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Alliance-driven governance: Applying a global commodity chains approach to the UK biotechnology industry

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Abstract

As the economy has globalized it has also regionalized leading to the integration of different spaces across different scales. A number of theories contend that the endogenous assets of these locations provide them with the means to compete in this globalizing economy, especially in relation to knowledge-based sectors like biotechnology. Amongst these theories, the cluster concept stands out. However, there is little support for the arguments that local linkages are the central contributors to innovation. Extra-local linkages have also been highlighted suggesting that other theories accounting for these linkages may prove useful in the discussion of knowledge-based sectors generally and biotech in particular. One such theory is the concept of global commodity chains which explicitly concerns the inter-connections within and across different geographical scales. As yet it has seldom been applied to the biotech industry. This article seeks to use the approach to explore the UK biotech industry.

Keywords: biotechnology, clusters, global commodity chains, global production networks, alliance-driven governance

Introduction

The current UK Labour government has pursued regional policies based on the idea that national competitiveness - conceptualized as economic growth measured by productivity - is dependent upon the expansion of a 'knowledge economy' (for example see DTI 1998, 1999c; Brown 2005). In policy discourse, the biotechnology industry, now increasingly defined more broadly as bioscience or life science industry, is presented as an important element in the development of this knowledge economy (DTI 1999a, 1999b; BIGT 2003). Such policy discourse has focused on the importance of clustering in the biotechnology industry representing regional development and competitiveness in spatially-bounded terms. In 1999, for example, there were two Department of Trade and Industry (DTI) reports emphasizing the importance of biotechnology clusters: *Genome Valley* (DTI 1999a) and *Biotech Clusters* (DTI 1999b). Alongside the DTI, other government departments have also sought to promote cluster development in the UK (e.g. DETR 2000; HM Treasury 2003; ODPM 2004[2000]). Consequently the promotion of clusters has been seen as a crucial aspect of regional development policies across multiple government departments as well regional development organizations (HM Treasury 2001; DTI 2003).

UK policy is based on the current emphasis in academic research on the collective, systemic and social processes produced through networks of actors creating locally-constituted 'virtuous' feedback in innovation and learning (see Asheim and Gertler 2005; Fagerberg 2005; although see Malmberg and Power 2005 for critique). What makes this research focus of particular interest now is the growing concern with the 'productivity crisis' in the biomedical industry and whether conceptualizing innovation in

certain terms has had a detrimental impact on technological development (see Pisano 2006). The productivity crisis refers to the relative dearth of new biomedical product approvals when compared with the growing levels of expenditure – both public and private – in research and development (R&D) (see FDA 2004; Nightingale and Martin 2004; Martin *et al* 2006).[1] Thus this article seeks to question the continuing emphasis on clusters – in theory and policy – in relation to the UK biotech industry and to present an alternative approach. I do so by drawing on the under-utilized global commodity chains perspective focusing on 'technology' as a unit of analysis and not just on the firm (e.g. systems approaches) or the region (e.g. cluster approaches).[2]

I have four main aims in this article. The first is to critique the application of cluster theory in explaining the UK biotech industry. In particular, I am interested in the use of cluster theory in understanding regional development by both academics and policy-makers. The interpretation of spatial relations and processes in cluster terms leads to an emphasis on knowledge, innovation and learning as "locally bounded processes" that should therefore be theorized in locally based terms (Phelps 2004: 978). My second aim is to develop a conceptual and methodological approach that can account for multi-scale processes of knowledge transfer, innovation and learning, drawing upon research in economic sociology and economic geography that highlight global economic processes; i.e. the global commodity chains (GCC) and global production network (GPN) literature

[1] See also Arundel and Mintzes (2004) and Joppi *et al* (2005) for concerns about the therapeutic advance of new biotech products.

[2] Current analyses of biotech innovation can be split, rather crudely perhaps, between 'systems of innovation' and 'cluster' approaches. Both address different concerns, but also encounter certain problems. In particular, the systems approach does not really address the specificity of place and the consequences this has for different actors. Although the clusters approach does address these issues more clearly, it also has a tendency towards technological determinism in that technology is presented as a given to which regions respond. In contrast, taking technology as the unit of analysis enables the consideration of how firms, places and technology are co-produced and is a perspective grounded in work from science and technology studies (STS).

(e.g. Gereffi 1996; Henderson *et al* 2002). The theoretical approach I use is based on a GCC analysis, although I incorporate the geographical dimensions of the GPN perspective as well to acknowledge the importance of spatial and historical specificity.

The third aim is to consider how innovation processes embedded across local, national and global scales are organized and coordinated by numerous actors that need to take into account multi-scale linkages in GCC governance. This I have conceptualized as an *alliance-driven global commodity chain* (ADGCC) that, furthermore, avoids the "binary distinction" (Phelps 2004: 979) often seen in research in economic geography linking the regional economy with the global economy (Amin and Thrift 1992; Bathelt *et al*, 2004).[3] As such ADGCC highlights the distinctiveness of new economic sectors like biotechnology and their multi-scalar position within and across developed economies. Finally, the fourth aim is to consider what implications an ADGCC approach has for policy-making in relation to the UK biotech industry, in particular, and for other countries similarly situated.

This article is organized in two main sections. The first provides a critique of the current cluster emphasis in research on the biotech industry followed by the development of theoretical approach based on GCC/GPN theories. The second section covers the evidence to support this argument consisting of a survey of biotech products, a case study of a biotech firm (Celltech, now UCB Pharma) and a case study of a biotech product (Mylotarg ®). In the conclusion I will discuss the policy implications of this alternative approach on the expansion of the biotech sector in the UK.

