Understanding the role of ICT networks in a biotechnology cluster

An exploratory study of Medicon Valley

Steinfield, Charles; Scupola, Ada

Published in:
Information Society

DOI:
10.1080/01972240802356091

Publication date:
2008

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Steinfield, C., & Scupola, A. (2008). Understanding the role of ICT networks in a biotechnology cluster: An exploratory study of Medicon Valley. *Information Society*, *24*(5), 319-333. https://doi.org/10.1080/01972240802356091

Understanding the role of ICT networks in a biotechnology cluster: An exploratory study of Medicon Valley[1]

Charles Steinfield
Michigan State University
steinfie@msu.edu

Ada Scupola
Roskilde University
ada@ruc.dk

1. INTRODUCTION

A considerable literature has focused on the critical role of business and industrial clusters found in cities and regions as drivers of any nations' economic health (Breschi & Malerba, 2001; Dunning, 2000; Markusen, 1996; Porter, 1990, 1998, 2000, 2003; Saxenian, 1994). In much of this work, the emphasis is on the way in which clusters of firms in common industries benefit from geographic co-location, enabling companies to achieve a higher level of competitiveness than they would otherwise if located outside of the cluster (Porter, 1998, 2000). Tacit and explicit knowledge spillovers through formal and informal communication channels that enhance learning and innovation by firms in the cluster, the presence of supportive local institutions, the availability of specialized suppliers and service providers, access to a qualified pool of workers, and pressures from local competition are several of the many factors posited to explain the growth and dynamism of local and regional industrial clusters (Feldman, 1994; Maskell, 2001; Porter, 2000; Saxenian, 1994; Scott, 2000; Storper, 1995).

The role of information and communication technologies (ICTs) in the development and maintenance of local industrial clusters has not received a great deal of attention by this research community. This is surprising, for two reasons. First, many of the mechanisms that cluster theorists believe enhance competitiveness of firms in clusters are related to communication, such as the notion that proximity increases the likelihood of in-person encounters, which can then facilitate the flow of information among cluster members. Second, both policy makers and the telecommunications research community have paid attention to the role of communications infrastructures as an input to local and regional economic success (Moss, 1987; Parker *et al.*, 1995). In the past decade, governments have focused much attention in recent years on the need for a local broadband infrastructure in order to stimulate the growth of local industry, particularly in knowledge intensive sectors like biotechnology and high technology (NTIA, 2004; OECD, 2001). Hence the use of the Internet, and by extension, broadband Internet access, are important ICT artifacts that may have implications for local and regional business clusters.

A focus on broadband access to the Internet - and the many applications such access enables including email, web presence, distant collaboration, and e-commerce - as the ICT artifact is justified in this context given that one of the key goals behind investments in local broadband access technologies, as well as other aspects of public telecommunications infrastructure, is to improve conditions for small and medium-sized enterprises (SMEs) (NTIA, 2004; OECD, 2004). SMEs are considered to be engines for economic growth, and in the United States, they account

[1] Manuscript submitted to The Information Society, revised March 2008. Earlier versions of this paper were presented to the workshop on *The Role of ICT in Interfirm Networks and Regional Clusters*, 7th Annual Conference on the Design of Cooperative Systems, Carry-le-Rouet, France, May 9-12, 2006 and the 2006 Hawaii International Conference on Systems Sciences, Kauai, January 3-6, 2006..

for the majority of the workforce and the gross domestic product (SBA, 1997). Public sector support is often justified by the argument that SMEs do not have the resources to build and maintain the ICT infrastructure needed to support inter-organizational transactions (OECD, 2004). Moreover SMEs are generally considered to be key participants in regional business clusters (Keeble & Wilkinson, 1999).

The goal of this paper is therefore to explore how the Internet may be used in industrial clusters, especially by small businesses. The two primary research questions addressed are as follows:

1) *How do firms embedded in a cluster use public ICT infrastructures such as broadband access to the Internet?*

2) *Does broadband access to the Internet benefit firms embedded in a cluster, and if so, under what conditions?*

Addressing these two research questions contributes to emerging theory on the mechanisms through which participation in a business cluster conveys competitive advantage. In addition, the answers can provide insights into a fundamental policy issue for local, regional, and national governments: whether, and if so, in what ways, provision of a public ICT infrastructure aids clusters.

