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Clusters as Key Determinants of Economic Growth:

The Example of Biotechnology

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Introduction

Clusters have become a key mode of economic co-ordination and focus of government policies across the world and for a wide variety of industries. In the UK, somewhat later than elsewhere in Europe, the USA and Japan, there has been government enthusiasm for encouraging cluster development, aimed particularly, though not exclusively, at high technology industry. The Competitiveness White Paper *Our Competitive Future: Building the Knowledge Driven Economy,* (1998) is clear on its commitment to supporting clusters and its view that they are beneficial to business. This commitment has already been followed up by an in-depth international research study and report on *Biotechnology Clusters* (DTI 19 1999) led by Minister of Science Lord Sainsbury. It is expected to be the first in a number of such government studies, including a *Cluster Mapping* exercise. Thus it is clear that cluster-thinking is on the move, with DTI playing a key role in promoting knowledge-development, interaction with business and policy-thinking in pursuit of the government's vision of a co-operative as well as competitive way of enhancing the UK's economic performance.

In what follows, illustrated answers will be provided to four key questions concerning clusters and clustering activities:

1) What are clusters?
2) Why are clusters important for business competitiveness?
3) How do clusters work?
4) Can clusters be built?

Reference will be made to a variety of industry examples, but as far as possible indications will be given of their role in the ICT industry.

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What are Clusters?

The Information Age Partnership definition of a cluster as a "geographical concentration of interdependent companies and institutions connected by a system of market and non-market links" is a useful starting point as it captures key elements of competitive and collaborative interaction that characterises firm relationships. It also recognises the importance of proximity to those relationships and that important relationships are not limited to those between firms only. It is thus close to Michael Porter's (1998) definition which is that: "A cluster is a geographically proximate group of interconnected companies and associated institutions *in a particular field*, linked by commonalities and complementarities". (Porter 1998, emphasis added) This in turn, underpinned the definition in DTI (1999) for the work on biotechnology clusters, as: "geographic concentrations of interconnected companies, specialised suppliers, service providers, firms in related industries and associated institutions (for example universities, standards agencies and trade associations) in particular fields that compete but also co-operate".

There is nothing wrong with these definitions except that they are all *static*, whereas the key feature of clusters is that they are *dynamic*. Hence we prefer the following factors to be included as well:

- A cluster displays a shared identity and future vision.
- It is characterised by "turbulence" as firms spin-off, spin-out and start-up from other firms or institutions.
- A cluster is an arena of dense and changing vertical input-output linkages, supply chains and horizontal inter-firm networks.
- It is likely to have developed localised, third-party representative governance associations that provide common services but also lobby government for change.
- A cluster may have caused governments to develop policies to assist cluster development, especially where market-failures are present.
- Over time, clusters can reveal features of emergence, dominance and decline.
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So we come to a preferred definition of a cluster as "geographically proximate firms in vertical and horizontal relationships, involving a localised enterprise support infrastructure with a shared developmental vision for business growth, based on competition and co-operation in a specific market field".

Why Clusters?

Why are clusters more prominent now than hitherto? Why does the hierarchical firm, so pronounced a feature of the mid-twentieth century corporate landscape, no longer act as the model for economic co-ordination? There are at least three key reasons for this. First, global competition, first from Japan and Southeast Asia, then from the US response to it, caused large corporations to reduce in-house production and administrative overhead while increasing outsourcing and learning, for example, resulting in so-called "lean production", in order to survive. Second, innovation became a leading competitive weapon and small, knowledge-based firms, often close to universities, were further up the technological learning curve. Third, the intrinsic rigidities of the hierarchical corporate organization meant rapid learning and accommodation to change could not be easily implemented.

A recent paper at the British Association for the Advancement of Science reported by Cookson (1999) states that:

- Looser groupings of firms in clusters have better, more efficient knowledge transfer than stand-alone hierarchical corporations.
- Clusters (e.g. Silicon Valley) combine higher turnover of scientists and engineers with extraordinary openness about technical information.
- Clusters kill-off unproductive projects through insolvencies while large firms have weak mechanisms for ceasing them.