[3] Bathelt *et al* (2004) refer to the important connection between 'local buzz' and 'global pipelines', especially in relation to different types of knowledge (i.e. tacit and codified respectively), whilst Amin and Thrift (1992) refer to the important effect that globalisation has had in creating local clusters (i.e. 'nodes in global networks'). In both cases, whether the conceptual definition of locations as tied into 'global' networks, as opposed to 'international' ones, illustrates the binary analysis Phelps (2004) questions.

Clusters, Commodities and Networks

Clusters and Biotechnology

The clusters concept is derived from the work of Porter (1990) who argued that national competitive advantage is constituted by 'home base' conditions (e.g. labour market, knowledge spillovers, supporting supplier firms) embedded in localized intra-firm and inter-firm linkages, inter-organizational collaboration and networks. In later work, Porter emphasized spatially-bound 'clusters' defined as:

> "…geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (e.g., universities, standards agencies, trade associations) in a particular field that compete but also cooperate" (Porter 2000: 15).

A growing body of literature in economic geography and regional studies has been critical of this cluster concept (e.g. Asheim *et al* 2006) and had an important impact on recent research on the biotech industry. Previous research on biotechnology innovation has drawn on a number of different approaches including systems of innovation, strategic management and the 'new economic geography' of Krugman and others (see Senker 2005; Birch forthcoming).[4] The more recent research in economic geography and

[4] There has also been a interest in varieties and national systems of capitalism approaches (e.g. Casper and Kettler 2001) emphasizing aspects of national economies like markets, labour, and intellectual property

regional studies concerns the local and regional scale with the conceptualization of concentrations of biotech firms and associated organizations as *biotech clusters* (e.g. Lawton-Smith *et al* 2000; Zeller 2001; Cooke 2002, 2004a, 2004b, 2004c, 2005; Audretsch 2003; Fuchs and Krauss 2003; Prevezer 2003; Bagchi-Sen *et al* 2004; Casper and Murray 2004; McKelvey 2004). There have been studies of Scotland (Leibovitz 2004), Maryland, USA (Feldman and Francis 2003), Cambridgeshire, UK (Casper and Karamanos 2003), and Lombardy (Breschi *et al* 2001), amongst other regions in countries like Sweden, Canada and Germany.

A stylized representation of biotech clusters includes certain key features (see Cooke 2004a; McKelvey *et al* 2004; Ryan and Phillips 2004). These features can be summarized as follows:

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

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rights that produce differences or similarities between different countries such as the USA and Europe (see Sharp and Senker 1999).

Although this stylized representation became widely publicized, it is also important to recognize that extra-local connections beyond the cluster are as important as local linkages for firms. Extra-local linkages provide important complementary capabilities like manufacturing (see Gray and Parker 1998) and the stimuli of international markets and global knowledge interactions (see Simmie 2004). Subsequent research in this area has as a result focused on the 'nodes of excellence' or 'megacentres' in the global network of biotechnology capabilities (e.g. Coenen *et al* 2004; Cooke 2004a, 2004c; Cooke and Leydesdorff 2006). However, despite an important consideration of global connections, such research still does not address the multi-scalar (local, national and international) linkages in biotech innovation processes.

In these later debates about biotech 'nodes of excellence' or 'megacentres' there is still an emphasis on the concentration of whole 'value chains' in particular locations (Coenen *et al* 2004; Cooke 2004a, 2004c, 2005; Cooke and Leydesdorff 2006; Zeller 2004) rather than on multi-scale networks. For example, Cooke (2005) highlights the importance of 'regional knowledge capabilities' and a process of specialization shifting to diversification as a cluster develops. In other work there is greater emphasis on the question of proximity and exactly what types of proximity prove central in biotech clusters (e.g. Coenen *et al* 2004; Zeller 2004; also Boschma 2005 for more general discussion), particularly the importance of 'functional proximity' (i.e. accessibility) (Coenen *et al* 2004).

Although there is greater sophistication in this more recent work there is still an emphasis on localized processes. Thus although the cluster approach promotes the idea of

studying the interactions between firms and other organization, it largely restricts such analysis to a particular scale or type of proximity. In contrast, it is important to explore the concentration *and* dispersal of innovation processes across multiple scales (Malmberg 2003; Malmberg and Power 2005; Malmberg and Maskell 2006). This is because local external economies from concentration produce both advantages and disadvantages for firms (see Parr 2002). For example, a biotech firm may benefit from its location near a university because of access to skilled labour and knowledge spillovers, but also have to compete with other organizations for labour and suffer reverse spillovers. In order to moderate these external diseconomies biotech firms need to be able to disperse innovation processes.

In their overview of the more general cluster literature, Malmberg and Power have claimed that there is actually little evidence that firms interact or collaborate more with other local firms and conclude that "collaborative interaction with similar and related firms in the localized cluster does not come out as a major knowledge creating mechanism" (Malmberg and Power 2005: 425). A number of other scholars have stressed the multi-scale dimensions of innovation, especially the role of global connections (e.g. Bunnell and Coe 2001; see Vallance 2007 for a review), which makes the consideration of such linkages in the UK biotech industry an important undertaking. However, this does not necessarily lead to a rejection of locally-bounded theories of innovation (e.g. clusters, regional innovation systems), but rather to the conclusion that the insights of both approaches need to be integrated more explicitly in future research.

