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Guilty by Association: A Cross-industrial Approach to Sourcing Complementary Knowledge in the Uppsala Biotechnology Cluster

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ABSTRACT *A wide range of industrial studies recognize the tendency of similar and related economic activities to co-locate in so-called industrial systems or clusters. While a cluster is defined by its cross-industrial relations the supporting and complementary role of cluster actors is seldom fully explored. This study will focus on the dynamics of cluster relations and give an account for the complementary nature of clusters by analysing anchor firms and complementary agents (such as specialized service providers and institutions for collaboration) in the Uppsala biotechnology cluster in Sweden. The empirical data used involves a triangulation of interview, survey and individual-based register data based upon a mapping of cluster actors active in 2002 and 2003. It is shown that both the formerly dominant pharmaceutical company and the local university have actively taken the role as anchor firms/organizations creating a local and dynamic milieu for biotechnology activities. Furthermore, it is shown that the local cluster consists of a variety of complementary agents contributing to knowledge spill-overs and cluster competitiveness.*

1. Introduction

During the last few years the field of economic geography has become more focused upon large urban areas as the locus of innovation and economic growth (cf. Florida, 2002) rendering various systems approach less important. In spite of this recent turn of events advocates of different system approaches, irrespective of terms and concepts like industrial districts (Marshall, 1920/1960; Asheim, 2000), clusters (Porter, 1990; Enright, 1998; Maskell & Malmberg, 1999) and innovation systems (Lundvall, 1992; Cooke et al., 1997), [end p. 1605] are still interested in the positive synergies that result from connectivity between economic and other actors. In essence, a common point of departure of most systems approach is the idea that firms are neither acting like individuals nor isolated agents. Instead, new products and production processes are seen to most often result from interactions and relations between firms and a variety of local actors that possess supplementary or complementary knowledge and competencies. The ability to innovate and create competitiveness is thus not just an outcome of intra-industry relations. Rather, dynamic externalities – such as knowledge spillovers – occur via buyer–supplier relations, collaborations and competition between firms and organizations in different kinds of industries and sectors of the economy (i.e. across industries).

However, most cluster analyses tend to focus on firm-to-firm relations of actors within the core of the cluster and/or relations with public or private research and funding organizations. An effect of this is that the complementary nature of the clusters (e.g. relations with specialized service providers and network organizations) becomes peripheral to the discussion of cluster development. In this respect, the industrial systems approach, and foremost the cluster approach, has theoretically and empirically still a lot to offer.

Biotechnology is in its essence a result of cross-industrial and cross-disciplinary scientific synergies between a wide variety of actors spanning both public and private sectors. Biotechnology has by many scholars, and not least policy makers, been viewed as a major source of scientific innovation in the global economy. Although highly globalized, the biotechnology sector is locally and regionally concentrated in specific industrial and scientific milieus or so-called local clusters. Swedish biotechnology is no exception, being more or less agglomerated in a few local or regional clusters centred upon major university cities. The city of Uppsala in Sweden has during the last decades grown to become a well-known centre of biotechnology competence. Here we find longstanding traditions and histories of academic and industrial excellence in biotechnology-related fields.

While a cluster is constituted by its members, it is also a result of evolutionary processes stimulating the build-up of a local knowledge base. This study attempts to further understand cluster dynamics within a local milieu by focusing on and merging the idea that the local knowledge base is stimulated and created by an anchor firm tradition (carried out by both private firms and public organizations) and that knowledge is furthermore actively and strategically sourced and diffused by cluster relations mediated by complementary agents. A cluster is thus incorporating activities that possess complementary knowledge, know-how, goods or services joined by a common set of knowledge bases (most often related to a technological platform). In the biotechnology cluster, activities are supported by the following: (a) public agents (i.e. universities, healthcare institutions or other research-oriented governmental agencies); (b) investors such as venture capital firms, angel investors or other financing institutions; (c)

complementary agents (i.e. specialized service providers such as research consultants, clinical (or contract) research organizations, patenting offices, recruiting firms and so on). Within the industrial systems approach, first, a heavy focus has rested upon relations between the industry and the public research sector. In some studies this has come to be known as “the linear model” (and as such is also widely contested). Secondly, relations and interactions with investors, and especially with venture capital firms, have during recent years become an interesting topic of research to a number of scholars. Although such foci are undoubtedly important, this study attempts to broaden the focus by examining the importance of complementary agents in clusters. [end p. 1606]

More specifically, the study aims at understanding cluster development by analysing the role of evolutionary processes and cross-industrial relations with firms and organizations acting as complementary agents. The study is exploratory and involves processes of identification and mapping of a biotechnology cluster and its integral parts, especially focusing on the role and importance of complementary agents for economic growth. This will be exemplified by an outlay of the evolutionary trajectories of the local biotechnology cluster in Uppsala, Sweden, and its complementary nature.

The article is structured as follows: Firstly, in the theoretical outlay of the paper a cross-industrial perspective on clusters and the importance of external economies is discussed. Subsequently, the empirical data, the case-study object and area are presented in the methods section. This is followed by two empirical sections: in the first, the history of the cluster according to an anchor firm tradition and the nature of complementary agents is analysed; in the second, the competitiveness of the cluster and the complementary agents are examined. The article ends with a concluding discussion.