These questions are investigated through a case study of a European biotechnology cluster known as the Medicon Valley, located in Denmark and Southern Sweden. Interviews with ten organizations in the cluster, including several SMEs, yields a number of insights into the complex interactions between use of ICTs in general - and the Internet in particular - and membership in an industrial cluster.

The Medicon Valley cluster is an excellent context for this research. In addition to being the home of Europe's third largest biotechnology cluster, this region has also aggressively deployed broadband Internet access. According to the most recent OECD data available, In June of 2007, Denmark had the world's highest per capita subscribers of broadband, including DSL, cable and fiber per 100 inhabitants (34.3%); well above the OECD average. The per capita subscription to broadband in Sweden is also very high (28.6%) and above the OECD average (OECD, 2007). In Denmark, the government has been an active proponent of ICT adoption and diffusion, with policies to promote greater broadband deployment. This was achieved by developing and implementing the policy plan for an "IT Society for all" in the mid-90s that had the purpose of making Denmark a world leader in the use of ICTs and e-commerce (Andersen and Bjørn-Andersen, 2001).

The remainder of the paper is organized as follows. In section two, previous literature relevant to the question of how ICTs are used in industrial clusters is reviewed. In section three, details about the case study are provided, including an overview of the research approach and general background on the Medicon Valley. In section four, findings from the interviews are described. A discussion of the results and implications for theory and practice is provided in section five. The sixth and final section offers conclusions, as well as study limitations.

2. LITERATURE REVIEW

The clustering of economic activity is a well known phenomena, usually explained by the benefits that proximity affords firms and consumers in reducing many different types of transaction costs (Leamer & Storper, 2001). Leamer and Storper (2001) observe, for example, that clustered retailing reduces buyers' shopping costs, proximity reduces transportation costs in many types of material productions, and intellectual exchange is greater when participants are located near each other. Porter (1998, p. 10) defines business clusters as a "critical mass of companies in a particular field in a particular location…" which, in addition to producers of some good or service, includes "…suppliers of specialized inputs, components, machinery, and services, and firms in related industries." Clusters can also include "firms in downstream industries, producers of complementary products, specialized infrastructure providers, and other institutions that provide specialized training, and technical support" as well as industry groups such as trade associations (1998, p. 10). Porter and other researchers have studied many aspects of industrial, or business clusters, including the preconditions for cluster formation, the forces driving cluster growth and development, the flow of knowledge and resources within and across clusters, and factors that influence cluster competitiveness and innovativeness (Breschi & Lissoni, 2001; Breschi & Malerba, 2001; Chiesa & Chiaroni, 2004; Porter, 2000; Powell *et al*., 2002; Saxenian, 1994).

Cluster theorists have identified distinct types of clusters based on the nature of the interactions among firms in the region and the connections between the cluster and firms in other regions of the world (Gordon & McCann, 2000; Markusen, 1996). An important distinction is the degree to which clustering occurs simply due to agglomeration economies such as the ability to take advantage of a common pool of specialized labor and other urban amenities, versus clustering occurring due to stable exchange or social relations among firms (Gordon & McCann, 2000). In the former case, clusters arise because of common factors that induce similar companies to locate in a particular area, but these firms may have little direct interaction with each other. Gordon and McCann (2000) further divide the latter type of clusters into two types: classical industrial districts and clusters build around social networks. Classic industrial districts are built out of stable exchange relations among firms, with spatial clustering arising from tendencies to co-locate to minimize transaction costs. Social network clusters are sometimes called new industrial districts, and arise less because of re-location for the purposes of minimizing transaction costs, and more because of the evolution of exchange relations out of social ties built around trust and social embeddedness (Gordon & McCann, 2000; Granovetter, 1985). These different cluster origins have quite different implications for the role of communication and information technologies. At a minimum, use of the Internet for the purposes connecting to external (outside the cluster) partners in agglomeration clusters should have little impact on the dynamics of exchange inside the cluster, since these types of clusters are not predicated on patterns of in-region exchange. However, there are clearly tensions that may arise with greater use of the ICT infrastructure with external partners when clusters are built around in-region exchange or social relations, to the extent that these out-region exchanges replace in-region ones.