Global Commodity Chains and Global Production Networks

The issues highlighted by Malmberg and Power (2005; also Malmberg and Maskell 2006) can be usefully addressed with the application of a global commodity chains (GCC) approach. For example, the cluster approach emphasizes interactions between firms and other organizations in local (and now global) terms, whereas the global commodity chains (GCC) and subsequent global production networks (GPN) approaches provide the means to conceptualize the multi-scalar basis of innovation processes and organizational interaction. The main conceptual reason for using a GCC approach is that it avoids both a firm-centric and a region-centric perspective, which enables the exploration and explanation of linkages along a technology or product value chain that cuts across local, national and international scales.

The GCC theory itself originated in the work of Gereffi (1994, 1996) who identified two governance models – producer-driven and buyer-driven – each focused on different manufacturing sectors – consumer durables (e.g. automobiles) and non-durables (e.g. apparel) respectively. According to Gereffi (1996) and others, the main foci of the GCC approach provide a number of conceptual benefits (see Table 1). There are also several weaknesses. The most important of these is the spatial disembedding implicit in the GCC characterization of production and organizational activity as a linear process rather than one that is geographically and historically bounded (Whitley 1996; Henderson *et al* 2002; Smith *et al* 2002; Coe *et al* 2004; Hess and Yeung 2006).

Table 1: Global Commodity Chains

GCC FOCI	BENEFITS
The organizational aspects of chains and the linkages between different economic networks	Recognizes the interplay between different institutional systems in production, rather than assuming that one system represents a dominant form or dominates production
The cross-national nature of organizations	Allows the analysis of linkages across local, national and global scales, rather than being limited to the localized interactions
The spatial dispersal of governance	Focus on governance enables research to consider the power relations between actors in the chain
Inter and intra-sectoral variations	The focus on a commodity, rather than sector or location, enables research to explore the variations within and between different industrial sectors

Source: Gereffi (1994, 1996, 1999), Raikes et al (2000), Bair (2005).

Although there have been attempts to link the dispersed organization of global commodity chains with the concentrated organization of localized production (e.g. Bair

and Gereffi 2001; Sturgeon 2001; see also Markusen 1996 on 'sticky places' for non-GCC perspective), such work has predominantly adopted a global value chain (GVC) approach (see Gereffi *et al* 2005). However, the GVC approach has a narrow emphasis on the "internal logics of sectors" rather than on the external linkages between different sectors, organizations and institutions (see Bair 2005: 164). Thus the concentration on inter-firm relations ignores the differences in regional and national economies and leaves out the relevance of place and the geographical embedding of institutions, path dependence and regulation.

The work of Henderson *et al* (2002), Coe *et al* (2004) and others on global production networks (GPN) *spatialize* the GCC approach because it acknowledges how innovation processes differ across different sectoral, organizational and institutional networks at different spatial scales embedded in processes of geographical concentration and dispersal (see Ernst 2002; Ernst and Kim 2002). 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, concerning the differences between actors at different scales, and relational, addressing the relationships between those actors within and across the different scales. Thus it is useful to incorporate these elements into the GCC approach, whilst retaining the focus of GCC on technology (or product) as a unit of analysis.

Alliance-driven Model of Global Commodity Chains

By incorporating aspects of the GPN into the GCC approach I have conceptualized an *alliance-driven* model (ADGCC), which can be applied to knowledge-

based sectors like biotechnology, to complement those outlined previously by Gereffi (1994, 1996, 2001a); one being producer-driven (PDGCC) and the other consumer-driven (CDGCC). The alliance-driven model is particularly useful because Gereffi's earlier models are oriented towards upgrading in developing countries through trans-border linkages (see Bair 2005). As such they do not focus on the role of multi-scale linkages for developed economies, especially in the context of the growing importance of knowledge-based economic development (see OECD 1996; DTI 1998; see Sokol 2004 for a critique). Thus it is useful to consider how regions in developed economies are constituted by multi-scalar innovation processes and whether the interaction across these scales enables regions and nations to adjust and adapt to global economic change. In particular, the relevance of such ties for less-favoured regions (LFRs) is crucial because they may enable these regions to counteract uneven development or alternatively they can reinforce it by concentrating investment in certain places.

The ADGCC model is derived from a number of theoretical and empirical insights in the existing literature on innovation processes, particularly in relation to the biotechnology industry. The model is outlined in Table 2 below, but I will also briefly summarize it here. First, the model applies to specific economic sectors (e.g. biotechnology) that entail high asset specificity and rely upon intellectual property (IP) protection to encourage innovation (see Arora and Merges 2004; Gertler and Levitte 2005; Orsi and Coriat 2005). Second, the capture of value from IP means that vertical disintegration is more commonly observed, leading to a diverse number of small firms (Arora and Merges 2004) and other organizations such as universities, lawyers, regional government agencies and suppliers, which necessitates the development of core

competency in making and managing collaborations and alliances (Prevezer 2001; Senker 2005). Third, the complexity of new science and technology and high asset specificity of products requires access to multiple markets and therefore the capability to operate across diverse institutional regimes at regional, national (e.g. FDA) and global scales (e.g. WTO) (Oβenbrügge and Zeller 2002). Finally, the high level of risk and uncertainty inherent in sectors dependent on high-cost, analytical knowledge and corresponding asset specificity mean that they are reliant upon certain types of investment, namely public and venture capital (Casper and Kettler 2001), and concomitant actors (e.g. national government, venture capitalists etc).

There are also a number of weaknesses in the ADGCC model. First, is it truly 'global'? Although this is an issue with all 'global' approaches (GCC, GPN, GVC), it is important to note that such perspectives may be more transnational than global in that they are still largely dependent upon national institutional structures despite multi-scale interaction (see Whitley 1996). Thus 'multi-scale' may be a more apt term. Second, does the GCC approach adequately deal with the role of the state as an actor? In relation to the biotech industry there has been considerable policy intervention across countries in order to promote the competitiveness of national biotech sectors (see Birch 2007), which requires unpacking and may be beyond GCC theory at present.