In brief, Porter (1998) holds that a number of advantages are derived from clusters, among these are the following:

1. Productivity gains arise from access to early use of better quality and lower cost specialised inputs from components or services suppliers in the cluster. Local sourcing can be cheaper because of minimal inventory requirements and transaction costs generally can be lower because of the existence of high trust relations and the importance of reputation-based trading. Common purchasing can lower costs where external sourcing is necessary. Serendipitous information trading is more likely in contexts where formal or informal face-to-face contact is possible. Complementarities between firms can help joint-bidding and scale benefits on contract tenders, or joint marketing of products and services. Access to public goods from research or standards bodies located in proximity can be advantageous.

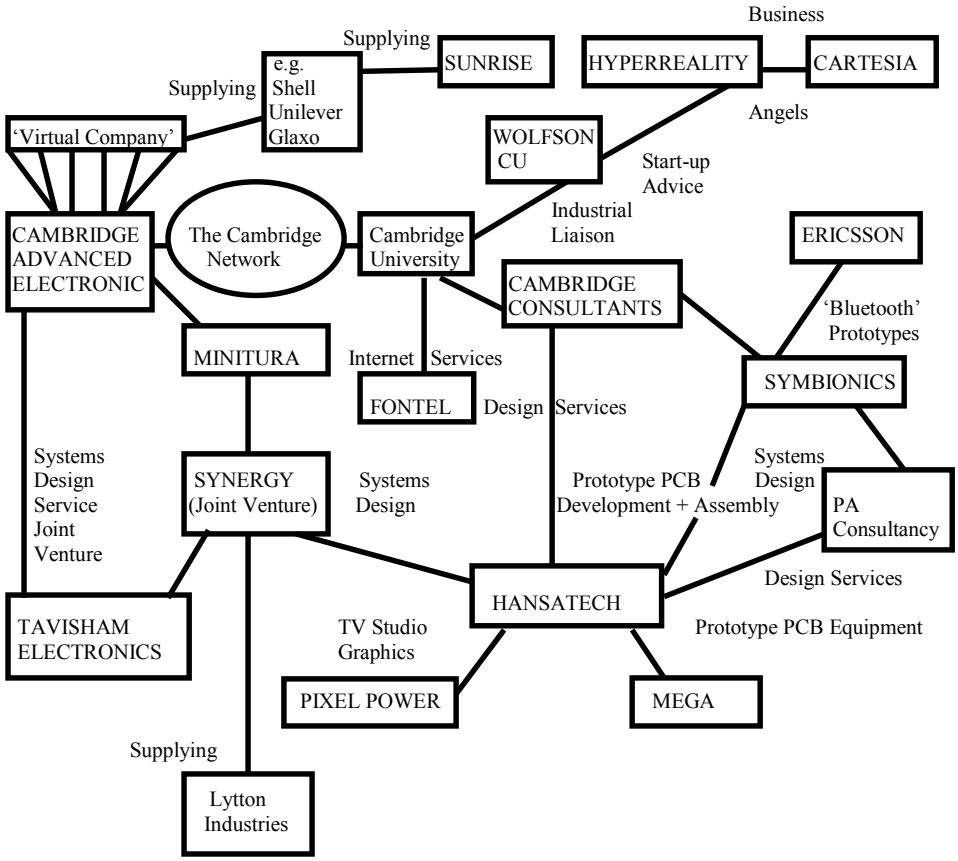
2. *Innovation* gains come from *proximity* between customers and suppliers where the interaction between the two may lead to innovative specifications and responses. User-led innovation impulses are recognised as crucial to the innovation process and their discovery has led to a better understanding of the interactive rather than linear processes of innovation. Proximity to knowledge centres makes the interaction processes concerning design, testing and prototype development physically easier, especially where much of the necessary knowledge is partly or wholly tacit rather than codified. Localised benchmarking among firms on organizational as well as product and process innovation is facilitated in clusters. Qualified personnel are more easily recruited and are of key importance to knowledge-transfer. Informal know-how trading is easier in clusters than through more distant relationships.

3. *New businesses* are more readily formed where better information about innovative potential and market opportunities are locally available. Barriers to entry for new firms can be lower because of a clearer perception of unfulfilled needs, product or service gaps, or anticipated demand. Locally available inputs and skills further reduce barriers to entry. A cluster in itself can be an important initial market. Familiarity with local public, venture capital or business angel funding sources may speed up the investment process and minimise risk premiums for new start-ups and growing businesses. Clusters attract outside firms and foreign direct investors who perceive benefits from being in a specialised, leading-edge business location. These may also be a further source of corporate spin-off businesses.