Despite the wealth of industrial cluster studies, relatively little research has specifically examined the role of information and communications infrastructure in influencing cluster success. There has been extensive research examining the role of the telecommunications infrastructure in economic development, particularly for less developed nations, regions, and rural communities (Gibbs & Tanner, 1997; Hudson, 1984; Jussawalla & Lamberton, 1982; Mansell & Wehn, 1998). There has also been a significant discussion about the importance of the telecommunications infrastructure for urban development (Moss, 1987). As noted above, these discussions have received renewed attention in recent years to help justify policies that facilitate the rapid

deployment of broadband access technologies such as digital subscriber loop (DSL) (NTIA, 2004; OECD, 2001, 2004). Yet, for some reason there has been relatively little explicit attention to ICT infrastructure use within the context of industrial cluster research (Steinfield, 2004b).

There are good reasons to explore ICT usage in industrial clusters. First, knowledge about ICT usage can better inform policy-making, suggesting opportunities for more targeted interventions than simply blanketing a region with broadband access. Some types of cluster members – small businesses in particular – may need extra assistance, for example, in incorporating ICTs into practice (Gibbs & Tanner, 1997). Second, ICT usage patterns may reveal underlying cluster dynamics that can complement existing cluster studies and help researchers better understand how clusters succeed. Research has focused, for example, on patterns of knowledge transfer among cluster members, focusing on the kinds of formal and informal exchanges that occur within clusters and across regions in order to explain the innovative capacity of a cluster (Cooke, 2001, 2002b; Dunning, 2000; Powell *et al*., 2002; Powell *et al*., 1996; Rogers & Larsen, 1984). Interactions over electronic networks may complement and enhance local knowledge sharing, replace it with non-local exchanges, or contribute to the importation of new knowledge that is then shared within a cluster (Simmie, 2003). Other research argues that the use of telecommunications services, such as electronic mail complements, rather than replaces, the need for co-location in cities and the value of face-to-face interactions (Gaspar and Glæser, 1998). Sinai and Waldfogel (2004) find that Internet can be both a complement and a substitute for cities. Third, research on ICT usage in industrial clusters may also shed light on the local and global impacts of the increasing use of electronic networks for a wide range of transaction and coordination activities (Hicks & Nivin, 2000). Electronic commerce researchers, for example, have begun to question the extent to which e-commerce helps or hinders local economies, and increases or decreases the centralization of economic activity (Steinfield & Klein, 1999; Steinfield & Whitten, 1999; Zaheer & Manrakhan, 2001). s

2.1. ICT Usage in Industrial Clusters

At a very basic level, there are two somewhat independent sets of functions that a local ICT infrastructure might fulfill in local business clusters. One set of functions relates to connectivity within the cluster for coordination and collaboration. This might include the increased ability that ICT networks provide for employees to connect to their firms from home or other external locations, enabling telecommuting and telework. Although research findings are mixed, telework use may improve a firm's productivity as well as its ability to attract and retain certain types of workers who might need flexible arrangements (Kraut, 1989; Westfall, 2004). In addition to such intra-firm uses are applications of ICT networks to facilitate information sharing and collaborative work within and across firms in a cluster. Most research on ICT-enabled collaborative work focuses on the support of distributed teams engaged in brainstorming, coauthoring, design, problem solving, or decision making tasks (Grudin, 1994), but this literature is generally quite disconnected from the research on coordination among firms in an industrial cluster. The second broad set of functions that an ICT infrastructure can provide for an industrial cluster is linked to the use of networks for electronic commerce transactions. There is a rich literature on electronic commerce, often distinguishing between business-to-business trade and business-to-consumer trade, but rarely is its use in the context of geographically-defined industrial clusters examined (Steinfield, 2004a, 2004b). Electronic commerce researchers have emphasized the way that electronic markets can support business communities, but these communities are virtual in nature, and, in some respects can be thought of as something of a substitute for proximity-based clusters (Steinfield, 2004a, 2004b).