Table 2: Alliance-driven Global Commodity Chain Model

	CHARACTERISTICS	THEORETICAL UNDERPINNINGS
Drivers of GCC	Public and venture capital	High asset specificity of new S&T leads to risk and uncertainty and therefore discourages short-term, low-risk investment.
Core Competencies	Collaborations, Regulations	Specialisation precludes integration so organisations rely on collaborations, whilst the complexity of new S&T necessitates an understanding of multiple regulatory regimes.
Barriers to Entry	Economies of complexity	High-cost, analytical knowledge (i.e. science) infrastructure and varied national regulatory policies inhibit entry.
Economic Sectors	Hi-tech, intangibles	Dependent upon intellectual property protection to ensure value capture.
Main Network Links	Alliance-based	The necessity of collaboration and regulatory adherence mean that organizations rely on the coordination of diverse incentives.
Predominant Network Structure	Matrix	The collective nature of innovation and high asset specificity mean that networks consist of dynamic and multi-organizational interaction.

Note: S&T stands for science and technology.

Biotechnology Global Commodity Chains

Research Context and Methodological Note

The global biotech industry includes approximately 4,400 firms of which roughly 450 are based in the UK (DTI 2005; Ernst and Young 2005). These UK biotech firms employ around 22,000 people of whom less than 10,000 work in R&D. These firms spent €1,758 million in R&D in 2003 and generated €5,041 million in revenues (DTI 2005). The U.K. biotechnology industry is relatively small, yet over half of UK biotech firms operate in the healthcare field producing high value-added commodities like biopharmaceuticals, whilst a significant number (22%) are service-based firms offering platform technologies (DTI 2005: 51).

In order to address the three theoretical and empirical aims of this article, I first present the results of a survey of UK biotech firms to illustrate the relevance of the GCC approach and the limitations of the clusters perspective. Second I explore the spatial embedding of one particular firm (Celltech) within a global alliance network, before showing how one of this firm's products (Mylotarg) represents an example of an alliance-driven commodity chain.

The survey consists of a commodity history questionnaire that was emailed to biotech firm respondents from an earlier research project (Birch 2006). I approached 56 informants in July 2005 and after two follow-ups received a 21% response rate; 12 people, although only 11 responses were useable. Respondents were asked to complete a product history questionnaire which contained a stylized 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 organizations involved and the location of those organizations in relation to the firm. A typology of the firms involved is summarized in Table 3 below, indicating the different types of products handled, including therapeutics, diagnostics, and platform technologies.

Table 3: Characteristics of Biotech Firms

	COMMODITY	FOUNDED	REGION	SIZE	STATUS CHANGE
A	Therapeutic	Late 1980s	East Midlands	50 to 250	Merged
B	Therapeutic	Late 1980s	South-east	50 to 250	Acquired
C	Therapeutic	Late 1990s	Eastern	50 to 250	-
D	Therapeutic	Pre 1980	South-east	Over 250	-
E	Therapeutic	Early 1980s	South-east	Over 250	Acquired
F	Drug Delivery	Early 1990s	South-east	Over 250	Acquired and Spun-out
G	Platform Technology	Early 1990s	Scotland	10 to 50	Subsidiary / Relocated
H	Platform Technology	Early 2000s	Eastern	10 to 50	-
I	Diagnostic	Late 1990s	South-east	Under 10	-
J	Diagnostic	Early 1990s	South-east	10 to 50	-
K	Agricultural Diagnostic	Early 2000s	Scotland	Under 10	-

For the firm and product cases studies I primarily used secondary data derived from a number of databases. The data on Celltech's alliance network between 2000 and

2004 was derived from the *Bioworld* database.[5] In the case of Mylotarg I used the *Biopharma* product database (Rader 2003),[6] company websites (e.g. Celltech, now UCB Pharma) and other organizational websites (e.g. PhRMA) as well as one survey response.

Global Commodity Chains in the UK Biotechnology Industry: Product Survey

The survey is primarily meant to illustrate the limitations of the cluster approach by showing that biotech commodity chains and consequently biotech innovation processes are not necessarily restricted to particular places. Although the sample size of the survey is small, it still provides a useful indication of organizational collaboration and interaction that contrasts with cluster theory. Each commodity chain stage (e.g. *basic science funding*, *research and development*, *marketing* etc) is stylized as independent and isolated from the other stages, which enabled respondents to choose the type and location of organizations involved. Respondents were also asked to indicate when the stage was considered to be internal. The geographical location of the stages is split between three scales in the tables below: the 'local' (light grey), the 'national' (grey), and finally 'international' (dark grey).[7]

The early stages of the commodity chain, starting with *basic science funder* and ending with *research & development*, show that the majority of activity occurs internally and nationally. *Basic science research* and *research & development* covers external organizations located at all geographic scales including international, although it is predominantly internal. In contrast *basic science funder* and *initial investor* organizations

[5] BioWorld is a regular news service covering the biotechnology industry; see http://www.bioworld.com/

[6] http://www.biopharma.com/

[7] Local is here defined as within 50 miles of the respondent.

are mainly external and located at the national scale, indicating the importance of public science funding and venture capital (VC). The results suggest that national public funding of the biosciences is a key driver of GCC as is national VC. The split between local and international external *basic science* also partially corroborates the importance of extra-local linkages highlighted in the cluster literature (e.g. Bathelt *et al* 2004; Coenen *et al* 2004; Zeller 2004). However, it also shows that there is relatively little cross-over (i.e. local *and* global) between territorial sources of knowledge (only one incidence) at this stage of the chain. Furthermore, the difference between *basic science* and *R&D* illustrates the importance of cross-scale collaboration and interaction in the innovation process.