2. Theoretical Points of Departure: Local Clusters and Dynamic Externalities

A large number of contemporary studies of economic growth deals with the importance of spatial relations and positive externalities (i.e. cost advantages outside the firm such as the availability of infrastructure and complementary inputs offered by suppliers and service providers; cf. Krugman, 1991). However, we seldom explicitly focus on the mechanisms by which complementarities are actively and strategically sourced. As a result, the importance of externalities is largely left unexplained or explained by reference to fuzzy concepts such as “in the air” or “buzz”. Different industrial system approaches are thus open for critique, which not least has to do with how we understand, define and use various cluster-related concepts (cf. Markusen, 1999; Malmberg & Maskell, 2002; Martin & Sunley, 2003; Malmberg & Power, 2006). In light of this critique it is however of interest to study cluster formations and to investigate the idea that agents working actively, consciously and strategically are not in fact most central to the dynamics of sourcing complementarities (be they knowledge or other resources).

In order to examine the role of complementarities for economic development we first have to recognize the importance of geography and the tendency of firms to co-locate in space or clusters. So as to answer some of the critique put forth above, we have to reinstate, or at least clarify, the idea that clusters are in essence cross-industrial and not limited to specialization within single industries (although the core of the cluster may have a narrow activity span). Secondly, we have

to understand why and how the cluster concept can be used as an important tool for recognizing the role of complementarities in local clusters. This also includes an evolutionary understanding of how knowledge and competence structures are formed in local clusters by anchor firms/organizations opening up action spaces and markets for complementarities and thus how complementary agents actively and strategically contribute to cluster growth.

2.1 Geography, Clusters and the Cross-industrial Perspective: Specializations Versus Diversity?

It is often suggested that geographic concentrations of economic activities, or clusters, may contribute to (or may be a result of) local or regional specialization. This in turn is believed [end p. 1607] to stimulate firm performance and overall economic growth in the region. It is argued that this is to a large extent a result of dynamic external economies and knowledge spillovers born out of longstanding relations and interactions between actors within a certain geographic area: be they so-called localization economies or urbanization economies (cf. Henderson et al., 1995; Malmberg, 1997; Feldman, 2000; Maskell, 2001; Cooke, 2004).

The latter suggests that innovation and economic growth are derived from flows of knowledge and resources across industries. In the literature this has rendered a series of studies where the notion of specialization is challenged by the idea of diversity (cf. Glaeser et al., 1992; Henderson et al., 1995) and where industrial dynamics is more or less linked to larger metropolitan areas (Jacobs, 1969; Florida, 2002; Frenken & Boschma, 2007). This has formally become known as the “urban turn” in economic geography: moving the theoretical analysis away from the systems approach towards the role of the urban agglomeration as such. The role of geographic specialization, and thus localization economies, for innovation (a view most commonly associated with Marshall, 1891; Arrow, 1962; Romer, 1986; Porter, 1990; Maskell & Malmberg, 1999) is thus dismantled. However, studies focusing on diversity and urban economies are often viewing specialization as a grouping of firms with the same standardized industrial classifications (and often on the rough two-digit level). According to this understanding of specialization it is of course hard to verify dynamics within clusters since cluster activities seldom are limited to a single industrial code. This does not comply well with the Porterian view on specialization and clusters. A cluster is in its essence defined as “a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by ‘commonalities and complementarities’” (Porter, 2000, p. 254, emphasis added). Additionally, one of the cornerstones in the cluster diamond model of the forces stimulating competitive advantage is “related and supporting industries” (i.e. organizations that share common technologies or that are complementary; see Porter, 1990; Sölvell et al., 1999; Porter, 2000).

Specialization is thus not all about industrial codes, but rather about a shared set of technologies or competencies. This line of reasoning is also followed by Feldman and Audretsch (1999, p. 421), who conclude that innovation is not subject to industrial specialization (i.e. firms within the same industrial code in a given area) but rather that innovation is stimulated by “a strong presence of complementary industries sharing a common science base”. From a geographic perspective a common set of knowledge and skills furthermore provides rich ground for the establishment of local networks where knowledge may be more easily diffused to other actors. These networks are highly specialized and locally embedded, but not geographically enclosed: through business interactions, collaborations and personal contacts the networks can reach out to

important actors in different parts of the world (Owen-Smith & Powell, 2002; Storper & Venables, 2002; Bathelt et al., 2004).

2.2 The Role of Knowledge Spillovers, Anchor Firms and Complementary Agents

The argument pursued above states that a vibrant cluster is centred upon relations between actors that share a common knowledge and competence base that is not least built up by cross-industrial relations carried by actors in supporting and complementary fields. A central element in understanding localization economies is to analyse how the cluster has evolved over time and the actors or agents involved in the process of knowledge [end p. 1608] spillovers, their complementary nature and how they are strategically sourced within the cluster.

Externalities in the form of knowledge and knowledge spillovers have been widely discussed and studied by a number of scholars (cf. Polanyi, 1958; Nonaka & Takeuchi, 1998; Feldman, 1999; Howells, 2002; Gertler, 2003). Knowledge in a specific place is accumulated and refined over time and tend to span across industrial borders and to include a number of actors in diversified action fields. The path and trajectory of a cluster are to a large extent determined by the pool of existing firms or anchor firms (Markusen, 1996; Feldman, 2003).