Most commonly the spread of ICT networks is viewed as one of the main factors contributing to globalization by virtue of the speed with which it allows communication, information, and transactions to flow across large distances, thereby reducing coordination and search costs that formerly inhibited such trade (Bakos, 1997, 1998; Cairncross, 1997). This view suggests that the advent of high capacity, global ICT networks enables increased outsourcing and encourages firms to replace local trading partners with distant ones that might offer lower costs and higher quality. At the extreme, the replacement of in-cluster trading relationships with distant ones might ultimately diminish the benefits that come from being in a cluster, especially those that are based on a set of stable exchange relations. A similar notion was considered in one review of the effects of ICTs on regional clusters, referring to the potential *centrifugal forces* generated by the use of ICTs, which can ultimately free companies from the constraints of geography and the need to locate in clusters (Maignan *et al*., 2003). Finally, ICTs also make it easier for distant competitors to access customers of cluster companies, increasing threats from other regions. This discussion suggests that *greater use of electronic commerce may damage a cluster by weakening the trading relationships among members and reducing local cooperation and opening up cluster members to new competition*. This leads to the first exploratory proposition:

P1: ICT usage can lead to cluster disintegration, by making it easier to connect with partners in distant regions.

Others have argued for a more nuanced view of the connection between ICT usage and the activities of firms in local and regional business clusters, recognizing that such clusters exist in an increasingly interdependent and global network of economic relations among nations. In a wide ranging review of research on economic geography, Scott (Scott, 2000), citing Veltz (Veltz, 1997) summarizes this view by observing the trend towards, "mounting levels of functional integration of different national economies; …durably anchored in … a worldwide archipelago of stable regional economies or global city-regions" (p. 494). ICT networks function to permit firms to locate in cities or regions where conditions are favorable (e.g. presence of a labor market with appropriate skills and education, presence of firms offering complementary products and services, etc.), without harming their ability to reach global customers and suppliers. Moreover, innovative firms can use their connections to a global ICT infrastructure like the Internet to bring new knowledge into a region, which may then diffuse among local trading partners (Hicks & Nivin, 2000; Zaheer & Manrakhan, 2001). Storper and Venables (2004) conclude that new technologies such as broadband telecommunications may facilitate dispersion of production, but they also destabilize activities, creating uncertainty and unknown opportunities, leading to a prediction that though the precise mix of activities involving face-to-face interaction and co-location will change, they will still be important well into the future, and will continue to generate agglomeration of highly-skilled individuals, firms, and bureaucracies in urban centres. Some research suggests that large firms, especially multinationals, play an important role in bringing in new knowledge into a cluster, which then spreads to smaller firms and improves cluster innovativeness (Simmie, 2003). The review by Maignan *et al*., 2003 also treats this type of effect, considering that use of ICTS can actually have a *centripedal force*, leading to increased strength of clusters. Such an effect might also arise from the "hub and spoke" and "satellite" cluster formations identified by Markusen (1996). In hub and spoke clusters, large firms in a region connect with other large firms around the world, as well as to smaller firms in the region. In satellite clusters, firms in a region depend on connections to firms in other parts of the world, with little trade with partners inside the region. This view suggests then a competing interpretation than the centrifugal force view: that *ICT usage enables export-oriented clusters to better access distant markets and import knowledge, without harming the internal dynamics that have helped to sustain the cluster*. This leads to the competing proposition:

P2: ICT usage will be associated with the strengthening of a cluster, rather than its disintegration.

