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Knowledge Bases and Spatial Patterns of Collaboration: Comparing the Pharma and Agro-Food Bioregions Scania and Saskatoon

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Abstract

The aim of this paper is to compare the spatial patterns of innovation and knowledge linkages of a biopharmaceutical and an agro-food biotech cluster. Dissimilarities can be expected based on substantial differences in terms of historical technological regimes and sectoral innovation system dynamics between the agro-food and pharmaceutical industries in general and particularly the distinctive analytic (science-based) knowledge base of biopharmaceuticals in contrast with the more synthetic (engineering-based) knowledge base of agro-food biotechnology. Empirically the study compares co-publications and co-patents of main actors for two typical cases: a biopharmaceutical cluster in Scania, Sweden and an agro-food biotech cluster in Saskatoon, Canada.

Knowledge bases and spatial patterns of collaboration: comparing the pharma and agro-food bioregions Scania and Saskatoon

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Summary:

The aim of this paper is to compare the spatial patterns of innovation and knowledge linkages of a biopharmaceutical and an agro-food biotech cluster. Dissimilarities can be expected based on substantial differences in terms of historical technological regimes and sectoral innovation system dynamics between the agro-food and pharmaceutical industries in general and particularly the distinctive analytic (science-based) knowledge base of biopharmaceuticals in contrast with the more synthetic (engineering-based) knowledge base of agro-food biotechnology. Empirically the study compares co-publications and co-patents of main actors for two typical cases: a biopharmaceutical cluster in Scania, Sweden and an agro-food biotech cluster in Saskatoon, Canada.

Introduction and aim of paper

Many policy-makers and scientists view biotechnology as the next big thing in the knowledge economy. On a regional level, biotechnology presence is especially heralded as a driving force for global competitiveness. This is illustrated by various policy programs specifically aimed at strengthening regional biotechnology activities, such as ‘BioRegio’ in Germany and the Biotechnology Cluster Innovation Program in Ontario, Canada. Also more generic economic policy often targets biotechnology as a core strategic sector to leverage future regional competitiveness. Examples are the EUs Objective 2 program supporting Genomic Technology and Informatics in Scotland, and VINNVÄXT, the regional program of the Swedish agency for innovation systems, VINNOVA, supporting the convergence of the Scanian food industry and biotechnology in the project ‘Innovation in Borderland’ as well as the life science sector in Uppsala through ‘UppsalaBio’. Confirming the importance of geographical location, empirical research on the global biotechnology industry shows a strong concentration in a handful of ‘megacentres’ (Cooke, 2002) or nodes of excellence (Feldman, 2001), such as San Diego, Boston and Munich. At the same time are global knowledge connections indispensable for R&D, innovation activities, and thus the competitiveness of biotech firms, resulting in the typical local nodes and global networks configuration (Gertler and Levitte, 2003).

These observations on the biotech industry feed gratefully into the continuously present and ever so often igniting discussion on the role of geographical proximity for interactive innovation, firm-based learning and knowledge transmission within the discipline of economic geography (e.g. Morgan, 2004). Even though agreement can be found in the assertion that globalization and localization are complimentary processes which tend to enhance rather than erode each other, accusations of under- or over-exaggerating the power of proximity for innovation are frequently heard. Acknowledging that innovation is an interactive process between economic agents that are socially and territorially embedded and culturally and institutionally contextualized (Lundvall, 1992), it can be argued that a discussion on the importance of proximity for innovation evolves around the construction of relational proximity (Torre and Gilly, 2000; Coenen et al, 2004). Briefly it refers to a more intangible closeness in terms of relations (e.g. through organizations and networks), reference and knowledge (e.g. norms, values, rules of thought and action). It needs to be admitted that it is a somewhat vague concept yet it recognizes that interactive learning does not need to be territorially confined as the actual explanatory power of proximity does not pertain to its quality of being physically close together as such (Amin and Cohendet, 2004). Instead it implies that social interactions, whether local or non-local, have to be actively constructed (Morgan, 2004). How the concrete spatial distribution of an industry’s innovation network is configured and being transformed also depends on its institutional setting and knowledge base. This is illustrated in a comparison between strongly localized furniture production and innovation in a typical Danish industrial district and the more distant knowledge links for a Norwegian electronics cluster (Asheim and Coenen, forthcoming).

In this paper we focus specifically on the role of proximity for knowledge dynamics in two biotech clusters. One of the reasons for the popularity of biotechnology in the knowledge economy can be found in its paradigmatic and pervasive character, potentially affecting all living organisms as its domain of application. The sector that so far has been most extensively influenced and analyzed is the pharmaceutical industry. Due to the extensive economic and societal impact of pharmaceutical applications this niche has become the largest, now representing about 70% of all biotechnology sales (Cooke, forthcoming). At the same time, a drastic and sudden shift suggested in the often coined term 'biotech revolution' is severely questionable as on an aggregate level the dispersal of biotechnology in industry is following a familiar pattern of slow but consistent diffusion rather than dramatic upheaval (Nightingale and Martin, 2004). Notwithstanding this, substantial qualitative changes are taking place with regard to innovative practices in a range of industries underpinned by biotechnology (OECD, 2004). Cooke (2004) categorizes these into biopharmaceuticals, agro-food and environment/energy biotechnologies. Each category produces distinctive economic geographies and innovation patterns. Whereas biopharmaceuticals is based on 'open innovation', referring to intra-industry R&D trade among universities and research institutes, pharmaceutical companies and small, dedicated biotechnology firms (DBFs), agro-food is organized around direct basic knowledge transfer between large agro-food biotechnology firms and large public research institutes (Cooke, 2004). This paper seeks to follow up on this distinction. Its aim is therefore to compare the spatial patterns of innovation linkages and knowledge flows of a typical biopharmaceutical cluster, i.e. the Swedish part of Medicon Valley[1] (Scania), and a typical agro-food biotechnology cluster, i.e. Innovation Place in Saskatoon, Canada, based on scientific publication and patent data. In doing so, we draw on a conceptual framework that differentiates between an analytic knowledge base, connected to epistemic communities and a synthetic knowledge base, connected to communities of practice. In addition to this differentiation, the following section discusses more generally the conceptual framework of regional and sectoral innovation systems. Section three provides a general comparison between pharmaceutical and agro-food bioregions. Section four presents

[1] Previously we have analyzed Medicon Valley as a cross-border cluster covering both the Danish and Swedish side. However, based on an analysis of intra-regional, cross-border publications we came to the conclusion that the cluster is embedded in two distinct (but related) regional innovation systems (Coenen et al., 2004).

the empirical work on specifically the biopharmaceutical cluster in Scania while section five does so for the agro-food cluster in Saskatoon. The conclusions compare these results and provide recommendations for future research.