Table 4: Initial Stages of Commodity Chain

	BASIC SCIENCE FUNDER	BASIC SCIENCE RESEARCH	INITIAL INVESTOR	RESEARCH & DEVELOPMENT
A: Therapeutic	Head office	Head office	**Internal**	**Internal**
B: Therapeutic	Pharma	University	Pharma	University Pharma
C: Therapeutic	PRO	PRO	PRO	PRO
D: Therapeutic	-	-	-	**Internal**
E: Therapeutic	UK Govt Dept, HEI grant bodies	University University	VC	**Internal** Pharma
F: Drug Delivery	University VC	**Internal** University	VC	**Internal**
G: Platform Technology	-	-	Business angels VC	**Internal**
H: Platform Technology	VC	**Internal**	VC	**Internal**
I: Diagnostic	Seed funds	**Internal**	Business angels	University, firms
J: Diagnostic	UK Govt Dept	**Internal**	**Internal**	**Internal**
K: Agricultural Diagnostic	HEI grant bodies	University	**Internal** External	**Internal** University

Source: Biotechnology Global Commodity Chains Survey (2005).

Note: VC (venture capital); PRO (public research organization); HEI (higher education institution).

The intermediary stages of the commodity chain, starting with *business services* and ending with *manufacturer*, is largely dominated by international scale interaction, although there are internal and national links as well. *Business services* and, especially, *supplier* organizations are international (where relevant) illustrating the importance of international knowledge inputs, whereas *late investor* organizations are national and

manufacturing is mixed. There is both national and international *manufacturing* interaction, as well as some limited internal and international *late investment*. The predominance of international based services (i.e. *suppliers* and *business services*) indicates that commodity chains are tied into specific types of international knowledge (i.e. non-scientific), possibly because local actors cannot provide such input because of knowledge specificity (e.g. global market conditions). The importance of national *later investment* suggests that national VC plays a continuing role 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 externalizes their production needs.

Table 5: Intermediate Stages of Commodity Chain

	BUSINESS SERVICES	SUPPLIER	LATE INVESTOR	MANUFACTURER
A: Therapeutic	-	-	-	**Internal**
B: Therapeutic	Pharma	Pharma Pharma	**Internal**	Pharma
C: Therapeutic	-	-	**Internal**	Joint venture
D: Therapeutic	-	External	-	**Internal**
E: Therapeutic	Small and large firms	Many firms	Public market	Contract manufacturers
F: Drug Delivery	-	External	VC, public market VC, public market	External
G: Platform Technology	-	-	VC	-
H: Platform Technology	**Internal**	External	VC	**Internal**
I: Diagnostic	External	External	-	-
J: Diagnostic	**Internal**	External	VC	**Internal** External
K: Agricultural Diagnostic	-	University	-	**Internal** External

Source: Biotechnology Global Commodity Chains Survey (2005)

Note: VC (venture capital).

The final stages of the commodity chain, starting with *regulator* and ending with *customer*, are dominated by international scale interaction. *Regulation* and *customer* are predominantly international, although in the latter case there is also a significant national base. *Marketing* is also international, although there is a significant internal element as well. These findings confirm research on the importance of both institutional context (e.g. Casper and Kettler 2001) and international demand (e.g. Simmie 2004). In particular,

there is a pronounced international (and national) dimension to regulation and sales that precludes significant localized interaction in biotech concentrations.

Table 6: Final Stages of Commodity Chain

	REGULATOR	MARKETER	CUSTOMER
A: Therapeutic	MHRA	-	Surgeons
	EMEA		Surgeons
B: Therapeutic	EMEA, FDA	Pharma	Public
C: Therapeutic	SDA	Joint venture	Private hospitals
D: Therapeutic	External	Internal	External
E: Therapeutic	FDA and European	Pharma plc	Physicians
F: Drug Delivery	FDA	-	-
G: Platform Technology	-	-	University, Biotech, Pharma
H: Platform Technology	**Internal**	**Internal**	External
I: Diagnostic	-	-	-
J: Diagnostic	**Internal**	**Internal**	Drug clinic, Police, Work
K: Agricultural Diagnostic	**Internal**	**Internal**	Universities, Vets, Feed Companies, Labs, etc
		External	

Source: Biotechnology Global Commodity Chains Survey (2005).

Note: EMEA (European Medicines Agency); FDA (Food and Drug Administration); HEI (higher education institution); MHRA (Medicines and Healthcare products Regulatory Agency).

The results of the survey show that the use of technology as the unit of analysis and the application of a GCC approach to the UK biotech industry does not support the emphasis on localized interaction and collaboration in the cluster literature. Obviously the

survey does not reveal the strength or extent of these ties, but instead suggests the usefulness of the GCC approach. It is also evident that there are major differences in the biotech sector by the types of products handled. Therapeutic products, for example, have more international interactions compared with diagnostic and platform technology products, suggesting that their innovation processes are more dependent upon multi-scale ties, not just in R&D, but also in marketing, regulation and eventual consumption. The overwhelming focus of the UK biotech industry on therapeutic products makes the further exploration of its innovation processes particularly relevant. In the following section I use case studies of a U.K. biotech firm and a biopharmaceutical product it was involved in developing to illustrate the *alliance-driven* model of innovation.