Within the field of information systems, two well known papers have directly explored to potential use of an ICT infrastructure to improve coordination within an industrial cluster, arriving at somewhat opposing conclusions. Johnston and Lawrence's (1988) seminal work on value-adding partnerships focused extensively on the Prato, Italy textile industry. In this cluster, several large textile mills had disaggregated into small, specialized firms, each focusing on one part of the overall value chain in textile production (e.g. washing, coloring, cutting, etc.). They showed how networks of firms worked in concert to meet the market demands for the good of the network, and pointed out how an inter-organizational information system was being used to facilitate coordination (Johnston & Lawrence, 1988). However, a decade later, Kumar and colleagues revisited the merchants of Prato, and found that the information system had been all but abandoned (Kumar *et al*., 1998). In their analysis, the system offered no real added value in terms of transaction cost reductions over the personal forms of coordination that had evolved over centuries of textile production in the region. Kumar *et al* (1998) suggest that trust and personal relationships – the social capital of the region – were effective substitutes for the inter-organizational system, rendering it unnecessary. Other research on clusters characterized by intense internal trading relationships has similarly observed the crucial role of social embeddedness, noting how personal connections create advantages for trading partners that may not arise in arms-length market transactions (Uzzi, 1996). This line of work suggests that *attempts to automate transactions and replace personal interactions within clusters may cause more harm than good*, a finding that parallels many other studies of the impact of business-to-business electronic commerce on buyer-seller relations (Kraut *et al*., 1999; Schultze & Orlikowski, 2002; Steinfield *et al*., 1995). This leads to a third exploratory proposition:

P3: Within the cluster, personal interactions – phone, face-to-face, or email – will continue to be a primary form of coordination and collaboration, rather than ICT-based automated transactions or structured collaboration systems.

The intersection between the cluster literature and studies of ICT use by small enterprises also offers competing views. Resource constraints have long been recognized as a barrier to innovation with technology (Tornatsky & Klein, 1982). Smaller companies are often depicted as not having the requisite resources – either in terms of expertise or capital – to gain the same level of benefit as large firms when it comes to ICT usage (Auger & Gallaugher, 1997). The level of IT knowledge is also generally low in SMEs. Small businesses often have difficulties recruiting and keeping well trained IT personnel (Thong, 2001). Even though there is often a general lack of IS expertise in SMEs, small companies are also less inclined to use external advice-giving services (Thong *et al*., 1996). Ilhstrom *et al*. (2003), in a thorough literature review of barriers to SMEs' IT adoption, distinguish two main types of barriers: internal and external to the corporation. The internal barriers include lack of understanding of opportunities, owners' perception of the business value, lack of measurable financial gains, lack of awareness of the potential benefits, lack of understanding of implementation techniques, perceived cost and insufficient organizational readiness. The external barriers include insignificant influence by industry, lack of external pressure from trading partners, poor promotion campaign by vendors, lack of security or perceived security hazards, lack of secure payment systems, legal issues and lack of standards.

When the ICT artifact is Internet access and usage, many of the benefits can follow, however, simply from the availability of low cost access, given that it allows global communications without the costs associated with private network infrastructures. Small companies in a cluster may benefit from the provision of low cost Internet access, given government policies that favor local infrastructure development to support the cluster. Additionally, the proximity to other firms

may give rise both to social networks that can serve as a conduit for support for innovative ICT uses, as well as enabling observation and imitation, once the economic barriers to access are resolved (Gordon & McCann, 2000). Indeed, some cluster research suggests that smaller firms in a cluster may actually be more innovative than their larger counterparts, because they are less rigid and less locked into established practices (Cooke, 2002a). *Smaller firms in a cluster, then, may benefit from ICT infrastructure investment while those outside of an established cluster do not*. This suggests a fourth exploratory hypothesis:

P4: Small enterprises in the cluster may experience some benefits from ICT that might otherwise not be associated with firms of this size.