How Do Clusters Work?

Clusters work through networks between a variety of business and other appropriate actors who are familiar with each other's expertise, trustworthiness, reliability and willingness both to share relevant assets (e.g. information or lending a machine or employee if needed) and engage in normal business relationships based on market exchange. Networks can be formal or informal, soft or hard (i.e. contractual, with an agreed project and business plan). In high technology industry, such linkages are likely to involve research organizations such as universities directly for knowledge, but also indirectly through spin-out firms. Aspects of this can be seen below (Fig. 1).

Figure 1. Aspects of the Cambridge IT Cluster



Can Clusters be Built?

This refers to the role of policy on different levels of government. While DTI (1999) and others correctly cast doubt on the difficulty, if not impossibility, of building clusters from zero this has not stopped governments trying to do so in the past. France and Japan built "technopoles" by attracting research branches to co-locate in special zones such as Sophia Antipolis and Tsukuba City. However, most commentators agree these are not clusters. Similarly, in North Carolina, Research Triangle Park has successfully attracted research laboratories but only recently have there been signs of some interaction with localised suppliers. Synergy effects are hard to create.

However, where there is something with which to work, especially in knowledge-intensive activity, then policy may enhance cluster formation. Some examples of this:

- Finnish regional science and technology policy encouraging universities to set up technology parks on university campuses with Nokia or other research labs acting as customer for software and computing services supplied by start-ups.
- In the US, clusters are often promoted at state level through setting up infrastructure, industry associations, grants, tax credits and R&D credits. But there still has to be a knowledge-generating source in the form of research labs or other key firms.
- In Germany, there are numerous federal and state-level initiatives, most notably BioRegio which funds at £50 million 3 biotechnology clusters. Start-ups, closely linked to research labs, local (often publicly-funded) venture capital and cluster management organizations, have grown from 170 to 223 during the two years since BioRegio was implemented in 1997.

The Clustering Phenomenon in Biotechnology

We have seen that biotechnology is dependent on small firms who are in turn dependent on public research budgets and venture capital or royalties and milestone payments from big pharma. But another feature of the industry is that the smaller firms tend to exist in geographically proximate clusters near to the knowledge source, i.e. universities and research laboratories specialising in biosciences and biotechnologies. In the final section of this chapter, three instances of this phenomenon will be briefly explored to demonstrate the importance, in the biotechnology sector, of local factors in global competitiveness.

Cambridge, Massachusetts

One of the biggest and most dynamic biotechnology clusters is in Boston, USA. The science base is exceptionally strong with the Massachusetts Institute of Technology (MIT), Harvard University, Boston University and Massachusetts General Hospital all nearby. Each year some USD 770 million in basic research funding flows through the system. Leading scientists and academic entrepreneurs, one of whom has been involved in some 350 patent applications, are found here. At MIT, in particular, the Technology Licensing Office is a major operation, also involved in assisting at least 20 start-ups per year be established. Massachusetts has at least 150 venture capitalists, most of them in

Boston or Cambridge. There are 132 biotechnology firms in the Greater Boston area (59 in Cambridge), 86 outside, employing 17,000 people in total. Finally, there are numerous intermediary bodies supporting the industry at state level, one of which, the Massachusetts Biotechnology Council, is an industry association which organizes common purchasing and other services such as promotion, educational placement and careers development for its 215 member firms.

Because of proximity and often common backgrounds from educational institutions, the level of inter-firm and firm-agency interaction is high. In these respects this industry constitutes an exemplary case of a cluster, though as with high technology clusters in general, global linkages to other clusters and, particularly "big pharma" partners or customers are also pronounced. The connection to other centres of biotechnology is testified by the presence in the Mass. Biotech. Council of promotional material from other clusters, including that of the Eastern Region Biotechnology Initiative (ERBI) based in Cambridge (UK).