Spatialising Global Commodity Chains in the UK Biotechnology Industry: Celltech Group plc Case Study

This case study illustrates how GCCs can be spatialized by incorporating elements of the GPN framework. In particular, the mapping of a firm's alliance network (i.e. its collaborations and interactions) is designed to reveal the extent of its multi-scale orientation. The case study firm – Celltech plc – was the first UK biotech firm founded in 1980 as the result of recommendations in the *Spinks Report* (ACARD *et al* 1980). It was initially funded half by the state through the National Enterprise Board (NEB) and half by private investors (Fairtlough 1989). It had exclusive rights to commercialize new genetic research funded by the Medical Research Council (MRC) as a response to the perceived failure of the MRC to protect the monoclonal antibody (MAb) research of Milstein and Köhler at Cambridge University (Sharp 1985; Fairtlough 1989; Bud 1993).

Celltech's early strategic focus was the technology transfer of UK public science, especially the monoclonal antibody research undertaken at the Laboratory of Molecular Biology (LMB) in Cambridge, and consequently it collaborated closely with the national public science base.[8] However, since over a third of its academic collaborations in the first 10 years were with overseas universities, such university-firm interaction was not limited to the local or national scale (Dodgson 1993a). There were a number of subsequent shifts in strategy.

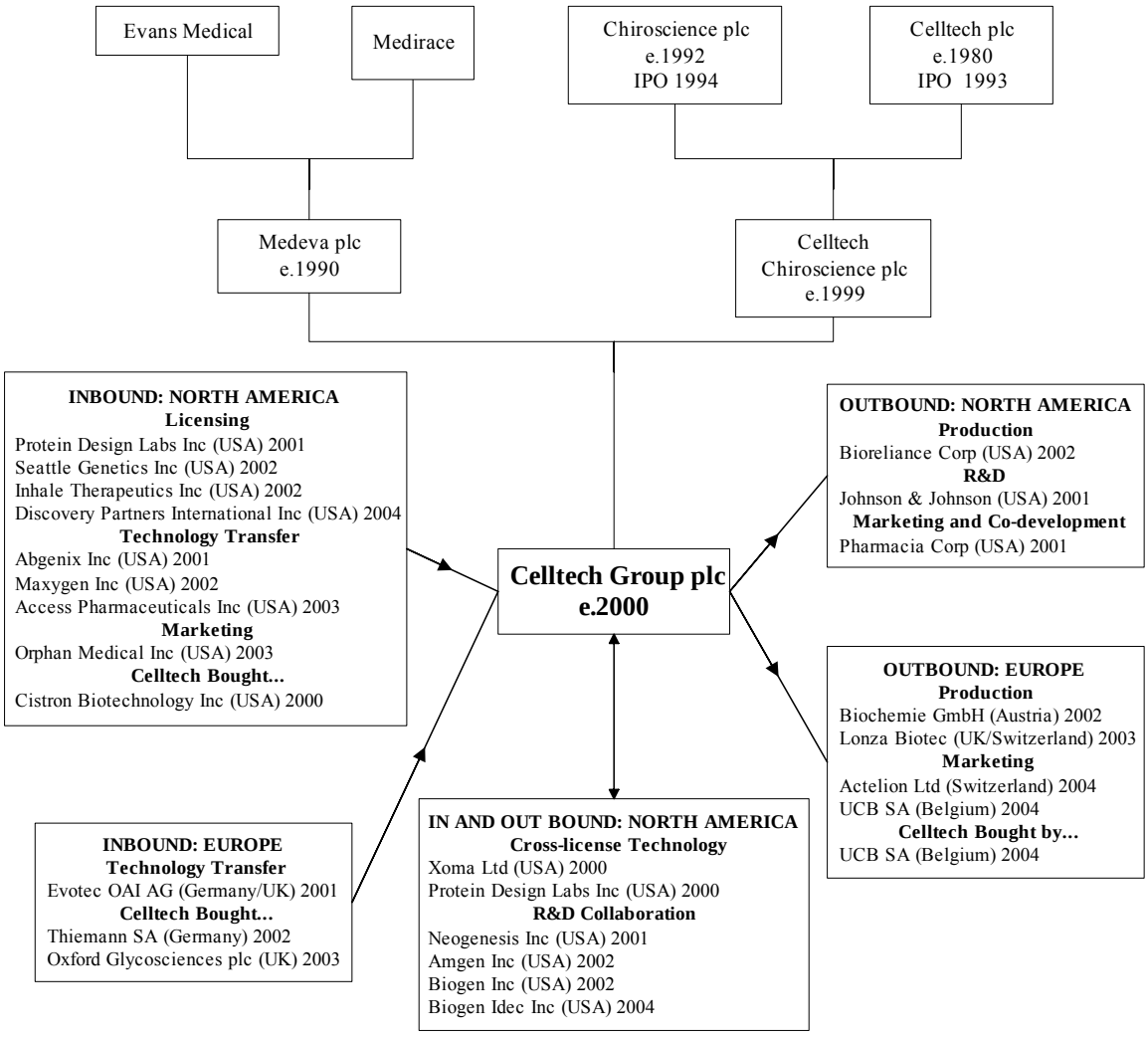
First, in 1983 Celltech started to contract in work and establish joint ventures with established pharmaceutical firms (e.g. Boots Company) in order to fund internal R&D efforts (Dodgson 1993b; Owen 2004). Furthermore, the loss of the MRC monopoly rights in 1983 meant that Celltech no longer needed to "assess every discovery offered to it" which could be "a time-consuming and often wasted effort" (Dodgson 1993a: 87).[9] During the period from 1985 to 1990 Celltech was dominated by the 'biologics' manufacturing division and a focus on the R&D and manufacture of MAbs (McNamara and Baden-Fuller 1999). This led to the collaboration with Lederle (a division of American Cyanamid), which is discussed below, when Celltech sought to match its capabilities with those of firms working on cancer treatments (Dodgson 1993b). Thus Celltech's unique manufacturing capability – for a new biotech firm – provided it with a capability that attracted national and international ties (Faulkner 1992). Second, in 1990 a new management team shifted strategy once again focusing more on therapeutic R&D, which led to the subsequent sale of the biologics division to the Swiss company Lonza in

