulation of profit for biotechnology and pharmaceutical firms. At the national scale, for example, the UK government has repositioned the National Health Service so that it is now a research appendage of the biomedical industry, offering access to disease populations and clinical trial participants (Vince 2006). On the supranational level, the European Union has promoted a number of specific pharmaceutical regulatory changes (see Abraham and Lewis 2000), as part of a strategy to enhance European pharmaceutical competitiveness (Abraham and Reed 2003). These changes have had a global impact, with the International Conference on Harmonisation (ICH) process, first convened in November 1991, influencing the regulatory policies of countries like the USA (Abraham and Reed 2002, 2003). The biotechnology industry depends upon these governance interventions for its 'success' – although it is important to note that it has never been profitable globally (Ernst and Young 2003c) – since the risks and infrastructure investment necessary for product development entail the coordination of innovation across a series of organisations that are spatially embedded at different scales.

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NOTES:

ⁱ Across this literature there is an emphasis on aspects of national economies like markets, labour, and intellectual property rights that produce differences or similarities between different countries or regions such as the USA and Europe (i.e. Sharp and Senker 1999).

ⁱⁱ There is also other relevant literature drawing on the idea of business systems (Whitley 1996) and more consumption focused 'systems of provision' (Fine and Leopold 1993), although I will not address either here.

ⁱⁱⁱ <http://www.bioworld.com/>

^{iv} <http://www.biopharma.com/>

^v <http://www.pharma.ucb-group.com/whoarewe/history/historycelltech/historycelltech.asp>

^{vi} <http://www.rxlist.com/cgi/generic2/gemtuzumab.htm>

^{vii} <http://www.phrma.org/publications/policy/admin/30.08.2005.1217.cfm>

^{viii} <http://hbswk.hbs.edu/item.jhtml?id=4769&t=bizhistory>

^{ix} http://www.fda.gov/cder/regulatory/applications/ind_page_1.htm