Much of the attention on business clusters today focuses on new industries, usually in emerging technology sectors such as information technology, new media and biotechnology (Audretsch, 2001; Chiesa & Chiaroni, 2004; Cooke, 2001, 2002a, 2002b; Lemarie *et al*., 2001; Powell *et al*., 2002; Powell *et al*., 1996; Saxenian, 1994; Saxenian & Hsu, 2001; Yukawa, 2004). In these types of knowledge-intensive clusters, rather than emphasizing transactions within the cluster, or even explicit coordination among cluster members, researchers have begun to focus on other ways that such clusters improve their competitiveness. A number of cluster researchers emphasize the importance of local trade or government-sponsored associations that work to promote the development of the cluster (Chiesa & Chiaroni, 2004; Cooke, 2002a; Turner, 2003; Yukawa, 2004). These associations engage in educational activities aimed at improving the cluster's human capital, branding and promotion activities such as conferences, exhibitions, Web sites, and business directories that help attract labor, venture capital, and business opportunities for the cluster, and online and offline social/community activities that create opportunities for knowledge sharing among cluster members, even when they do not explicitly trade with one another . These latter activities, strengthened by the geographic proximity of firms in a cluster, are also viewed as important mechanisms to improve the exchange of tacit knowledge – knowledge gained through habit, culture and experience that is not easily codified and shared (Asheim & Isaksen, 2002; Howells, 1996; Lam, 2000; Polyani, 1967; Steinfield, 2004a). Importantly, many of these activities explicitly involve *the use of ICT as a tool for cluster promotion and development*, even if not strictly for the purposes of supporting inter-firm electronic commerce transactions (Scupola & Steinfield, 2008).. This suggests our final exploratory proposition:

P5: There is an important role for ICT usage in cluster promotion and development by agencies that providing cluster support activities.

2.2. Summary

A number of key roles for the ICT infrastructure in business clusters are suggested by the above review. First, firms within the cluster benefit from the presence of high quality local Internet access. It can enable more flexible work arrangements and lower costs for firms to support distributed workers that need to collaborate. Second, although some concern has been expressed regarding the potentially destabilizing effects of the Internet on clusters, in that it permits firms to substitute distant trading partners for local ones, research from a social embeddedness perspective suggests this is an unlikely outcome. Rather, the studies reviewed above suggest that connection to a global ICT infrastructure like the Internet benefits clusters by improving access to distant markets without harming internal cluster dynamics. Moreover, the use of ICTs further promote cluster innovation by facilitating the transfer of technology from distant markets to firms in the cluster, which can then diffuse through informal channels even when firms in the cluster have little trade with each other. Third, a relatively less developed thread in the literature suggests that smaller firms in clusters may be able to benefit from ICT infrastructure investments, despite the

common finding that they are less likely to gain from technology innovations. Finally, the review points out that in new knowledge-intensive clusters, an important use of ICTs is to help promote and maintain cluster brand identity, as well as to facilitate information sharing within the cluster.

3. A CASE STUDY OF THE MEDICON VALLEY

The roles for ICT infrastructures in business clusters were examined in a case study of a well known European biotechnology cluster, The Medicon Valley located in Denmark and Southern Sweden, in the summer of 2004. We selected this biotechnology cluster for several reasons. First, this is an increasingly important sector in many economies, and there have been repeated attempts worldwide to develop successful clusters in biotechnology (Cooke, 2002b). Given this worldwide interest, there has been significant research on biotechnology clusters (Audretsch, 2001; Audretsch & Stephan, 1996; Cooke, 2002a, 2002b; Frank, 2002; Wolff, 2003; Yukawa, 2004). Second, small firms play a significant role in the field of biotechnology, and are important participants in biotechnology clusters (Audretsch, 2001). Third, the Medicon Valley has been a highly successful example of a biotechnology cluster, achieving a prominent global position in this highly sought-after sector (Coenen *et al*., 2004; Moodysson & Jonsson, 2007; Frank, 2002; Wolff, 2003). Fourth, it is a knowledge intensive industry, placing more emphasis on information transfer than the transfer of physical goods (Cooke, 2002b; Powell et al., 2002; Powell et al., 1996). Hence, it offers great potential to reveal important uses of ICTs for information sharing and coordination within the cluster. Finally, biotechnology is a global industry, and the Medicon Valley has several significant multinationals that anchor the cluster (www.mediconvalley.com). As such, biotechnology clusters contain what Porter calls "traded industries" (Porter, 2003) offering an opportunity to explore global ICT usage, including e-commerce connections with distant markets.