If we look at the biotechnology sector springing mainly from MIT and Harvard in Cambridge, supported by Massachusetts General Hospital and, to a lesser extent, Boston University in Boston, we have to talk of biotechnology nowadays in the Greater Boston area, since many start-ups have moved out to Route 128 and even beyond Route 495 to Worcester as the encompassing area. The geographical breakdown, bearing in mind the 59 firms in Cambridge is as follows: 132 firms are located east of Route 128 (59 in Cambridge, 16 in Boston, the remainder between there and Route 128), 58 are located between Route 128 and Route 495 (including 11 in Bedford and 6 in Wilmington) and 25 are located west of Route 495 (including 11 in Worcester). Many of these, especially in the outer locations, are based on science or technology parks, as are many start-ups on the technology park campuses of the key universities.

The market segment breakdown is that 34% of firms are in the therapeutic products sector (meaning they have grown beyond the early stages, typically in platform technologies, including diagnostics), 20% are in scientific equipment or supplies; 15% are in scientific services; 14% in human diagnostics; 10% are in environmental and veterinary and 7% are in agricultural biotechnology (animal, plant, diagnostic and transgenics). Perceived industry growth areas are: in medical therapeutics (genetically produced protein, vaccines, gene therapy, human growth hormones); human diagnostics (monoclonal antibodies, biological imaging, DNA probes, biosensors and polymerase chain reaction); ag-bio (nutraceuticals, rapid diagnostic testing and transgenics) and BioInformatics (biological discovery, patient databases, etc.) Seventy-nine firms were founded in the 1980s including (>300 employees) Biogen, Genetics Institute and Genzyme. A further eighty-eight began between

1990 and 1997, the remainder are more recent start-ups or inward investments. Employment grew from 7,682 in 1991 to 16,872 in 1998. As the industry matures, the number of start-ups is decreasing annually. Between 1996 and 1999 seven mergers and acquisitions occurred. Financing of companies in biotechnology is high-risk and analyses show that public investment is strongest at the risky process or product development stage.

Of considerable significance as agents in the regional innovation system, within the *knowledge generation* and *diffusion* sphere, are the following:

- Massachusetts Department of Economic Development: has a key role in business and trade development, improving the business climate (R and D tax credits, investment tax credits), responding to lobbying from industry associations, providing grants to growth firms and inward investors.

- Massachusetts Institute of Technology: leading centre for biotechnology research and commercialisation; campus incubators and technology park; MIT Entrepreneurship Centre trains scientists in entrepreneurship; MIT Technology Licensing Office, identifies technologies suitable for start-ups, introduces technology to potential investors (usually venture capitalists).

- Harvard University: PhD programmes in Biochemistry, Biology, Biophysics, Cell and Development Biology, Genetics, Microbiology and Molecular Genetics, Technology etc; Joint Harvard - MIT Division of Health and Technology; School of Medicine; School of Public Health.

- Massachusetts General Hospital and Boston University: research and commercialisation at Boston University, Bio Square Technology Park.

- Whitehead Institute of Biomedical. Research: an independent research and teaching institution (affiliated to MIT in teaching). World leading research in genetics and molecular biology. International leader in the Human Genome project, source of comprehensive, published genome data; technology licensing programme and start-up scheme.

- Massachusetts Technology Collaborative: state-founded**,** independent body to foster technology-intensive enterprises. Cluster-building strategies.

- Massachusetts Biotechnology Council: trade association representing biotechnology firms (162 full and 83 associate members), provides educational, careers, and promotional information to the industry and conducts common-purchasing contracting for biotechnology firm members.

In conclusion, leading exploitation firms such as Genzyme, patenter and inventor of the therapeutic product which controls the genetically caused Gaucher's disease, are closely intertwined with this generation and diffusion system. Moreover, Genzyme as a founder member of the Partners Healthcare System with Brigham and Women's, and Massachusetts General hospitals on research funded at $400 million by the National Institutes of Health, reinforce the system. Along with Biogen and Genetics Institute, plus other internationally known firms such as BASF, Corning and Quintiles and a host of SMEs and start-ups, this means the Greater Boston region is supported by the generation and diffusion organisations and associations already noted, and clearly functions as a well-integrated regional innovation system based on a cluster of leading-edge biotechnology businesses.