Innovation systems, knowledge bases and communities

This paper has its theoretical vantage point in the systems approach to innovation and cluster literature. In order not to re-iterate ourselves, we only briefly discuss a basic overview of the cluster and regional innovation system literature. This paper builds further on previous work to which we refer for a more in-depth discussion of these concepts (Asheim and Gertler, 2005; Coenen et al., 2004; Ryan and Phillips, 2004). In short, innovation systems as well as clusters capture the notion that innovations are carried out through a heterogeneous network of various actors, often comprising the triple helix of industry, universities, and (multi-tier) government (Etzkowitz and Leydesdorff, 2000), underpinned by an institutional framework (Edquist, 1997; Porter, 2000). In this, institutions, understood as sets of common habits, routines, established practices, rules or laws, regulate the relations and interactions between these actors (Edquist and Johnson, 1997). Central to both is the emphasis on inter-connectivity, between actors as well as institutions, providing scope for complementarities or systemicness. In terms of boundaries, many varieties of innovation systems can be distinguished, such as local, regional, national, sectoral and technological. Characteristically a cluster refers to firms in similar or adjacent industrial sectors in a small geographic area, which explains the considerable overlap that exists between regional innovation systems (RIS) and clusters. Because of their distinctive territorial respectively sectoral perspectives they should however not be conflated. As such, a RIS relates to the boundaries of an administrative region (Cooke and Leydesdorff, forthcoming) while a cluster refers to the notion of a functional region (Malmberg, 2003). A RIS can, in principle, stretch across several sectors (and thus, clusters) in the regional economy, provided that firms and knowledge organizations interact in a systemic way.

In contrast to traditional, neo-classical approaches which have reduced knowledge to ubiquitous free-flowing information, we acknowledge that learning between economic actors is an inherently social process (Lundvall, 1992). Therefore it can be interpreted as situated action in which the organizational and institutional context provides structures and shared meanings for action and communication in which people are able to learn (Nooteboom, 2000). In terms of systemicness the RIS approach draws substantially on complementarities following from frequent interactions and untraded interdependencies on the regional level in the form of conventions, informal rules and habits (Storper, 1997) thereby distinguishing itself from a national innovation system written small (Howells, 1999). The main rationale for applying a regional perspective is that it allows for a bottom-up, grounded approach in analyzing innovation interaction and inter-organizational learning processes. It acknowledges the role of embeddedness to its full right. This refers to the importance of personal relations and networks for economic action and outcomes ingrained in a social and cultural context through social integration (Granovetter, 1985). It is however important to note that the RIS approach refers to localized rather than to local learning as it acknowledges the need to combine both local and non-local skills and competences in order to go beyond the limits of the region (Doloreux, 2004). Similarly, the 'local buzz, global pipeline' metaphor stresses the importance of complementary non-local connections that clusters need in order to prevent a cognitive and economic lock-in by tapping into new and valuable knowledge created in other parts of the world (Bathelt et al., 2004). It thus needs to be acknowledged that a regional innovation system is linked to global, national and other regional systems of innovation within a multilevel governance perspective. The RIS approach offers scope for contextualized empirical analysis of innovation systems by acknowledging the inherently interlocked character of a regional system in overarching structures and institutions (Asheim and Gertler, 2005).

As mentioned in the introduction, the knowledge base provides an important dimension by which regional innovation systems can be contextualized (and differentiated). Within the innovation systems family, sectoral innovation systems (SIS) are probably most pronounced in their focus on the impact of specific knowledge bases on innovation processes. As this paper compares two different applications of biotechnology the following provides a closer look at how the sectoral differs, overlaps and complements the regional innovation system framework. A SIS is defined as "a system (group) of firms active in developing and making a sector's products and in generating and utilizing a sector's technologies" (Breschi and Malerba, 1997, p. 131). Similar to RIS, actors, networks and institutions are its main building blocks (Malerba, 2005). Contrary to RIS however, its boundaries are specified by a certain product group characterized by a common knowledge base rather than on a territorial basis. Co-evolution and path-dependency are two other characteristics that both approaches have in common which can be traced back to the important role attributed to institutions. When taking a closer look at the broad concept of institutions, an interesting difference can be noticed linked to the threefold categorization by Scott (1995) into regulative, normative and cognitive rules. Studies of regional innovation systems seem to be mainly geared towards analysis of regulative (e.g. formal rules, laws, standards and governance structures) and normative rules (e.g. values, norms and codes of conduct). In comparison, studies of sectoral innovation systems pay more attention to cognitive institutions such as problem-agendas, paradigms, categories, classifications and search heuristics. Therefore SIS is more concerned with the impact of different technological regimes on innovation processes. Through this concept, Nelson and Winter (1977) explain that much engineering practice in firms is not so much fine-tuned to price-related changes on the market but on technical ideas and beliefs about where to go, what problems to solve and what sort of knowledge to draw on (Kemp et al., 1998).

Malerba (2004) relates three dimensions of knowledge to the notion of a technological regime: opportunity, appropriability and cumulativeness. Opportunity refers to the likelihood of successful innovation, appropriability to the possibility of protecting innovations from imitation and of reaping profits from innovative activities and cumulativeness represents the degree to which the generation of new knowledge builds upon current knowledge. Based on these dimensions he distinguishes various types of sectoral innovation systems. Agro-food is generally characterized by rather low degrees of opportunity, appropriability and firm-level cumulativeness. Opportunities for innovation are typically aimed at lowering production costs by introducing new (raw) materials or process machinery and at improving quality control schemes (Lagnevik et al., 2003). Assets and production inputs based on such price competition are easy prey for processes of ubiquification: i.e. they become in practice available everywhere at more or less the same cost, gradually (and increasingly swiftly) eroding the competitive advantage of the innovator (Maskell and Malmberg, 1999). Moreover, the ability to innovate depends strongly on the adoption of knowledge developed elsewhere (Wilkinson, 2002) which hampers the endogenous built-up of firms' technological competencies. Malerba (2004) thus concludes that an agro-food sectoral innovation system (in general) consists of few innovative firms and high degrees of geographical dispersion. The latter he explains by the relatively simple and codifiable nature of the knowledge base making spatial proximity not relevant for knowledge transmission. Acknowledging Breschi and Malerba's (1997) note that there may be exceptions to this pattern, case-studies on the food-industry show that examples of food clusters can be found (Nilsson et al., 2002; Onsager and Aagen, 2003; Porter, 1990) due to natural geographic factors, specific historical industrial trajectories, the role of institutions and specific competencies of firms. More importantly, this work is set before the introduction of biotechnological principles in agro-food, where the case of Saskatoon provides a telling example of the centripetal effects of scientific and research excellence (Ryan and Phillips, 2004).