[...] existing firms serve as anchors that attract skilled labour pools, specialized intermediate industries and provide knowledge spillovers that benefit new technology intensive firms in the region. Established firms may provide expertise and knowledge about specific applications, product markets, and technical development trajectories that move generic scientific innovations in a particular direction, which, over time, may distinguish the specialization of the industrial cluster. (Feldman, 2003, p. 312)

Feldman pinpoints two central aspects important for regional development that will be pursued in this study. Firstly, that clusters evolve over time and that the history of the cluster is centred upon specialization in a given technological or innovative area. Secondly, that the barriers of development are breached by one, or more, major local actors. This line of reasoning is also put forth by Carlsson (1997b), see also Carlsson and Stankiewicz (1995), where the anchor firm is viewed as a prime mover, and as such open up action spaces for other actors—most commonly by means of market interactions or more indirectly in the form of knowledge spillovers. The evolutionary perspective is also brought forward by Frenken and Boschma (2007), who state that growth is a legacy of spatial distribution of resources built up in the past and as a result of product variety within the firm and cities.

In the related variety discussion growth in a particular location and in an industry is largely due to the process of product diversification and an increase of product variety in the economy. A cross-industrial perspective should therefore also encompass actors that interact with firms or organizations within or outside their own industry affiliation. Synergies come from the combining of resources in new ways by agents that complement or supplement a product or a process. As agents they actively and strategically outsource their knowledge and competence to firms in the biotechnology industry as inputs in different parts of their operations.

In a local cluster context this would in turn imply that complementary agents are an important and integral part of the innovation process. This, of course, raises the question of whether a geographic cluster in fact is a result of a need for, and a local presence of, complementary agents

or service providers, or put more bluntly: can clusters really exist without the presence of complementary agents? To answer this question we have to understand the nature of complementarities and the actors involved, and according to Porter (1998) all the linkages between cluster members create a value that is greater than the sum of its parts.¹ The connectivity among actors in a cluster and to what extent they complement each other are ultimately a determinant for cluster survival and sustainability. However, this notion is seldom fully explored in most cluster analyses. [end p. 1609]

Complementarities may take many forms and are largely determined by the nature of the cluster. In general, however, complementarities can be described as “the adding on” to existing products or services (e.g. in terms of customer needs; boosting collective productivity by coordination of activities across firms and organizations; cluster marketing by referrals, in trade fairs, in periodicals and by delegations; and finally by promoting the cluster as an attractive sight where potential customers are able to “shop around” for inputs provided by different cluster members). Complementary agents are thus viewed as a vital part of any cluster. The mere presence of complementary agents suggests that clusters in fact are cross industrial. Although firms in the fringes of the cluster may possess different industrial characteristics, they often share a common set of competencies or at least a deep understanding of the competences in question.

In summary, a cross-industrial approach towards the dynamics of clusters and knowledge spillovers, and especially where the sourcing of complementarities is highlighted, may help us understand the importance of local clusters for economic growth.

3. Empirical Basis and Case Study Outline

This study draws upon an empirical set of data gathered within a larger research project (see Waxell, 2005). The material used in this study is based on a triangulation of three empirical sources in the following referred to as the Uppsala bioproject: 24 in-depth and semi-structured interviews with key actors, mainly CEOs, in various firms or organizations that are part of the cluster; a longitudinal database (PLACE, 2003) including a unique set of data of every individual in working age in Sweden (here data from 1995 has been complemented and compared with data from 2002) and an internet-based survey answered by 106 firms (corresponding to a response rate of 43 percent) within or connected to the local cluster setting (the results of the survey is also reported in Teigland et al., 2004).

The exploratory part of the article is based on an identification process of cluster actors resulting in a thorough mapping of firms and organizations active in the Uppsala biotechnology cluster in the turn of the year 2002 and 2003. The mapping is grounded upon various public business registers, industry and trade organization membership lists, media reports and interviews. The cluster mapping has also been used as framework for gathering survey data and to identify firms and organizations in the PLACE database. The outline of the mapping has furthermore rested upon various industrial system approaches (notably the technological systems, the innovation systems and the cluster approach) in order to identify actors and structures relevant to define and describe the biotechnology cluster.

3.1. Defining the Biotechnology Cluster

The main characteristic of the biotechnology industry is that it is demanding, both in terms of knowledge and capital. The industry does in this sense depend upon public research-oriented organizations and educational infrastructure (such as provided by universities) as well as investors willing to finance research or product development processes that are both risky and time consuming. Regarding the latter, venture capital firms fill an important function. The importance of these actors and their institutional “stickiness” is not least recognized by the Scandinavian approach to industrial systems (Lundvall, 1992; Eliasson & Eliasson, 1997; Carlsson, 2002). However, the cluster approach [end p. 1610]

(Porter, 1990; Sölvell et al., 1999; Porter, 2000) also stress the significance of actors in related, complementary and/or supplementary fields, such as specialized suppliers and service providers, for giving the cluster members a competitive edge making them able to compete on global markets. Taken together these actors make up a cross-industrial system of interconnected firms and organizations.