[8] Celltech was initially going to be established near Cambridge and the academic research base there (e.g. LMB), but lack of property availability meant that it was set up in Slough instead (Cooke 2001).
[9] Shareholders had also criticized Celltech for "spreading their efforts too thinly" during its first few years (Owen 2004: 29).

1996 (McNamara and Baden-Fuller 1999). Furthermore, Celltech strengthened its position as an R&D focused firm through the merger with other biotech firms (e.g. Chiroscience in 1999) and as a fully integrated company with the acquisition of pharmaceutical marketing capabilities (e.g. Medeva in 2000).

The transformation of Celltech from a firm primarily concerned with the transfer of technology from UK public science into a global company is most obvious when mapping the formal alliance and collaboration structure for the years 2000 to 2004. Using secondary data from the *Bioworld* database it is possible to illustrate the direction of knowledge and technology interaction between Celltech and other organizations (see Figure 1). Thus it is possible to show that Celltech did not depend on local, regional or even national interaction and collaboration during this period; at least in regards to formal arrangements. Even for the period between 1997 and 2004, almost all (93%) the alliances of Celltech, Chiroscience and Medeva were international and they were especially tied into the USA (81%). While the data is limited and the level of informal interaction unreported, they still show the international orientation of Celltech's interactions. In particular, Celltech drew upon science and technology from the USA through licensing, cross-licensing, technology transfer and R&D collaborations with biotech firms, and in turn the production and marketing capabilities of European and US large pharmaceutical and biotech firms.

Figure 1: Company Alliance Chain: Celltech Group plc 2000-2004



Source: Bioworld database (http://www.bioworld.com/)

Throughout Celltech's 25-year existence, it is possible to identify a clear national and international orientation that was driven by the emphasis on monoclonal antibody (MAb) technologies. The initial technology transfer of national public science was followed by the search for joint ventures and contract work, which cut across national borders and helped to fund internal R&D efforts. Consequently, Celltech's unique position with its biologics manufacturing capability enabled it to pursue a therapeutic

strategy built on the international linkages it had developed. Without the shift from national-scale technology transfer to international contract work and manufacturing, Celltech would not have been able to develop its MAb capability nor participate in the development of Mylotarg. By engaging in contract work and subsequent collaboration with Lederle, Celltech was able to develop its in-house capabilities and build up a patent portfolio that provided long-term benefits (Dodgson 1993b). Without these alliances, Celltech's subsequent embedding in an international alliance structure would have been significantly curtailed.

Alliance-driven Global Commodity Chain Case Study: Mylotarg ®

The second case study of the biotech product Mylotarg represents a useful example of an alliance-driven global commodity chain (ADGCC). Whereas the Celltech case study showed the need for a spatial dimension in commodity chain analyses, the Mylotarg case study shows how biotech innovation processes are embedded within organizational linkages and complementary capabilities. Mylotarg is the conjugation of a recombinant humanized 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.[10] It was the first such antibody-immunotoxin (i.e. antibody-targeted chemotherapy) to be approved by the Food and Drug Administration (FDA).[11] The product consists of three main elements:

[10] http://www.rxlist.com/cgi/generic2/gemtuzumab.htm (accessed November 2005)

[11] http://www.phrma.org/publications/policy/admin/30.08.2005.1217.cfm (accessed November 2005)

- 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;
- Humanization 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.

Mylotarg's commodity chain incorporates a number of different scientific and technological developments over a 20 year period, from the identification of the anti-cancer agent through to its approval by the FDA in 2000 (see Table 4). All the components were crucial to its development: (a) the discovery of calicheamicin as an anti-cancer agent; (b) the need to develop a delivery system because the agent was such a powerful toxic; and (c) the combination of the agent with a CD33 antigen-binding antibody which needed to be humanized as a monoclonal antibody because it was derived from a rodent.

Table 7: Alliance-drive Global Commodity Chain - Mylotarg

	LOCATION and ORGANISATION
Basic Research	1. New York, Lederle (calicheamicin), 2. Washington state, Fred Hutchinson Cancer Research Center (murine antigen)
Development	1. Berkshire (UK), Celltech (humanization technology) 2. California, Protein Design Labs (humanization technology) 3. New York, Lederle and Berkshire, Celltech (humanized monoclonal antibody)
Trials (Phase I & II)	USA and Europe
Approval	Maryland, FDA
Manufacture	1. New York, Lederle (now Wyeth) 2. Berkshire, Celltech (licensed technology) 3. Berkshire, Lonza – spin-out from Celltech (licensed technology)
Packaging	Puerto Rico, Wyeth

Source: Rader 2003; PhRMA website (http://www.phrma.org/publications/policy/admin/30.08.2005.1217.cfm); Rxlist website (http://www.rxlist.com/cgi/generic2/gemtuzumab.htm); survey respondent.