A sectoral innovation system perspective on the pharmaceutical industry clearly provides a different configuration. Here the technological regime is, arguably, characterized by very high opportunity conditions. The knowledge base for drug discovery and drug development is highly fragmented, dispersed and in transition, which allows for a high level of heterogeneity and new entry in the population of innovating firms (Malerba, 2004). The extent of appropriability is determined by two factors: the extent of intellectual property protection and collaborative relations with firms and organizations possessing complimentary knowledge and competencies. Regarding intellectual property rights, Malerba and Orsenigo (2001, p. 11) argue that "pharmaceuticals has historically been one of the few industries where patents provide solid protection against imitation. Because small variants in a molecule's structure can drastically alter its pharmaceutical properties, potential imitators often find it hard to work around the patent". Secondly, because of substantial advances in various disciplines of life science such as genetics and molecular biology since the 1970s, its potential applications in pharmaceuticals increased dramatically. Neither dedicated biotechnology firms nor traditional large pharmaceutical firms are able to master all the capabilities needed to bring these new pharmaceutical innovations to market and are thus dependent on universities and each other for complimentary competencies (Nilsson, 2001). Such symbiotic relationships also allow individual firms to accumulate specialized knowledge within their particular technological niche, further reinforcing heterogeneity within the innovation system. Subsequently, Malerba (2004) concludes that on the basis of these characteristics of the technological regime, the pharmaceutical industry displays a dual spatial pattern in terms of knowledge dynamics: local nodes and global networks.

As illustrated above, the SIS approach manages to clearly point out some key differences between agro-food and pharmaceuticals. Thereby it can complement a predominantly territorial perspective on innovation systems as it explicitly accounts for different industrial dynamics on the basis of its typical knowledge characteristics. On the other hand, it is a very broad and general differentiation that typically dichotomizes low-tech from high-tech and runs the risk of conflating knowledge-intensive industries and R&D-intensive industries. As such it neglects the important issue of distributed knowledge bases. In a critique on the new economy's neglect for knowledge-intensive yet not R&D-intensive industries, Smith (2000, p. 19) argues that "the relevant knowledge base for many industries is not internal to the industry, but is distributed across a range of technologies, actors and industries". Empirically his study shows how the relatively internal R&D-poor Norwegian food processing industry draws on a broad spectrum of technologies and knowledge areas such as biotechnology, electronics, instrumentation and engineering, reflecting the heterogeneous activities along the value chain. Similarly, pharmaceuticals sometimes rely on non-R&D based, mundane knowledge bases as Benneworth (2003) illustrates in a case on the biotechnology industry in the North East of the UK. Here, firms managed to niche themselves by specializing in instrumentation, diagnostic kits and analytical software and pharmaceutical manufacturing (in a strict sense). As such, the notion of distributed knowledge bases draws attention to the importance of cross-sectoral knowledge linkages. This is especially relevant in new, emerging sectors such as agro-food biotechnology where sectoral boundaries have not yet consolidated.

Notwithstanding this, an essential distinction can be made on the basis of the epistemological characteristics of knowledge formation distinguishing analytic or science-based from synthetic or engineering based (Laestadius, 2000). In its philosophical meaning, analytical refers to the way of reasoning by which the truth of a proposition is established independent of fact or experience involving inference from general principle (theory driven). Synthetic, on the other hand, pertains to knowledge having a truth value determined by observation or facts (trial driven). Even though (natural) science and technology (engineering) are intimately interwoven and interdependent social practices, science refers primarily to exploring and codifying patterns in the behavior of nature whereas technology (engineering) refers to "transforming the world to fit some preconceived end; adapting means in order to do something; to produce entities that fulfill function" (Nightingale, 1998). So, while science or analytic knowledge formation aims to break down systems, synthetic knowledge formation or engineering aims to integrate or construct systems. These are of course rather fundamental categories that, if taken literally, would not fit comfortably in the pragmatic context of innovation systems. By definition all innovation would belong to the synthetic tradition of knowledge generation. However, when relaxing the strict dualism between analytical and synthetic in its philosophical sense, this distinction points nevertheless to a substantial difference in innovation practices between various industries (Asheim and Gertler, 2005). As such, a distinction is made between analytic industries where innovation mainly concurs with the creation of new knowledge as such (e.g. pharmaceuticals) and synthetic industries where innovation predominantly refers to the application or novel combination of existing knowledge (e.g. furniture).

Moreover, surprisingly little work has been conducted on interactions in terms of actual knowledge flows and linkages connecting the actors in a network of an innovation system or cluster (Archibugi et al., 1999). Further attention could also be paid to the context specific nature of knowledge and its active social negotiation and interpretation (Latour and Wolgar, 1979). This calls for a shift from a static analysis of innovation networks and actors as repositories of knowledge to a more dynamic position stressing the (social) practice of knowledge in action (Amin and Cohendet, 2004; Brown and Duguid, 2002). Communities of practice are defined by the communal (shared) practice of its members, by which is meant undertaking and engaging in a task, job or profession while communicating regularly with one another about their activities (Brown and Duguid, 2002). Its members are informally bound together by shared experience, expertise and commitment to a joint enterprise (Gertler, 2004).

They are able to produce and internalize shared understandings through collaborative problem-solving. Furthermore, communities are increasingly seen as key conduits of knowledge formation and exchange that enable interactive learning which takes place in embedded inter-organisational cluster relations (Bathelt, forthcoming). They seem to accommodate the situated, pragmatic and interactive nature of learning processes 'in action' within and across organizations in a better way than individual-centered or classical organization-centered approaches (Amin and Cohendet, 2004). In addition, Benner (2003) points out that the community approach duly recognizes that successful work practice requires continual learning which is often (and increasingly so) rooted more in occupations than in business enterprise. As such, the notion of communities overlaps with the growing prevalence of alternative organizational forms, especially of temporary, flexible, project- or task-focused groupings, noted by Grabher (2002). But as we pointed out elsewhere (Asheim and Coenen, forthcoming) this trend needs to be contextualized depending on the knowledge base of industries and institutional framework in question.