Accordingly, the biotechnology cluster is encompassing more than just biotechnology firms and may be divided into four cluster components developed and described in Waxell (2005) and Waxell and Malmberg (2007). The biotechnology cluster is here conceptualized as a coherent system of relations between actors that utilize a similar pool of knowledge and skills, specifically in biotechnology-related areas (Figure 1).²

The central component in the cluster consists of firms within the biotechnology industry. Following Audretsch (2001, p. 3) biotechnology is here defined as follows:

A group of techniques and technologies that apply the principles of genetics, immunology and molecular, cellular and structural biology to the discovery and development of novel products.

This definition more or less states that it is the processes involved making a product that should be the basis for classification of a biotechnology firm and not the end product per se. The biotechnology industry is thus, in terms of end products, a diverse industry where firms may be further divided into a number of categories, for example, firms within biotechnological drug development, diagnostics (and certain types of medical technology), bioproduction, biotechnology supply (including bioinformatics and chromatography), health food, agricultural biotechnology and environmental biotechnology (for a more detailed discussion on the definition and characteristics of the biotechnology industry see Waxell, 2005).

The second and third component is made up by public and private research organizations and financial organizations, respectively. In the case of Uppsala, although there has been a fair amount of venture capital going in to several biotechnology firms in the turn of the millennium, the VC sector is heavily underdeveloped in terms of number of local VC actors. While these two components have been widely studied by various scholars (cf. Audretsch & Stephan, 1996; Zucker & Darby, 1996; Audretsch & Stephan, 1998; Zucker et al. 1998; Nilsson et al. 2000) the main interest, in this paper, is to focus on the fourth component (i.e. supporting and complementary organizations).

Figure 1. The biotechnology cluster components

[end p. 1611]

3.2. Complementary Agents within the Biotechnology Cluster

The fourth component, supporting and complementary organizations, of the biotechnology cluster is composed of firms and organizations that are cross-industrial in the sense that they are to be found in different industrial sectors of the economy, especially in relation to standard industrial classifications and practices. As such they exist on the fringes of the cluster or in the intersection between different clusters (cf. Power & Jansson, 2004). Within the biotechnology cluster these firms are foremost specialized service providers, but are also network organizations and formal institutions for collaboration (IFCs). Here these actors are referred to as complementary agents.

In order to grasp the basic nature of complementary agents it may be pointed out that specialized complementarities are important inputs into the biotechnology industry, especially the services rendered by firms in patenting and law. Other vital services sought for by biotechnology firms are provided by actors in the fields of recruiting, accounting and consulting, and research-oriented or other consultancy. Although many of these services may seem to be more or less generic, there is a high degree of specialization towards biotechnology-orientated firms within the cluster. This type of technological specialization is according to Feldman (2003), a reflection of the localized nature of knowledge spillovers. Furthermore, the knowledge possessed by individuals may also transform and adapt more generic knowledge into specialized technological trajectories.

Networking complementarities are formal organizations mainly operating towards stimulating local/regional or industry-related relations between different actors. Examples of networking complementarities are policy concerted cluster initiatives, IFC, science parks, etc.

Although many complementary agents may not be classified as biotech, they do in fact have a deep understanding of maybe not biotechnology processes per se, but rather of how a biotechnology firm is run (which will be argued for in later section). A basic notion of the needs and conditions of the biotechnology firm is therefore needed.

4. The Uppsala Biotechnology Cluster: Industry and Complementarities

The Uppsala region, which is 70 km to the north of Stockholm, Sweden, has been receiving increasing worldwide recognition during the last decade as a strong and dynamic cluster in the field of biotechnology. In relation to its population size, Uppsala has been recognized as a cluster competent to compete with much larger regions in the world. In recent years, efforts have also been made to internationally market biotechnology sector in the larger Stockholm–Uppsala region.

The local cluster is to a large extent specialized in the area of biotechnology supplies and has a fair amount of well renowned firms ranging from large to medium sized, for example, GE Healthcare (former Amersham Biosciences), Phadia (former Pharmacia Diagnostics), Biacore, Biotage (the merged company of Pyrosequencing and Personal Chemistry), Gyros, A ° mic and Alpha Helix. Alongside with the two universities this suggests that Uppsala comprise a unique and locally defined centre of expertise (Table 1).

A mapping of the biotechnology cluster in Uppsala has identified about 80 biotechnology firms that together employ around 5000 individuals. The cluster taken as a whole is estimated to employ about 8000 persons in approximately 160 firms and organizations. Although the competitiveness of the cluster to large extent can be assigned to the [end. p. 1612]

Table 1. Number of actors identified in the Uppsala biotechnology cluster 2002/2003

Cluster components	No. of firms/organizations	Estimated no. of employees
Biotechnology firms	83	5000
Public and private research organizations	18	2500
Financial organizations	11	200
Supporting and complementary organizations	48	300
Total	160	8000

Source: the Uppsala bioproject

biotechnology firms, important actors for the local development can also be found within the sector for public and private research organizations. Here, among others, we find Uppsala University, Uppsala University Hospital, the Swedish University of Agricultural Sciences, the Medical Products Agency, the National Veterinary Institute and the National Food Administration (Figure 2).

In the following, the role and nature of complementary agents within the cluster will be exemplified and analysed. In order to understand the build up of a successful local cluster there is also a need to analyse the importance of local anchor firms and organizations and how these create technological trajectories upon which knowledge is created, diffused and transferred.