The expansion of Celltech's biologics manufacturing capability provided it with a crucial advantage that led to the initial 3-year contract research on Mylotarg starting in 1986. Even though Celltech's position was threatened by a major management shake-up

in 1990 (Dodgson 1993a), it was still able to reposition itself as a joint partner in the project because of the crucial role played by its science and technology (i.e. MAbs). The shift in power in 1990 can be seen as a consequence of Celltech's build-up of internal capabilities and capture of valuable knowledge through strong IP (Dodgson 1993b; see Arora and Merges 2004). Furthermore, the combination of the chemistry capabilities of Lederle (now Wyeth) with the biotech capabilities of Celltech (now UCB) ensured that both organizations were reliant upon multi-scalar linkages that connected different sites of innovation (e.g. regional, national, international) with one another to ensure successful development of a product. Thus because each organization involved in the commodity chain brought different (yet complementary) capabilities to the innovation process, it would have been difficult to integrate them in one organization, necessitating the establishment and pursuit of such multi-scale collaborative ties.

Conclusion

The aims of this paper were to show that an alternative approach to cluster theory may be useful in understanding innovation processes in the biotech industry, at least in relation to the UK and possibly other small countries. The adoption of a global commodity chains (GCC) approach, tempered by the spatial dimensions of the global production networks (GPN) perspective, proved a useful conceptual tool to do just that. In particular it provided the means to adopt technology as a unit of analysis in order to avoid either a firm-centric or region-centric view.

The product survey showed that biotech commodity chains involve an array of different organizations, not all of which were local as suggested by the cluster emphasis

on locally-bounded value chains. Furthermore, it showed that for therapeutic products national and international links were central to successful technological development. No single commodity chain relied solely upon interaction with local organizations and consequently biotech innovation processes depend on capabilities embedded across multiple scales; e.g. local-based R&D, national-based basic science funding, international-based marketing and customers. This analysis therefore provides an example of the sort of research agenda that can be pursued by applying GCC and GPN approaches to the biotech industry.

The importance of multi-scale interaction and collaboration was reinforced in the case study of Celltech, especially in the mapping of formal alliances between 2000 and 2004. Celltech is positioned within a series of alliances that connect to US-based biotech firms, especially as sources of knowledge, and to large pharmaceutical firms who provided the financial resources necessary for manufacturing and/or marketing of Celltech products.[12] Celltech's alliance network shows how it drew upon international knowledge and also served as the knowledge source for other international firms. While this analysis did not include more informal connections that Celltech may have had with local firms, in this particular case the limited number of such firms in its close vicinity (i.e. Berkshire) precluded the possibility of a dense local network.

Finally, the case study of Mylotarg also provided evidence of the importance of multi-scale ties in biotech innovation processes. The collaboration between Celltech and

[12] Celltech was purchased by the Belgium firm UCB in 2004. This acquisition was a consequence of Celltech's need to support its development of the drug CDP870 for arthritis and Crohn's Disease. Celltech needed a partner after Pfizer purchased Celltech's previous collaborator, Pharmacia, in 2002 and pulled out of development after an unsuccessful renegotiation of the collaboration (Timmons 2004). Perhaps problematically, the acquisition of Celltech by UCB illustrates the continuing dependence of biotech firms on large pharmaceutical companies for the development of new products (see Pisano 2006).

Lederle (now Wyeth) in Mylotarg's development indicates the importance of international interaction, although not necessarily in terms that correspond to a 'global' innovation process as opposed to transnational one (see Whitley 1996). However, it did illustrate the spatial and historical specificity of organizations such as Celltech, which was embedded in UK institutions (e.g. universities, government) that provided it with a set of capabilities that were essential to Mylotarg's development. A multi-scale ADGCC is therefore a useful tool to analyze how innovation processes operate across and within countries.

So what are the policy implications of this GCC approach? At present the UK government has been a strong proponent and promoter of cluster policies in regional development (e.g. DTI 1998; HM Treasury 2001), introducing several policy initiatives designed explicitly to encourage clusters; e.g. the 2000 Innovative Clusters Fund and the 2001 Regional Innovation Fund (DTI 2003: 102-3). If the biotech industry is intended to produce high value-added products for export and high-skilled employment, its current record is at best mixed. In some cases, the emphasis on clusters may prove detrimental to these efforts on several fronts.

First, the emphasis on biotech clusters in UK policy focuses public expenditure on encouraging local interaction and infrastructure oriented to facilitating such relationships. This can be seen as a consequence of the fear of losing national competitiveness to other countries, a priority that has pervaded UK biotech policy literature since the *Spinks Report* (e.g. ACARD *et al* 1980; BIGT 2003). Instead, it may be more useful to encourage the development of extra-regional collaboration through the improvement of national and global networking capacity; especially linking biotech firms with large,

downstream biomedical companies (see Gray and Parker 1998). Localized learning does not provide enough certainty to side-line the importance of these multi-scale linkages.

Second, because it is important to consider multi-scalar collaboration, it would also be necessary to avoid the concentration of funding in specific regions of the UK (e.g. Cambridgeshire) and possible problems with continuing uneven development (Massey 1995) and technological lock-in (Hassink 2005). Furthermore, different locations provide different advantages to biotech innovation processes because of their different institutional structures. Consequently the emphasis on certain locations may stultify biotechnology in other places.

Finally, the role of power in commodity chains is crucial, especially alliance-driven ones. However, as the Mylotarg case showed, small biotech firms can reposition themselves within their established commodity chains because of their specific capabilities as long as these are adequately protected by IP rights (see Arora and Merges 2004). However, there is a fine line between adequate protection and the stifling effects of over-protection (see Orsi and Coriat 2005), necessitating a careful balance between the desire to stimulate innovation and encouraging new scientific research.

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