3.1. Research Methods

Data for the study were gathered from archival sources, interviews with representatives from companies in the region, and interviews with representatives from the Medicon Valley Academy, a not-for-profit, member-financed association that works to promote the region. In all, representatives from ten organizations, including the Medicon Valley Academy, were interviewed. A mix of small and large firms was chosen to help reveal differing ICT and e-commerce usage patterns among smaller enterprises. Among the larger firms, high level managers responsible for IT infrastructure investment and application development were interviewed. Among the smaller firms, this type of position did not exist, and the head of each company was interviewed. All of the interviews were conducted in June of 2004, and each lasted a minimum of one hour. Interview questions were open-ended and unstructured, attempting to elicit the variety of ways that firms use ICTs to interact and exchange information and products with other firms in the region, as well as with suppliers and customers outside the region.

3.2. The Medicon Valley in Brief

The Medicon Valley occupies a region covering Copenhagen and surrounding towns in Denmark, and the southern part of Sweden region known as Scania, including such cities as Lund, Malmo and Gothenburg (see Figure 1). It is home to five science parks, hundreds of biotechnology, life sciences and pharmaceutical companies, and more than a dozen universities. Table 1 provides a number of statistics about the region, based on information from the Medicon Valley Academy (www.mva.org).

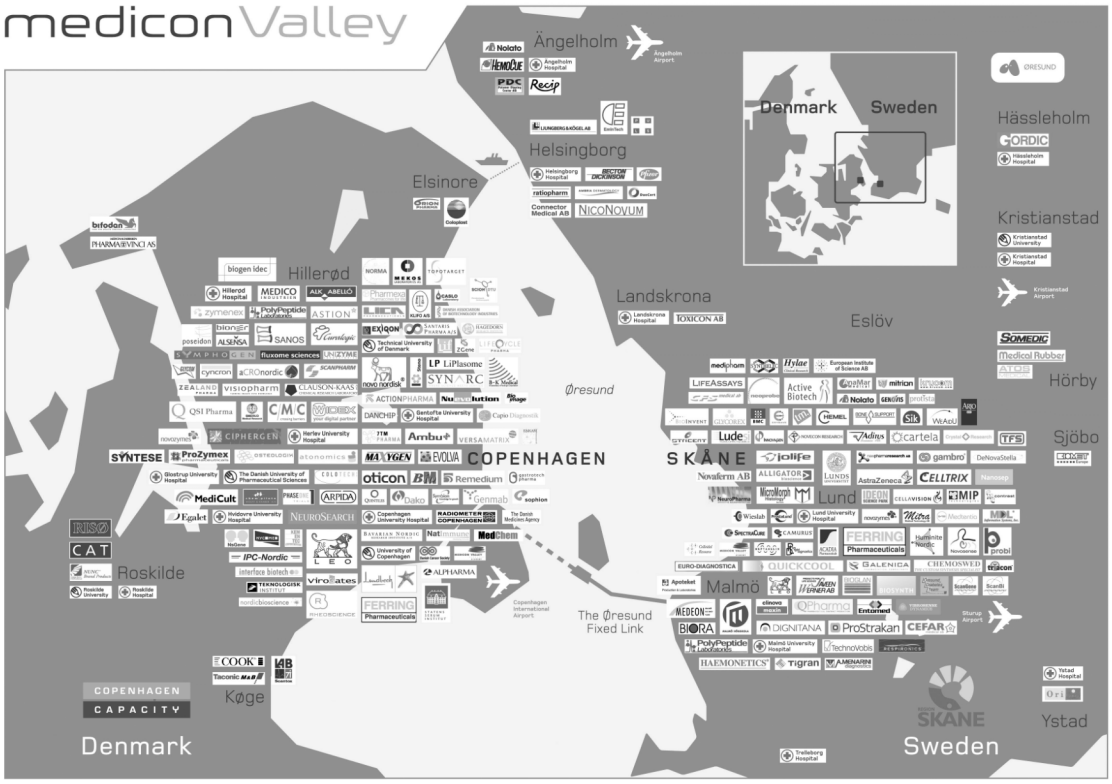

Figure 1. The Medicon Valley. (Source: Medicon Valley Academy)

The region has enjoyed remarkable success, and is now ranked as the number three biotechnology region in Europe (www.mva.org). It was officially named Medicon Valley in 1997, but has been a center for pharmaceutical and life sciences research for much longer, with four of the world's leading pharma companies located there: AstraZeneca, H. Lundbeck, Leo Pharma, and Novo Nordisk. The region is considered to be especially competent in three major biotechnology research areas: diabetes, inflammation, and neurosciences (Boston Consulting Group, 2002).