4.1. Local Development and the Role of Anchor Firms

Contemporary growth and dynamism of an industrial cluster is most often the result of historical processes (Carlsson, 1997a; Edquist, 1997; Porter, 1998). A key factor for growth in biotechnology clusters across the globe is the longstanding relationship between industry and academia (cf. Audretsch & Stephan, 1996; Eliasson & Eliasson, 1997; Zucker & Darby, 1997;

Zucker et al., 1998). This is also the most prominent feature regarding the growth and development of the contemporary biotechnology cluster in Uppsala.

The origin of the Uppsala biotechnology cluster stems from the protein research established at Uppsala University during the 1930 and 1940s by the two Nobel laureates in chemistry: The Svedberg (1926) and Arne Tiselius (1948). The work carried out by members of the research teams connected to Svedberg and later Tiselius was path breaking and would emanate in a world leading to scientific knowledge about biotechnology-related processes. The spillover of knowledge to industry, however, first came about in the 1950s when the pharmaceutical firm Pharmacia decided to relocate its operations from Stockholm to Uppsala. The main basis for the decision was the successful collaborations between the firm and the above-mentioned research teams (see Backlund et al., 2000; Waluszewski, 2003; Widmalm, 2004; Waxell & Malmberg, 2005).

The collaborations between the two actors paved way for a number of research discoveries and novel products, for example, dextran further developed within Pharmacia Biotech (today GE Healthcare) and immunoglobulin E (IgE antibody) which was to become the basis for the operations of Pharmacia Diagnostics (today Phadia). [end p. 1613]

Figure 2. The Uppsala biotechnology cluster 2002/2003

Source: the Uppsala bioproject and Uppsala kommun, stadsbyggnadskontoret (2003).

Furthermore, as a result of the longstanding relations Pharmacia developed over the years and via a series of mergers and acquisitions into a major player on the world pharmaceutical market. Pharmacia had grown to become a key actor, or anchor firm, with local ties and global reach.

Although Pharmacia was divided into several business and research units (e.g. pharmaceuticals, biotechnology and diagnostics), the company was for a long period of time organized as an integrated organization sharing the same facilities and sales unit. However, during the late 1980 and the 1990s, Pharmacia went through a series of restructurings [end p. 1614] spinning off several of its different units: many of them in the Uppsala area. Through several mergers and spin offs of especially biotechnology-related operations Pharmacia had now become more of a classic pharmaceutical company. In 1995, Pharmacia merged with the American company Upjohn

resulting, among other things, in the relocation of the research unit away from Uppsala. Although this was considered a major downturn for the region, especially in local and national media, several of the researchers and managerial staff remained in Uppsala seeking employment in remaining and newly established biotechnology firms (Fridh, 2003).

In a historical perspective Pharmacia and the two local universities, Uppsala University and Swedish University of Agricultural Sciences, have fostered a local competence in biotechnology-related fields that is hard to duplicate in other locations. As anchoring firms or organizations they both embody and develop core competencies in the cluster and furthermore open up action spaces for new or existing cluster members. These action spaces may take the form of transactional linkages (i.e. market interaction) or stimulate other forms of knowledge spillover (Carlsson, 1997a). Antonelli (2000) stresses that large R&D intensive firms, such as Pharmacia, play an important role – partly as employers that may use the local competence fostered at the universities and as business partners, but also as sites where knowledge can be moulded to fit industrial objectives and research becomes more product orientated. This line of argument fits well into the history of Pharmacia (cf. Andersson, 1996; Frankelius, 1999; Eliasson & Eliasson, 2006). In fact, Pharmacia has often been described as the region’s “third university” as it has provided the personnel with applied research, managerial, industrial and marketing skills.

At Pharmacia many of us have acquired basic research, international operations and business skills. For us in Uppsala this has been to a great help when it comes to having competent personnel at hand – absolutely! Having access to a competent staff is very important. This has also been especially valuable for the entrepreneurial phase here in Uppsala where small businesses have been able to expand and become sustainable.

(Interview with biotechnology firm, translated from Swedish)

Or as another informant puts it:

If you look at Personal Chemistry, Pyrosequencing... many in the staff are “Pharmacia people”. At Pharmacia they have been fostered in everything from entrepreneurship to quality assurance to business management – well, yes everything. It has functioned as a nursery, you may say. It has meant a lot for Uppsala. [...] It’s the synergy resulting from Pharmacia and the university that, in my opinion, has made Uppsala biotech intensive.

(Interview with biotechnology firm, translated from Swedish)

In summary, the local knowledge pool in several biotechnological areas is a result of these past events. In the core of the cluster we find firms developing and producing biotechnology methods, instruments and research tools. This orientation, or specialization, has furthermore served to differentiate the Uppsala biotechnology cluster from other biotechnology-related clusters in Sweden, foremost in the Stockholm, Gothenburg and Öresund region. [end p. 1615]

4.2. The Cluster Life Cycle and the Role of Complementary Agents

As anchor firms or organizations develop over time they tend to spin-off valuable market ideas or products, especially in the local or regional setting. In milieus where spin-offs are created and the entrepreneurial spirits are high there are also market opportunities arising for complementary

agents. These firms/organizations are an integral and important part of a cluster in the sense that they are assisting firms in the core of the cluster by means of specialized services or products.