In Coenen et al. (2004) a distinction is made between communities of practice, linked to industries based on a synthetic knowledge base and epistemic communities (Knorr-Cetina, 1999; Cowan et al., 2000), linked to industries based on an analytic knowledge base. The latter are bound together by their commitment to enhance a particular set of knowledge while not being primarily concerned about the application of this knowledge. As Amin and Cohendet (2004) argue, knowledge dynamics in social networks of epistemic communities can therefore more easily involve distanced ties and relationships supported by increased mobility offered through cheap and extensive air travel, the internet, and specialized literature. A compelling example is provides by the Human Genome Sequencing Consortium, involving research centers in the US, UK, Germany, France, Japan and China. Also Zeller's (2004) study of learning processes in multinational pharmaceutical companies provides a case in point. Similarly, Bathelt (forthcoming) differentiates between a community of practice and an epistemic community by arguing that autonomy and self-organisation are weaker in the latter. Characteristically, epistemic communities accept some collectively accredited procedural authority (e.g. peer review) and code-book of conventions to facilitate their common goal of pursuing knowledge. Such a code-book allows scientists to speak the same universal, scientific 'tongue' allowing for trans-national communication. Kuhn (1970) refers to this community specific code-book as the "disciplinary matrix" (p. 182) consisting of its formal components or representations (e.g. $E = mc^2$), commitment to beliefs in particular models (e.g. that molecules of a gas behave like tiny elastic billiard balls in random motion) subscription to certain values (e.g. the accuracy of predictions) and, finally, the well-known Kuhnian paradigms or problem-solving exemplars. Communities of practice, on the other hand, are often concentrated around a concrete problem-solving practice or task (typical for a synthetic knowledge base) that requires frequent and specialized communication and ’co-action’, which in turn is facilitated by co-location. Here an example is provided by a community of engineers involved in developing and testing a specific piece of equipment (Gertler, 2004).

Pharmaceutical and agro-food bioregions in a comparative perspective

Following the SIS approach, clear differences can be identified in innovation dynamics between the food and pharmaceutical sectors in general. Acknowledging the diffusion and adoption of biotechnology in both sectors, the following section analyzes the spatial distribution of innovative collaboration specifically in biopharmaceuticals and agro-food biotech. The rationale for this comparison is that though being grounded on the same platform technology, these industries differ substantively with regard to their predominant knowledge-base. The pharmaceutical industry has its origins in natural sciences like chemistry, biology and medicine. Since the shift from traditional chemistry based ‘random drug design’ to modern biology based ‘rational drug design’ in the 1970’s, biotechnological research techniques have largely displaced orthodox chemical capabilities (Casper and Matreves, 2003). This radical shift of technology created strong incentives for new entries and reduced the earlier dominance of large, chemistry based, pharmaceutical companies (Nilsson, 2001). Over the past two decades the number of possible applications has expanded rapidly and the role of universities and small research oriented ‘dedicated biotech firms’ (DBFs) has increased even further (Cooke, 2004). Simultaneously, and probably also consequently, there has been a shift towards more fundamental science as a key activity in the pharmaceutical innovation and production process, decreasing the role of trial-and-error experimentation in labs. Nightingale (2000) has coined this shift the transition in biology from predominantly ‘wet’ experimental science to theoretical in silico science referring to the increased use of computer aided molecular discovery. Major R&D is conducted at universities, research institutes and DBFs, and subsequently in-licensed by large pharmaceuticals that take care of manufacturing, marketing and distribution of the final product (Carlsson, 2002). The agro-food industry, in contrast, does not originate from academic science but has its roots in agriculture. Traditionally, the food industry has largely drawn on an empirical, experimental up-scaling of artisan processes and substitution strategies to replace specific raw materials by means of chemical, and more recently, biological synthesis[2] (Wilkinson, 2002). Similarly, agro-food biotech follows a more trial-driven (synthetic) engineering tradition as opposed to

[2] As regards biological synthesis, the introduction of genetically modified organisms has led to a severe increase in technological opportunities while at the same time being heavily debated in terms of societal impact.

the theory-driven (analytical) epistemology of biopharmaceuticals (Laestadius, 2000). Typically innovation in agro-food biotech draws on the integration of several contributory knowledge bases. R&D is generally conducted in-house by large multinational corporations fulfilling this integrative role while DBFs have a far more limited role in the innovation process (Cooke, 2004). Similar to biopharmaceuticals, agro-food companies have ties with universities and research universities yet based on a distinctively different knowledge profile.

The above advancements in biotechnology have substantially increased the degree of technological opportunity in pharmaceuticals and agro-food industries, which in turn has altered their geographies. In both sub-sectors a strong concentration of activity in nodes of excellence has emerged. Moreover, these clusters tend to increase in density as the sectors grow. This has been demonstrated in numerous studies from various parts of the world. Among the most important nodes of excellence in biopharmaceuticals are the 'megacentres' Boston, San Francisco and San Diego in the US, Toronto and Montreal in Canada, and Munich, Stockholm and Oxford-Cambridge in Europe (Cooke, 2005). These regions also host world leading universities in life-sciences and large pharmaceutical companies (Cooke, 2004; Feldman, 2001). This indicates that access to highly qualified (and locally mobile) labor is an important factor attracting firms and research institutes to these nodes, as well as spill-over from 'open science' (Owen-Smith and Powells, 2004). In agro-food biotechnology clusters the presence of large 'anchor firms' (Feldman, 2001) plays a relatively more pronounced role. Here, most clusters are located in historically agricultural areas such as St. Louis, Connecticut and Raleigh in the US; Guelph and Saskatoon in Canada; and Wageningen, Basel and Edinburgh in Europe (Ryan & Phillips, 2004). Due to this historical agro-industrial specialization, research institutes with close ties to industry have often been established in such regions. But contrary to the more fundamental life-science knowledge infrastructures in biopharmaceutical clusters, these research institutes are characterized by 'hands-on' competence in the more applied areas of food and agricultural technologies. Here, the position of biotechnology is one among a heterogeneous set of other technological systems whereas this position seems to be more dominant in the pharmaceutical industry.

Spatial concentration (across different places) is thus a characteristic feature of both bio-pharmaceuticals and agro-food biotech. Particularly for pharmaceuticals, global connections between the clusters are however of complementary value due to the global distribution of relevant and often rare knowledge (Cooke, 2005). To what extent such global connectedness is the case for agro-food biotechnology has not been investigated to the same degree. Assumingly, the differences in scientific origins and localization are reflected in the organization of innovation projects. Following from the introductory discussion this would implicate a less spatially distributed pattern of collaboration in agro-food biotech compared to biopharmaceuticals. This assumption draws on the typically synthetic knowledge base that characterizes the industry and, related to this, the importance of communities of practice. This contrasts the typical analytic knowledge base in pharmaceuticals in which epistemic communities provide an explanation for the dual pattern of local nodes and global connections in terms of knowledge dynamics. This assumption is investigated empirically by comparing patterns of knowledge collaboration among DBFs in the biopharmaceutical cluster in Scania, southern Sweden, with knowledge collaboration among major actors in the agro-food biotech cluster in Saskatoon, Canada. As indicators for knowledge collaboration we employ patent and scientific publication data. In addition to the comparison between an analytic and a synthetic biocluster, a second comparison is made between patents and scientific publications (within and across these respective clusters) as such. It can be argued that collaborative patents refer to the extent of synthetic knowledge co-production while collaborative publications refer to the extent of analytic knowledge co-production. Patents are primarily connected to specific products or processes. They aim to protect the intellectual property rights embodied in the new knowledge that has been created by means of this novel product or process. As such, patent collaborations can be conceived as a tangible outcome of knowledge creation in communities of practice. Publication collaboration, on the other hand, reflects the creation of new knowledge of relevance in a scientific context. In other words, the deliberate production of new knowledge is a goal (and outcome) by itself. As such it refers to the primary activity of epistemic communities. Given that patents are more closely connected to communities of practice, spatial proximity may be of greater importance for facilitating knowledge flows in general because of the need for face to face interaction and co-action. In contrast it may be easier to build relational proximity across longer distances given that publications relate to epistemic communities.