The Cambridge (UK) Economy and Biotechnology

As in Boston, the economy around biotechnology is important, but by no means overwhelmingly so by comparison with other economic sectors in Cambridgeshire. Thus Cambridgeshire County Council estimate that in 1998 there were some 37,000 high technology jobs in the area and that these comprised 11% of the Cambridgeshire labour market. South Cambridgeshire had about 66% of these jobs while Cambridge city accounted for most of the remainder. The main high-tech activity is R and D, supplying 24% of total high-tech employment, of which electronics comprises 17%, computer services 13%, scientific instrumentation 8%, and biotechnology, fifth in line, 7%. Probably, the estimate of some 2,600 employees in biotechnology (and chemicals) for the county is a not unreasonable figure. However, if we inspect the ERBI Biotechnology Sourcebook (1998) the number of core biotechnology firms in Cambridgeshire listed there is 36. So the discrepancy between that figure and the estimate of 200 biotechnology firms by Segal, Quince Wicksteed in 1998 needs some qualification. The first qualification can be offered with some confidence and that is that in ERBI's list of Cambridgeshire biotechnology firms there are venture capitalists, research institutes, management consultants

and lawyers. Together these total 96, so in the cluster support firms and agencies exist in an approximate 2:1 ratio with biotechnology firms. ERBI considers this a significant underestimate and in its new survey (1999) estimates numbers, in general, of about one-third higher. This would take the Cambridgeshire figure to around 50 core biotechnology firms. The second reason for the discrepancy is that the probably significant number of very small start-ups in incubators and the like are under-represented in the ERBI figures published thus far. So, we may conclude that Cambridgeshire's core biotechnology industry consists of no less than fifty firms and the broader cluster (venture capitalists, patent lawyers, etc.) probably consists of not much more than 200 firms, including the core biotechnology firms.

Cambridge has a presence in two of the main fields of biotechnology. The first is primarily medical and biopharmaceutical, the second is agro-food biotechnology and the third, environmental. It is clear from both ERBI data and the SQW (1998) estimates that Cambridgeshire specialises in biopharmaceuticals. The two categories of "biopharmaceuticals including vaccines" and "pharmaceuticals largely from chemical synthesis" register fourteen and nine Cambridgeshire-based firms respectively. Examples of the former are Actinova, Amgen and Hexagen, and of the latter, Chiroscience, Napp and Quadrant. In addition to these two key categories are direct biotechnology services like clinical trails, diagnostics and reagent supply. A further eight Cambridgeshire direct-services firms are listed in the ERBI Sourcebook, which, it will be recalled, probably underestimates the numbers by about one-third (not counting micro-firms). Cambridgeshire has four "ag-food bio" firms but ERBI lists no bioenvironmental firms. It is important to note that Cambridgeshire also hosts twelve biotechnology equipment and instrumentation firms according to ERBI.

The growth in the number of biopharmaceutical firms has been from one to twenty-three over the 1984-1997 period, an average of just under two per year, but the rate has been more like four per year in the last two years of that period. Equipment firms grew from four to twelve 1984-97, and diagnostics firms from two to eight. In Table 1 Section 1a shows the distribution of technology-based companies in Cambridgeshire, while 1b shows the distribution of support services.

Table 1. Shares of biotechnology and services functions

1a Biotechnology Firm Distribution		1b Biotechnology Services Distribution	
Biopharmaceuticals	41%	Sales & Marketing	29%
Instrumentation	20%	Management Consulting	23%
Ag-food Bio	17%	Corporate Accounting	15%
Diagnostics	11%	Venture Capital	15%
Reagents/Chemicals	7%	Legal & Patents	8%
Energy	4%	Business Incubation	10%

Source: ERBI (1998)

Thus, it is clear that Cambridgeshire has a rather diverse biotechnology processing and development industry as well as services support structure, even though the industry is relatively young and small. Some of the service infrastructure, and perhaps the equipment sector, benefits from the earlier development of Information Technology businesses, many also spinning out from university research in Cambridge.

The infrastructure support for biotechnology in and around Cambridge is impressive, much of it deriving from the university and hospital research facilities. The Laboratory of Molecular Biology at Addenbrookes Hospital, funded by the Medical Research Council; Cambridge University's Institute of Biotechnology, Department of Genetics and Centre for Protein Engineering; the Babraham Institute and Sanger Institute with their emphasis on functional genomics research, and the Babraham and St. John's incubators for biotechnology start-ups and commercialisation, are all globally recognised facilities, particularly in biopharmaceuticals. However, important research institutes in agricultural and food biotechnology, such as the Institute for Food Research, John Innes Centre, Institute of Arable Crop Research and National Institute of Arable Botany, are also located in the Eastern region. Thus in research and commercialisation terms, Cambridge is well placed in biopharmaceuticals; and with respect to basic and applied research, but perhaps less so in commercialisation, i.e. in the ag-food industry.