According to a cluster life cycle, perspective local ties and relationships become less important as firms within the cluster develop and become more internationalized (DeMartino et al., 2006). Although these tendencies are perceptible within the Uppsala case, there are also some exceptions. As Pharmacia developed into a multinational actor on the market for pharmaceuticals and biotechnology-related products the company still had a strong connection to other actors within the local milieu. An increasing number of biotechnology start-ups in the Uppsala biotechnology cluster would however suggest that the cluster not yet has reached maturity and peaked out. The empirical data tells us that although the local and even national markets are reported to be of limited importance there are still observable differences in market strategy and local connectivity between larger, mainly global firms, and smaller research-based firms. Research-based biotechnology small and medium-sized enterprises (SMEs) in general report more interaction with other local actors. Although the local environment is reported to be of limited importance in the survey in terms of sourcing biotechnology supplies, the local milieu is however viewed as a rich source of competent and specialized service providers (survey part of the Uppsala bioproject, see also Teigland et al., 2004).

The mapping of the Uppsala biotechnology cluster reveals a number of specialized complementarities (see Table 2). As above noted the need to source complementary services is to a large extent dependant upon firm maturity and size. However, the need for high quality services offered by a spectrum of specialized consultants are especially vital for newly established firms, mainly in a developing phase, since they often lack time or economic resources to hire personnel with a particular competence on a short notice to deal with the problems at hand. These firms have to work with resources that are easily transferred, and to source and buy services from consultants are often more efficient than building up the necessary competence in-house. Although the services may vary in nature, it is [...]

Table 2. Supporting and complementary organizations in the Uppsala biotechnology cluster 2002/2003

Subsection	No. of firms/organizations
Patenting and law firms	6
Research consultancy firms and other related consultancy firms	19
Accounting and consultancy firms	3
Recruiting and staffing firms	4
Networking organizations	15
Science parks	1
Total	48

Source: the Uppsala bio project.

[end p. 1616]

[...] however important that a potential service provider is familiar with the technologies and processes used within the firm.

In an early stage many of these firms have a heavy research focus. The start-up is mainly built up around a university research team or a few entrepreneurs that have licensed or come up with an idea that is incorporated into the firm. But originally the research is often technology driven, which means that you have to add on other competencies. If it is a really attractive project you may be able to attract venture capital, and after that you may be able to hire a few persons... but it takes time. Some competencies may even be really hard to find.

(Interview with consultant firm, translated from Swedish)

The mapping of the local cluster in Uppsala identified a number of, albeit minor, patenting firms or law firms specializing in patenting, trade marks and brand names, intellectual property protection, copyright, and market law. Some firms also assist researchers and inventors at the university with issues concerning commercialization of ideas and scientific results, product development, marketing, licence trading, financing, and negotiations and agreements. In general, patenting facilitates financing and further research and development of a product or an idea. When a firm is working on and establishing a business plan it is crucial to state and bring forward the possession of an attractive patent. As patenting and related issues are time consuming and complex, it is very common that biotechnology firms outsource and purchase services linked to patents, intellectual property rights and coverage to protect or trade rights.

Another important group of firms characterized as specialized complementarities are smaller and research-based biotechnology firms specializing in research consultancy. These firms are mainly managed by university-based researchers and professors doing consultancy on the side of their regular employment at the university.³ However, many of these are registered as one-man companies and as such lacks employees in official business registers which in turn often causes a drop out in the statistics. We may thus conclude that there are more research-based consultancies in the cluster than here reported (and in most studies in general).

The cross-industrial nature of specialized and complementary services in the biotechnology cluster moreover includes firms within recruiting and staffing, accounting and consulting, and other consultancy.

You need to have a certain mass of people to make something work. We do not have enough employees to undertake these tasks [referring to accounting, business and human resource management]. So, it helps in our daily operations to buy these services, or parts thereof.

(Interview with biotechnology firm, translated from Swedish)

Although the activities of these firms at a first glance seems to be more or less generic, a majority of these cluster members are in fact specialized towards serving firms within biotechnology or related industries. Within recruiting and staffing, for example, it is imperative that the recruiter has the ability to understand what kind of knowledge and competence is needed and sought for by

the biotechnology firm. This is foremost of value when a specific type of scientific knowledge is in demand by the biotechnology firm, but does also comply for positions within sales, marketing and management. [end p. 1617]

You may as well source many of these services in the Stockholm area—the distance is not that far. But when it comes to recruiting... people are not prone to move at all. [...] In many cases we have asked ourselves where we can find professional assistance. The answer is that we can not go further than to Stockholm – that is how it works. Because you need to be here, or we can go there, within the hour... But to be fair, it does not have to be within walking or biking distance.

(Interview with biotechnology firm, translated from Swedish)

Regarding other consultancies one may also find a need for services within (e.g. documentation and information, education, statistics, IT management, systems development, engineering, mechanics and packaging).

On a network level cooperation and relations within a cluster are often emanating from social networks. Different types of organizations are in general established in order to stimulate these kind of relations and to act as intermediaries between actors in a region. The purpose is to stimulate collaboration, interaction and knowledge spillover in a region or a specific industry. These IFCs (see Sölvell et al., 2003) are mainly local or regional industry or trade organizations and different types of cluster member organizations.