Practically the comparison is made using patent and publication data collected from Science Citation Index (SCI) and United States Patent and Trademark Office (USPTO). The knowledge collaborations are initially analyzed along two dimensions: (1) intra-organizational vs. extra-organizational and (2) intra-regional vs. extra-regional. The extra-regional collaborations are then further specified as illustrated on figures 1-4. Two periods are compared: 1990-1996 and 1997-2003. The rationale for making these distinctions is that there was hardly any biotech activity in the studied regions before 1990 while the mid 1990s can be seen as a turning point in at least two ways: (1) due to aforementioned technological breakthrough, the level of activity increased significantly in the regions in the mid 1990s, both with regard to number of actors and knowledge output, and (2) preconditions for inter-organizational collaboration changed significantly with the rise of information technology and the Internet in particular. This bibliometric analysis is followed up with three more qualitatively oriented case studies of selected DBFs in Scania.

The Scanian biopharmaceutical cluster

The Scanian biotech cluster is located in the urban area of Malmö and Lund. It is the second largest biotechnology region in Sweden with a strong focus on biopharmaceuticals after Stockholm/Uppsala. The region hosts the largest university in Scandinavia, Lund University, with about 5000 researchers and 40000 students, 10 hospitals of which two are university hospitals, and 36 DBFs (VINNOVA, 2003). 20 of the DBFs are primarily specialized in biopharmaceutical applications and 11 in bioproduction and biotech tools, which are predominately applied in the pharmaceutical industry. Most of the firms are small in international comparisons. Half of the firms have less than 10 employees, while only two firms exceed one hundred (Biotech Sweden, 2004). One of the world's leading pharmaceutical firms, Astra, was founded in Lund. After its merger with Zeneca in 1999 (becoming AstraZeneca), the company continues to have its R&D head office located here. Also Pharmacia Corporation (merged with Upjohn in 1995 and acquired by Pfizer in 2003) had one of its major research units in the region until recently. Since July 2000 Scania is functionally connected to the Danish biotech cluster in Copenhagen through the construction of the Øresund-bridge, making cross-border 'Medicon Valley' by scope and scale fully comparable to established megacentres as Boston and Munich (Cooke, 2005). Previous studies analyzing the cross-border integration of Medicon Valley, considered it however relatively limited in terms of co-publications (Coenen et al., 2004). Also Lundquist and Winter (2003) warn against exaggerated optimism over the economic integration of the Øresund region in the short run. Nevertheless, on a long-term perspective regional integration will probably be strengthened when taking on-going political and economic efforts and initiatives into consideration. For example, Medicon Valley Academy[3] (a network organization dedicated to life sciences) has initiated several promotional measures to facilitate cross-national interaction among firms and to promote further growth of the region.

The bibliometric analysis of knowledge collaboration covers all DBFs located in the region. The selection of firms is based on a list compiled by Medicon Valley Academy. At the start of this study in July 2003, the list included 36 Scanian firms. After a crosscheck with VINNOVA's (2003) selection and a manual verification of the company websites, three firms were excluded[4]. The reason for starting the analysis from a firm perspective is that DBFs

[3] http://www.mva.org
[4] Two of the firms that were excluded only had a sales department in the region while the third had no activity at all.

conduct the core of the innovation process in biopharmaceuticals. By adopting basic science from universities, DBFs "make the technology ready for use" (Carlsson, 2002, p. 110). Subsequently, large pharmaceuticals take care of manufacturing, marketing and distribution. Albeit interesting as a benchmark of the Scanian regional innovation system, using bibliometrics of university research or big pharma would stretch the boundaries too much from a sectorally-defined cluster perspective. After collecting the material we found out that 18 of the DBFs had scientific publications listed in SCI by the end of 2003, and 14 had granted patents registered at USPTO. In sum, 21 firms were either identified as patent assignee or appeared in the scientific publications. Hence, four categories can be identified: 1) firms that had both patents and publications, 2) firms that had neither patents nor publications, 3) firms that had patents but no publications, 4) firms that had publications but no patents. The second category is of minor interest to us, while the other three were studied more in-depth through case studies, complementing the aggregated mapping presented below. In sum the firms produced 61 patents and 202 publications during the period 1990-2003. Since our main interest is knowledge collaboration, sole publications and sole inventions was excluded[5]. This leaves us with a total amount of 183 publications and 58 patents. The findings are illustrated graphically in figures 1-4 (see appendix).

As regards patents (figures 1-2) the geographical distribution of collaborations in the period 1990-1996 (involving 7 Scanian DBFs) was concentrated in two nodes outside Scania: Stockholm and Frankfurt. No less than 61 percent of all collaborations were intra-regional. In the second period, 1997-2003, the geographical distribution of collaboration (involving 12 Scanian DBFs) was somewhat more dispersed but still concentrated in a few nodes. About the same share as in the previous period was intra-regional. In terms of geographical distance the distribution was not particularly wide-spread. The major nodes were still found in Stockholm and Frankfurt, but with growing relevance of London, Munich, Gothenburg and Oslo. Comparing this with the general picture of biopharmaceutical megacentres as described by Cooke, it seems like the size of the nodes in terms of scale of activity are relevant: four of the six nodes qualify as megacentre candidates, while Gothenburg is the third biggest Swedish bioregion. The only outsider in this context is Oslo. These collaborations were represented by one single firm which had an employee working part-time at the University of Oslo.