Within a 25-mile radius of Cambridgeshire are found many of the "big pharma" or specialist biopharmaceutical firms with which commercialisation development by smaller start-ups and R&D by research institutes must be co-financed. Firms like Glaxo Wellcome, SmithKline Beecham, Merck, Rhone-Poulenc Rorer, Hoechst Pharmaceuticals in the big pharma category are represented, and in the specialist biopharmaceutical sector: Amgen, Napp, Genzyme and Bioglan *inter alia*. Thus, on another of the criteria for successful cluster development, namely access within reasonable proximity to large

customer and funding partner firms, Cambridge is, again, fortuitously positioned.

Finally, with respect to ag-food bio, Rhone-Poulenc, Agrevo, Dupont, Unilever and Ciba are situated in reasonably close proximity to Cambridge. Hence the prospects for linkage, though more occluded by public concerns about Genetically Modified Organisms than in the case of health-related biotechnology, are nevertheless propitious in locational terms.

Cambridge is relatively well blessed with science and technology parks, though the demand for further space is significant. At least eight of the aforementioned biopharmaceuticals including vaccines firms are located on Cambridge Science Park itself. St. John's Innovation Centre, Babraham Bioincubator, Granta Park, the Bioscience Innovation Centre and Hinxton Science Park are all recently completed, under construction, or under planning review. Most of the newer developments are taking place within short commuting distance of Cambridge itself, on or near main road axes like the M11, A11, A10 and A14. This is evidence of the importance of *access* for research-applications firms to centres of basic research, reinforcing also the point that not everything concerning biotechnology must occur "on the head of a pin", i.e. in Cambridge city itself.

The final, important, feature of the biotechnology landscape in Cambridge and the surrounding Eastern Region is the presence of both informal and formal networking between firms and research or service organizations and amongst firms themselves. Cambridge Network Ltd was set up in March 1998 to formalise linkages between business and the research community, connecting both local and global networks in a systematic way. It is mostly IT-focused, though some of this spills over into biotechnology, given its demand for IT equipment and opportunities for IT delivered patient and clinician services through, for example, telemedicine. Of more direct relevance to the biotechnology community are the activities of ERBI. This biotechnology association is the main regional network with formal responsibilities for; newsletter, organizing network meetings, running an international conference, website, sourcebook and database on the bioscience industry, providing aftercare services for bio-businesses, making intra- and inter-national links (e.g. Oxford, San Diego), organizing common purchasing, business planning seminars, and government and grant-related interactions for firms.

Thus it is relatively easy to see that the Cambridge biotechnology sector operates as a cluster. Indeed, it could be said to be a paradigm case of the clustering phenomenon which, though presently small, has major growth potential. This is because it is Europe's leading biotechnology cluster in a business with expected global turnover of $70 billion in 2000. Because of the sunk costs associated with co-location by venture capitalists, specialist

patenting, legal, accountancy and insurance services, the immobility of the key knowledge-driving resource, the university and the presence of a critical mass of biotechnology firms and entrepreneurs, Cambridgeshire is likely to remain the focus it has become.

Heidelberg, Germany

Heidelberg is Germany's oldest university and has one of the best science bases for biotechnology. Two Max Planck Institutes, for Cell Biology and Medical Research, are located in the region, as is the German (Helmholtz) Cancer Research Centre (DKFZ). The European Molecular Biology Laboratory, and European Molecular Biology Organization are there, along with one of Germany's four Gene Centres, the Resource Centre of the German Human Genome Project, two further medical genetics institutes and two plant genetics centres. Three other universities, Mannheim, Ludwigshafen and Kaiserslautern, and three polytechnics complete the generation and diffusion sub-system. There are a number of Germany's leading big pharma firms nearby, such as BASF/Knoll (Ludwigshafen), Boehringer Mannheim Roche Diagnostics (Mannheim), and Merck (Darmstadt). But the heart of the BioRegio is the Heidelberg-based commercialisation organization, the Biotechnology Centre Heidelberg (BTH). This is a three-tired organization consisting of a commercial business consultancy, a seed capital fund and a non-profit biotechnology liaison and advisory service. Central to BTH's functioning is Heidelberg Innovation GmbH (HI) a commercial consultancy that takes company equity in exchange for drawing up market analyses, business and financing plans, assisting in capital acquisition and providing early phase business support for start-ups. It is a network organization, relaying information, partnering organizations seeking contact with local biotechnology companies and linking to research institutes and local authorities.