In a specific location organizations are established to stimulate these relations and act as intermediaries between local or regional actors. Among others, the Foundation for Cooperation Between the Universities in Uppsala, the Business Sector and the Community (STUNS) has the purpose to create synergy effects between research, industry and the surrounding community. The organization consists of representatives from the two universities, the County Administrative Board in Uppsala (Länsstyrelsen), Uppsala County Council (Landstinget), the City of Uppsala and Uppsala Chamber of Commerce. The organization is actively working to stimulate entrepreneurial activities, especially those emanating from the scientific community. Since a couple of years back a project managed by STUNS was developed into fairly advanced cluster initiative, called Uppsala BIO, with the aim of boosting collaboration and ultimately to support local development in the region. The initiative is mainly financed by the national VINNVÄXT programme endorsed by Vinnova (Swedish Agency for Innovation Systems) during a 10-year period, starting in 2003. The initiative has four objectives: (a) to run a cross-disciplinary research programme, BIO-X, with a focus on commercialization of scientific results; (b) to run a entrepreneurial and project management education; (c) to support the regional innovation system through the incubator Uppsala Innovation Centre (UIC) and (d) to communicate and market regional competences (Teigland et al., 2006).

Many of the complementary agents are located in the local science park, which has developed into a breeding spot for complementary activities. Science parks often function as arenas where close relations are stimulated between technology- and research-intensive firms with similar objectives and characteristics. Uppsala Science Park hosts a number of university spin-offs in biotechnology-related areas, as well as the universities' holding companies and a number of

complementary firms specialized in patenting, business and project management, and other consultancy.

Additionally, in a cluster with many start-ups and entrepreneurial activities there is also a need for qualified services in business management and project development. A major task for these firms is to discover potential and promising ideas or scientific results and assist with project development, commercialization and even to help out with early financing. Some of these firms are organized as umbrella organizations embracing networks of [end p. 1618] independent consultants in specialized fields. This may be exemplified with one of the firms interviewed gathering a small number of consultants. The competence within the organization is concentrated to three business areas: business management, project management and specialist competence within bioscience. The organization has successfully performed several assignments for local as well as national clients within the biotechnology industry. Roughly about half of the assignments are sourced within the local or regional milieu, while the other half is sourced from clients in the rest of Sweden or from other parts of the world.

All in all, there are in Uppsala a relatively large number of consultancy firms offering specialized services towards the biotechnology industry. Many of them are important especially for biotechnology start-ups as they fill gaps within the firm where in-house human resources or competence is lacking.

5. The Competitive Nature of the Cluster and its Components

To further exemplify the importance of complementarities in a cluster we may examine the competitiveness of the components that the cluster builds upon. First, however, the Uppsala biotechnology cluster as a whole will be put into perspective. Although the mapping reveals a concentration of biotechnology-related activities in Uppsala, the success of the cluster is nevertheless a tricky question to investigate. One way of measuring competitiveness is by analysing wages in terms of yearly income levels.

Overall, the biotechnology cluster in Uppsala appears to be fairly competitive. The income level of individuals affiliated to the biotechnology cluster during 1995 and 2002 is well above the Swedish national average.⁴ It is not uncommon that income levels may differ between different regions. However, according to Table 2, the income level of persons working in the wider local labour market in Uppsala is nearly at par with the average income in Sweden. We may thus conclude that the higher income level in the cluster is not merely a regional effect (Table 3).

The income level in the cluster is not only higher, but if we also compare the changes in the income levels over the years we find that the earnings in the biotechnology cluster have increased more than in the nearby or vast surrounding. To make these changes even more evident the earnings have been geared to a national index in base amounts. This in turn [...]

Table 3. Yearly income levels (SEK) for individuals in the Uppsala biotechnology cluster, Uppsala local labour market, and Sweden in 1995 and 2002

	Median income ^a			Median no. of base amounts ^b		
	1995	2002	Diff.	1995	2002	Diff.
Uppsala biotechnology cluster	183 000	260 000	77 000	5,13	6,85	1,73
Uppsala local labour market	158 000	209 000	51 000	4,42	5,51	1,10
Sweden	159 000	209 000	50 000	4,46	5,53	1,07

Source: PLACE (2002), the Uppsala bioproject.

^aLargest source of income (>1 base amount).

^bLargest source of income geared to the price index in base amounts.

[end. p. 1619]

Table 4. Yearly income levels (SEK) for individuals in the stock of organizations belonging to different cluster components, the Uppsala biotechnology cluster in 1995 and 2002

Cluster component	Median income ^a			Median no. of base amounts ^b		
	1995	2002	Diff.	1995	2002	Diff.
Biotechnology industry	223 000	338 000	116 000	6,23	8,93	2,70
Public and private research organizations	180 000	256 000	76 000	5,05	6,75	1,70
Complementary organizations	199 000	309 000	111 000	5,56	8,16	2,60
Financial organizations ^c	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total	186 000	282 000	96 000	5,22	7,44	2,22

Source: PLACE (2002), the Uppsala bi project.

^aLargest source of income (> 1 base amount).

^bLargest source of income geared to the price index in base amounts.

^cObservations too few.