Comparing the above picture with the distribution of co-publications (figures 3-4), striking differences can be identified. Although a large share of the collaborations in 1990-1996 was also intra-regional and the extra-regional collaborations were concentrated to a few nodes, the

[5] Sole publications and inventions refers to the fact that no other organization than the firm is involved.

co-authors were far more distributed than the co-inventors. The megacentres Stockholm/Uppsala, London and Paris were identified as important, but also peripheral regions such as Umeå (north of Sweden) and Minnesota (US). There was some collaboration with Copenhagen, which at that time was geographically proximate, but not yet functionally connected by the bridge. In the second period the pattern became considerably more diffused, with quite some intercontinental linkages. Still, most of the collaboration was concentrated to close-by Scandinavia and northern Europe. More strikingly though is the fact that 90 percent of all collaborations were with universities and/or other public research organizations, which provide evidence to the thesis of the role of epistemic communities for co-publications as opposed to product/process oriented patents. Another important finding is that the average number of inventors was about 3.5 in both periods, while the average number of authors had increased from 5 to about 5.5. The average number of addresses in the publication material was about 3 in both periods studied, which indicates some but not particularly high degrees of intra-organizational co-authorship. This further strengthens the assumption that publications are primarily handled within epistemic communities transcending formal organizations.

This quantitatively oriented analysis yields a general indication of the spatial distribution of collaborative innovation efforts among the clustered firms. However, it provides no real answer to questions concerning the role of space, communities of practice and epistemic communities in various collaborative relations. Indepth case studies geared at this specific problem area are more suitable to address this question. In semi-structured interviews with research managers at nine of the 33 DBFs in Scania, more detailed explanations to the observed patterns were sought. In sum, 16 interviews were conducted. Even though the studied firms differ a lot both with regard to size and scope, they share some basic characteristics in the organization of their innovation activities as well as in their patterns of external collaboration.

Innovation activities are mainly organized in cross-functional project teams with a limited number of external partners upon whom the firms are highly dependent. Face-to-face meetings are considered important only in certain parts of the innovation process. Especially this is the case in the early phases of development when there is no strict division of labor established. However, since the number of external partners is limited these meetings are handled relatively easily across long distances through frequent travels. In later phases the process becomes more strictly divided between highly specialized experts (or groups of experts), and most communication within the project group is about coordination rather than common problem solving. Because of this, spatial proximity is less crucial for the knowledge exchange as such. What matters are rather a high degree of shared cognitive understanding and affinity in terms of professional skills regardless of geographical location. Yet, proximity is seen as a benefit for the collaboration since it makes it easier to arrange project meetings, and also since it makes it easier to retain administrative control over the projects.

When identifying and selecting new partners, their scientific profile is considered far more important than their geographical location. Due to the deep involvement of key researchers, scientific partners are often identified through the R&D manager's or other key-employees' professional network. Other sources used to identify potential collaborators are scientific publications, trade fairs and scientific conferences. Another growing source of information used in search for new partners is the Internet. However, despite the downplayed role of geographical proximity for knowledge collaboration, more than 40 percent of all co-authors are still located in Scania in the second period studied. A closer look at these collaborations reveal that nearly all are partners at Lund University. According to the interviewed R&D managers this is the case because they have been employed at these particular departments themselves and feel confident collaborating with them. They know their specific area of competence and their scientific qualifications. Several of the studied firms have been founded by researchers at Lund University, and some still have part-time professorships and act as supervisors for PhD-students.

The agro-food biotech cluster of Saskatoon

Ryan and Phillips (2004) conclude that the only biotechnology clusters in the world exclusively oriented to agro-food are in North America. The Saskatoon cluster is one of the most advanced agricultural-dependent examples. It grew out of a series of events beginning with the establishment of the College of Agriculture and the University of Saskatchewan in the early part of the 20th century. The development of Canola in the 1970s – a low erucic acid and low glucosinolates variety of rapeseed - served as the defining event that launched the evolution of the cluster as we know it today. Saskatoon is acknowledged as "…a key starting point for Canadian rapeseed efforts" (Khachatourians et al, 2001: 41). Since the mid 40s, the Canadian Agriculture Research Station began a continuous programme on rapeseed research which, by 1998, was named the Centre of Excellence in Canola. Over the years, researchers from a number of public institutions, in Canada and abroad, worked to develop better varieties of rapeseed. Using traditional breeding methodologies, key efforts led by Dr. Keith Downey at Agriculture Canada in Saskatoon resulted in the development of a low erucic and nutritionally superior variety of rapeseed – modern day canola. Saskatoon-based public sector research served to advance the widespread acceptance of the canola-quality oil for consumption. The collective activities of both the public and private sectors throughout the 1980s and 1990s led to the commercialization of the first transgenic canola crop in the mid 1990s (Khachatourians et al, 2001). More recently, the federal government's injection of funding into genomics-based research activities in the region has represented a new, more evolved approach to knowledge generation activity and the building of renewed regional capacity. The success of the Saskatoon region lies in its ability to be responsive to changing market demands and for its actors (both private and public sector) to occupy a number of stages in the innovation chain (Phillips, 2002). The cluster remains flexible through its capacity for collective action through public-private partnerships and in its ability to accumulate and leverage know-how and know-why knowledge and research capacities to bring new products to the market. In this case, generation of synthetic knowledge is realized through multiple actors carrying out multiple activities over time, subject to technological and industrial change. Typically, basic research and many of the proprietary technologies are imported, assembled with locally produced germplasm into new crop varieties and then exported as intermediate product to global markets. Regional based activity also includes ongoing field trial activity which occurs in and around the Saskatoon region as well.

As previously outlined, synthetic knowledge is 'trial driven' knowledge and refers to the application or combination of existing knowledge. Field trials are a major integrating activity in the Saskatoon region, and throughout the province of Saskatchewan in general, in terms of agro-food and biotechnology. Respondents to Innovation Systems Research Network (ISRN) survey conducted in the Saskatoon area in 2001-2002 suggest that the region offers companies and organizations access to an arable land base to assess the physiological and agronomic traits of canola. In the process of bringing novel crop varieties to market, plants are grown in confined field areas and evaluated by government scientists (CFIA 2005). Saskatchewan is home to a significant portion of the field trials conducted in Canada. Over the period of 1990-1996, there were almost 3000 field trials conducted across Canada. On average per year, 47% of these field trials were located in Saskatchewan. This average decreased to 30% from 1997-2003 although the aggregate number remains at close to 3000 for this same period. From 1990-1996, an average of 89% of these Saskatchewan-based field trials involved canola varieties . This average drops to 53% in the latter period of 1997-2003. Reductions in terms regional output and a de-emphasis on canola varieties in Saskatchewan relative to national numbers signals a shift in the agro-food biotechnology market focus with a reduction in post-commercialization activity, particularly in canola. During the latter period, localized activity appears to switch to field trials in varieties of wheat, alfalfa and flax.