The key initial financing element of BTH is BioScience Venture. This was established by local big pharma and banks, managed by HI and acts as a seed fund and lead investor in early start-ups. It also seeks international venture capital to finance second round developments. Assessments of project viability are made with advice from HI and BioRegio Rhine-Neckar e.V., the third element of BTH. The last-named seeks out commercial projects and recommends the most promising for BioRegio public funding support. Business proposals have run at some 50 per year since 1996, but between 1996 and 1998 only nine start-ups had been established, a figure that had risen to seventeen (including biochip and biosoftware firms) by July 1999 (Dr. Thomas Stahlecker, CTA Stuttgart, personal communication, July 1999). The total number of biotechnology SMEs (excluding start-ups) was 20 in July 1998. Most are in the healthcare sector, with some in plant genetics. The main location for

this cluster of some thirtyseven biotechnology firms is the Heidelberg Technology Park for SMEs and the adjoining Biopark on the university's science campus. This has 10,000 square metres of laboratory and office space plus a further 6,000 on the Production Park nearby, where start-ups move to once they have grown beyond the research phase. A joint venture by local firms and universities has been to establish the Postgraduate BioBusiness Programme. This is designed to provide scientists with hands-on experience of business administration through three months' coursework and nine months of practical training in industry (König 1998).

Once more, key ingredients for successful clustering are present, including close proximity for firms on the technology park to both big pharma in Ludwigshafen and Mannheim and leading edge science in Heidelberg. The *Land* of Baden-Württemberg has a biotechnology initiative but also distributes its funding among the Freiburg BioValley (one of Germany's most dynamic BioRegios) Ulm, and Tübingen-Stuttgart as well as Rhine-Neckar region. As we have seen elsewhere BioRegio funding is principally used for start-ups, most of whom are currently making losses. But through the network-like character of BTH, lead investor capital from BioScience Venture can be tripled by leveraging both federal BioRegio funding and *Land*/corporate venturing funds. Thus reasonable sums of start-up capital can very easily be raised at low risk to the, in any case, essentially public lead investor. The *Land* helped fund Heidelberg Technology Park, subsidises a patenting support initiative, providing grants to universities for making patent applications, and funds a Young Innovators pre-start-up funding programme for university and research institute personnel (Clarke 1998).

Conclusions

Clusters are evident around the world in both traditional and high technology industries. They are usually fairly geographically concentrated, dynamically interacting combinations of firms, intermediaries, funding organizations and transfer agencies acting consciously to develop the cluster. They offer advantages over large hierarchical firms because of overspills enabling knowledge to flow reasonably freely and opportunities for co-operation as well as competition. Productivity, innovation and new business formation are enhanced under such circumstances. Clusters work by acting as an economic community based on informal and formal, hard and soft forms of networking between firms and agencies. Consciousness of cluster existence and a formalised, membership-based association able to keep all in touch as needed is often key to successful clustering.

Furthermore, public efforts to create clusters, as distinct from mere agglomerations of similar activity (e.g. research) have not been entirely

successful. Where a seed crystal, such as a key outsourcing firm or research laboratories seeking to commercialise knowledge and IPR exists, public intervention can be important in further activating and enhancing cluster development. But ultimately the market decides how successful a cluster will be.

The combination of small-firm excellence in commercialisation, big pharma excellence in marketing and distribution, as well as non-biotechnological research, and strategic public research budgets, seems to have emphasised the localised clustering mode of economic co-ordination in this most globalized of industries. For the present, with biotechnology products only accounting for 5% of the global drugs market, with an industry expectation of 25% in the medium-to-long term, these relationships are in dynamic tension.

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