[...] provides a measure that reduces any effects brought on by inflation and that is easier to compare. During the period individuals working in the cluster have increased their income by 1.73 base amounts (or 77,000 SEK), which is a far larger increase than in the wider local labour market (1.10 base amounts) or in Sweden in general (1.07 base amounts). By using the income level as a measure of competitiveness we may conclude that an employment within the cluster is more attractive than an employment outside the cluster. Moreover, high salaries indicate that the industry has been able to attract competence and talent, which in turn is an important input in the process of creating cluster competitiveness.

By analysing income levels of individuals employed within firms or organizations that were active both in 1995 and 2002, the so-called stock of organizations, we may also study internal conditions within the cluster. This, of course, greatly reduces the number of individuals identified in the empirical material, but does still provide a more stable ground for comparisons. When breaking down the biotechnology cluster in Uppsala into its major components we can see that the median income level varies between the different components (see Table 3).⁵ As would be

expected, individuals employed at one of the biotechnology firms in the cluster have the highest income for each year, respectively. Although there are relatively few individuals belonging to the stock of complementary organizations, it is however interesting to observe that the income level of individuals in this component is nearly reaching up to the level of those employed within the biotechnology industry. There is furthermore a wide income gap between individuals in the complementary part of the cluster compared to employees affiliated to the component for public and private research organizations.⁶ Compared over the years it may moreover be noticed that it seems to be more lucrative to first of all belong to the core of the cluster (i.e. a biotechnology firm) and secondly to a firm or organization engaged in complementary activities (Table 4).

The above findings suggest that complementarities, alongside the biotechnology industry, are a vibrant and competitive part of the local cluster, and as such fill an important role. [end p. 1620]

6. Concluding Discussion

In this article it is argued that a cluster is larger than its core industries and is encompassing complementary agents cutting across industry affiliations that contributes to cluster or regional growth. Processes leading to innovation and competitiveness are from an industrial systems viewpoint carried by actors sharing and diffusing knowledge by means of interactions: be they local or global. However, in order to further explore these processes we have to acknowledge the cluster and its full potential. This means that complementary agents or complementarities ought to be viewed and analysed as active and strategic sources of knowledge that create a valuable input in the innovation process. A vibrant local cluster and the knowledge and competence embedded therein thus offer great opportunities for firms in supporting complementary parts of the economy.

As shown here the local milieu in Uppsala hosts a variety of firms and organizations with supporting and complementary skills in biotechnology-related fields. During the past decades the technological trajectory guide-lining local and economic development in the Uppsala setting has to a large extent been carried out by local anchor firms/organizations. As anchor firms they foremost have provided and enriched the local milieu with a knowledge and competence structure, wherein entrepreneurial biotechnology-related activities have been able to take root and where these have been supported by a dynamic framework of complementary agents. Empirical data shows that there is a strong presence in the local milieu of specialized service providers with the relevant skills and competences sought for by the biotechnology industry, especially smaller biotechnology firms and start-ups. Despite the fact that many services are in principle relatively insensitive to distance, it is obvious that in practice spatial proximity and face-to-face contact make communication easier and lead to an increased understanding of precisely what services are needed. This has also been recognized by several organizations working towards strengthening in particular local or regional relations between actors spanning both private and public sectors.

In summary, the presence of competent complementary agents is seen as one of the major strengths of the Uppsala milieu. Moreover, according to the interviews many persons active in different parts of the cluster have a track record of the previous employment in biotechnology firms and thereby possess industry knowledge that is not available in most places in the country.

Physical as well as social proximity is furthermore simplifying the procurement process, which in turn stimulates the process of knowledge spillover. Many actors in the local milieu know each other and in many cases have worked together in other biotechnology companies. It seems then that if we are to understand the basis of the cluster and its competitive capacity, we should also incorporate complementary agents into the analysis. Further comparative studies of either various local milieus or industries are thus needed where the cluster and the actors therein are defined in a similar manner.

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Notes

1. This could be exemplified by a tourism cluster: a tourist seeking a good skiing experience is most often also attracted to a place given the quality and availability of its hotels, restaurants, nightclubs, shops, transport facilities, and so forth. The actors in the cluster is dependent on the value created and provided by the primary attraction, but also the quality of existing complementary agents.
2. Whether the actors in the biotech cluster are in fact interconnected, or to which degree, is discussed and analyzed in Waxell (2005) and Waxell and Malmberg (2007).
3. Teaching employees at the universities in Sweden have a lawful right to, beside their regular employment, outsource R&D activities or to be employed by a second party as long as the activity is not deemed as publicly damaging for the university in question.
4. Technically the income level is geared to a price index (price base amount) that is yearly regulated by the Swedish government. Individuals earning less than one price base amount have been excluded in order to reduce the effects of temporary employees on the income level (such as students working during the summer period).
5. The yearly income level in the Uppsala biotech cluster is here measured as the median income of individuals stating one of the organizations belonging to the stock of organizations in the cluster that were active in both 1995 and 2002 as their largest source of income during each year respectively. The stock of organizations has been used to get a more stable comparison of income levels.
6. Due to the nature of the database material it should however be noted that the component for public and private research organizations also comprises the entire university organization where only parts thereof is engaged with biotech related research or activities.

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[end p. 1622]

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