The source population for the Saskatoon cluster was estimated in 2002 to include about 110 actors, including firms, associations, research institutes, government programs, departments, and venture capitalists. Research institutes represent the greatest portion of the source population (35%) and are the largest employers of biotechnology-dedicated workers. They include university colleges, departments and extension divisions that supply the local cluster with various research outputs, and federal, provincial and regional research organizations. Firms, representing 34% of the source population, include enterprises active in development and commercialisation activities related to life science. All major agricultural biotechnology multinational enterprises had operations in Saskatoon in 2002 (many just 1-2 employees while others had up to 100 workers at some time over the period), in addition to some smaller DBFs. A further 15% of the source population was made up of venture capital operations. The remaining 17% of actors were government agencies and industry associations, all of which have aggressively positioned Saskatoon as a centre for global agro-food innovation (Phillips et al., 2004). The source population was further segmented according to the number of employees per actor. The majority of actors were found to employ fewer than 50 people. The largest actors were all research institutes (7 with 50-150 employees and 5 with more than 150 employees).

As anticipated by Malerba (2004), private sector activity is minimal in agro-food biotech, with most efforts led by public sector counterparts. This goes also for the Saskatoon cluster. Given this public sector dominance, in the region represented by actors as National Research Council-Plant Biotechnology Institute (NRC/PBI), Agriculture and Agri-Food Canada (AAFC) and the University of Saskatchewan (U of S), one would expect that the output (particularly in publications) over the 1996-2003 period would be substantial. Therefore, in order to narrow the search and to obtain a more manageable data set, we concentrate our analysis of knowledge collaborations in two ways: (1) by research foci[6], and (2) by lead authors and inventors[7]. The former are fair representations of regional market focus and the latter have been identified as significant contributors or 'stars' in terms of knowledge output for the Saskatoon region. The list of authors and inventors also includes individuals that work in the private sector, so although primary output in terms of patents and publications appears to be largely led by the public sector, we also want to account for any private sector activities. Based on our search criteria, we found that regional activity in terms of publications amounted to 80 for the period 1990-1996 and 143 for 1997-2003, whereas patenting activity output totaled 31 for the period 1990-1996 and 24 for 1997-2003. Again, as collaborative

[6] Search parameters ***Brassica*** = rapeseed, canola and brassica. Search parameters ***Animal-related*** = mucosal, immunity and vaccine.

[7] Search parameters ***Brassica*** lead authors/inventors = Taylor, Zhou, Potts, Rakow, Keller, Datla, Georges, Dormann, Wang, Oelck, Robert, Ripley, Abrams, Gusta and Reaney. Search parameters ***Animal-related*** lead authors/inventors = Bolton, Fontaine, Potter, Babiuk, Rioux, Shryvers, Mittal, Khachatourians and Acres.

activity is of major interest, sole publications and sole patents were excluded leaving a total of 138 publications and 50 patents.

The distribution of patent assignees across organizational types in the defined time periods is as follows: of the 27 co-invented patents identified 1990-1996, 20 indicate public sector assignees (i.e. NRC/PBI, AAFC or the U of S). The Vaccine and Infectious Disease Organization (VIDO), a not-for-profit research and commercialization agency of the university, was the assignee for 5 of the 27 patents in this time period and the remaining 2 assignees are from the private sector and public/private sector respectively. For the time period of 1997-2003, 16 of the 23 patents had public sector assignees. VIDO's patent-based activity diminished significantly in this period. The organization was not an assignee on any patent nor was it listed as an inventor during this period. Rather, it appears new private sector actors were introduced during this period both as assignees and as co-inventors[8]. Overall, private sector assignees grew from representing just over 3% of patents in the first time period to 22% in the latter.

The geographical distribution of collaborative activity for 1990-1996, in terms of patents (figures 1-2), was limited to North America. Intra-regional activity accounted for 83% of all linkages with another 7% attributed to collaborations with other Canadian regions (i.e. Calgary/Alberta, Guelph/Ontario, Ottawa/Ontario, Gatineau/Quebec). The remaining linkages (10%) were with counterparts in the United States from California, New York and Nebraska. Although patent activity marginally diminished in the second period (1997-2003), from 27 to 23, the number of collaborators per patent increased slightly to 3.7 per patent from 3.2 per patent in 1990-1996. Intra-regional activity still accounts for the most significant collaborative activity at 81% and Canadian collaborations still accounting for 7% of activity. South of the border, collaborative activity diminishes slightly to 9%. However, these slight reductions in collaborative activity in North America are replaced with linkages overseas; one with the U.K. and one with India. In the latter time period, it appears that Saskatoon-based patent collaborations are showing signs of dispersing internationally.

Consistent with the Scanian data and with our theoretical assumptions, co-authorship between the Saskatoon region and its counterparts appeared far more distributed than in incidences of co-patenting activity (figure 3-4). Intra-regional collaborations accounted for 69% of all

[8] The private sector actors included: Saskatchewan Wheat Pool (local), Pharmaderm (local), AgrEvo Canada Inc. (local), and Pioneer HiBred (Des Moines, Iowa). Saskatchewan Wheat Pool was the dominant private sector actor as either sole or joint assignee for 3 patents. The remaining private sector actors were only accountable for one patent each.

collaborative activity across both time periods. Collectively, intra-regional collaboration and collaborations with other Canadian counterparts accounted for a total of 89% in 1990-1996 and 81% in 1997-2003. Overall, co-publishing activity appears to be dispersing significantly in the latter period. In terms of non-domestic collaborations, actors in the Saskatoon agro-food cluster co-published with exclusively private sector actors in Germany, with exclusively public sector organizations in United Arab Emeritus, and with a split of both public and private actors in the United States in the earlier time period. However, activity dispersed further in 1997-2003 in that the cluster actors collaborated with more countries and regions worldwide which also included Ethiopia, Australia, France, Switzerland, the Netherlands, England, India, South Korea, Belgium, China, Poland and Italy. In this latter period, collaborative activity dispersed and increased particularly with the United States. Publishing activity increased significantly in the second period (1997-2003) from a total of 80 articles to a total of 143 as does the number of collaborators per publication from 1.8 in 1990-1996 to 3.6 in 1997-2003.

Overall, the public sector dominated all collaborative activity in publications and patents. In terms of collaborative activity in publications, the public sector – including all actors across all regions – accounted for 74% of all linkages in the time period from 1990-1996 and for 59% of same for 1997-2003. Private sector activity in terms of publications more than doubled in the second time period, from 3% to 8%. Remaining collaborative activity (23% for 1990-1996 and 33% for 1997-2003) was led by the 'quasi' organization VIDO[9].

Conclusions

The aim of this paper has been to compare the spatial patterns of innovation and knowledge linkages of a biopharmaceutical and an agro-food biotech cluster. Dissimilarities can be expected based on substantial differences in terms of historical technological regimes and sectoral innovation system dynamics between the agro-food and pharmaceutical industries in general. Theoretically, a major distinction is made between the particularly analytic knowledge base of biopharmaceuticals and the more synthetic knowledge base of agro-food biotechnology. Subsequently we have argued that this has important consequences for the configuration of each of the cluster's distributed knowledge bases. In previous empirical studies on biopharmaceutical clusters, the typical local-node, global-network has been extensively demonstrated. To what extent this also is the case for agro-food biotech clusters is

[9] VIDO is renowned for the research, development and commercialization of products used by producers in the food animal industry and represents a unique organizational configuration. It is a non-profit organization owned by the University of Saskatchewan, however it is considered financially self-reliant.

one of the main issues and contributions that this paper addressed. Based on the theoretical discussion, it can be expected that knowledge dynamics in an agro-food cluster are relatively more localized than for biopharmaceuticals. In other words, learning processes and knowledge exchange are to a higher degree situated within locally grounded communities of practice as opposed to less territorially-tied epistemic communities. The empirical study draws primarily on a comparison between co-publications and co-patents of the Scania biopharmaceutical cluster in Sweden and the Saskatoon agro-food biotech cluster in Canada. Here we have differentiated between two periods, 1990-1996 and 1997-2003, as the mid 1990s can be seen as a turning point for biotechnology. Our empirical results clearly support this assumption as witnessed by the increased output and increased collaboration (in scope and scale) in terms of publications and patents.

Also when comparing the clusters' distribution of collaborative relations, our theoretical assumptions are supported. Three major results should be highlighted. First, the agro-food biotech cluster of Saskatoon displays a less functionally distributed knowledge base than the biopharmaceutical cluster of Scania, as measured in average number of inventors per patent and average number of authors per publication. The Saskatoon case displays an increased degree of co-authorship in the second period (from 1.8 to 3.6), but still much lower than Scania (5 to 5.5). Hence, while there is significant inter-organisational exchange of knowledge in biopharmaceuticals, research in agro-food biotech seems to be more concentrated and integrated within large organisational bodies. This should, however, be seen in a comparative perspective given that the findings on the agro-food biotech cluster also point at the importance (and validity) of a distributed knowledge base. Second, the agro-food biotech cluster of Saskatoon displays more locally oriented patterns of collaboration than the Scanian biopharmaceutical cluster, both in terms of patents and publications. While the share of intra-regional co-authorship decreased sharply in the Scanian case (from 65% to 42%) the Saskatoon figures remained constant at 69%. If other intra-Canada collaborations were included, the Saskatoon figures are 81%, compared to Scania where only 55% of all collaborations are intra-Sweden. As regards co-inventions, none of the regions displayed any obvious change in spatial distribution over time, but the Saskatoon figures of intra-regional collaboration (81%) remain much higher than in Scania (66%). When including extra-regional domestic collaborations, the Saskatoon figures rise to 90%, while the corresponding figure for Scania is 73%. Third, the extra-regional linkages of the agro-food biotech cluster of Saskatoon are spatially more diffused than the extra-regional linkages of the Scanian biopharmaceutical cluster. The Scanian linkages are first and foremost oriented to Europe and North America, in large part to other well known biopharmaceutical nodes like Stockholm, Gothenburg, Munich and California, whereas many of the Saskatoon extra-regional linkages are connected to places like Guelph, Ottawa, Winnipeg and Düsseldorf. This illustrates the difference in search patterns for relevant knowledge between biopharmaceuticals and agro-food biotech. Furthermore, our in-depth studies of Scanian biopharmaceutical firms confirmed the importance of individual scientists at world leading universities with a suitable scientific profile. Collaboration partners were almost exclusively chosen on the basis of this criterion, regardless of geographical location. Spatial proximity was appreciated for easing collaboration, but long distance was not seen as a prime obstacle. Taken together, these three findings support our theoretical assumption of agro-food biotechnology as predominantly based on synthetic (engineering) knowledge exchanged within (product/process oriented) communities of practice, while biopharmaceuticals are predominantly based on analytic (scientific) knowledge exchanged within (knowledge oriented) epistemic communities.

The second comparison, between patents and scientific publications as such, also conform to our theoretical assumptions. In both clusters co-inventions are more locally oriented and distributed to fewer nodes than co-authorships. In the latest period studied 66% of all co-inventions among the Scanian firms were intra-regional, compared to 42% of all co-publications. Corresponding figures for Saskatoon were 81% for patents and 69% for publications. Comparing the share of domestic co-inventor linkages with domestic co-authorships, the Scanian figures are, as mentioned above, 73% for patents and 55% for publications, while corresponding figures for Saskatoon are 90% and 81%. Also when looking at the total number of collaboration nodes, the picture is pretty clear. In both cases, co-inventor linkages are concentrated to a limited number of nodes, exclusively within the same continent. Co-authorships, on the other hand, are more widely distributed to numerous nodes, also across continental borders. On the basis of these findings it can be argued that patent collaboration reflects synthetic knowledge co-production in communities of practice, whereas co-publications reflect analytic knowledge co-production in epistemic communities.

What this paper primarily shows is that biotechnology should not be conceived as one homogeneous industry. Instead a distinction based on ‘carrier’ industries (in this case pharmaceuticals and agro-food) is essential to more fully understand the way that biotechnology is influencing our economies and societies. From a policy point of view, such a more demand-inclined perspective could at least compliment the currently dominating technology push rationale. Even though our empirical results support our theoretical assertions, differences and similarities between biopharmaceutical and agro-food biotech clusters need to be investigated further, also based on more qualitatively inclined case studies of innovation projects, in order to gain more insight on the suggested differences between epistemic communities and communities of practice. In both cases learning and innovation remain inherently social processes. While locally available ‘untraded interdependencies’ and frequent (face-to-face) interaction remain crucial territorial anchors for knowledge production and transmission in communities of practice, epistemic communities allow for complimentary, extra-local knowledge conduits based on sociality embedded in professional affinity and scientific practice. It needs to be stressed that communities of practice and epistemic communities should not be seen as each other’s antipodes but rather as two substantially different but nonetheless complimentary social circuits for knowledge production and innovation. Thus, acknowledging that clusters need local as well as extra-local knowledge, it is important to allow for the possibility of multiple embeddedness (Hess, 2004) where it is not so much a question of either/or. Similar to the multi-level governance perspective in innovation systems, the interconnectedness of various geographical scales ought to be stressed as a starting point for analysing (biotechnology) clusters.

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