Table 1. Statistics on the Medicon Valley

Population in the region	2.9 mil.
Number of universities	14
Number of hospitals	26
Number of life sciences researchers	5,000
Number of biotechnology companies	125
Number of pharma companies	70
Number of medical technology companies	130
Number of clinical research organizations	15
Number of employees in biotechnology, pharma, and medical technology	41,000
Percent of all life sciences exports relative to all of Sweden and Denmark	60%

Source: Medicon Valley Academy (www.mva.org)

4. FINDINGS

Tables 2 and 3 present basic descriptive information for each company interviewed, including the ICT applications for inter-firm coordination discussed in the interviews. Company identities are not revealed at the request of those interviewed. Quotations from interviews are provided to illustrate interviewee perceptions.

The six firms listed in Table 2 are biotechnology and pharmaceutical producer firms, while the four firms in Table 3 provide various types of supportive products and services. In general, the pharmaceutical and biotechnology producers are all export oriented, with the lion's share of their output destined for markets outside Denmark.

> "Our customers are all over the world, it is a global industry, we have a number of potential customers and they are scattered all over the place, we are not depending on the local industry…" (Development Director, large biotechnology research firm, June 9, 2004)

> "Medicon Valley is not our main audience." (Marketing Director, large biotech firm, June 18, 2004)

The large companies among the set of pharma and biotech producers all maintain extensive internal information technology infrastructures, and in some cases use extended information systems to enable structured transactions with large suppliers and distributors of their products in other countries. Several of the firms mentioned use of electronic commerce mainly in the form of inventory-replenishment for their global distributors, rather than for retail-oriented sales to consumers. For example, one IT director from a large pharma company noted:

> "E-business is not allowed with end customers. We are launching an e-business application which allows third party customers to order goods on the web site. That is going to a pilot over the next 3-4 months and then we will use it with the distributors. It is with those countries where we do not have our own subsidiaries. By doing that we hope to manage their inventory and by doing that we could save a lot of money and so can they." (IT Director, large pharma company, June 23, 2004)

This is not surprising, given that their products would not normally be sold directly to consumers, but through a complex set of health care intermediaries. Within the cluster, there is little in the way of direct transactions or coordination among these firms. They do work with researchers from universities or smaller start-ups, and the interaction is largely using email when it does occur over an ICT infrastructure. Some efforts at structured computer-supported collaboration were mentioned, but in some cases, these efforts were not generally viewed as successful.

> "For collaboration we are not using any complicated stuff here…we use email, we have used some web-based e-rooms with outside partners and they work quite well." "[Question: collaboration with other research companies?] that is mainly e-mail and personal communication face-to-face you know… networking is based on personal communication." (IT Director, large pharma company, June 23, 2004)

> "The problem we hit all the time with collaborative processes is that for these to truly be a success, and we've implemented many of these at various levels, to truly be a success, we guess, because we've never had one that was a true success, it's always been a partial

success, for a true success, it has to be as easy as sending an email." (IT Director, large pharma company, June 10, 2004)

Table 2. Descriptive Information on Biotech Producer Firms Interviewed

Type of Company	No. of employees	Main products	Market Focus (local vs. non-local customers)	ICT applications
Large pharma	18,800	Wide range of pharmaceutical products, engages in research and development of new drugs.	Has presence in 69 countries, sells to distributors in 179	Has a significant internal IT infrastructure, including global network linking operations. Has some limited e-commerce capabilities, but most connections with external partners are via email. Has many partnerships, involving research collaboration. Will allow some external connections to internal network and has tried using computer-based collaborative systems, but much still done using simple email.
Large pharma	3,300	develops and manufactures drugs, significant R&D.	Sells drugs in more than 90 countries, R&D located in Medicon Valley. Has four manufacturing facilities elsewhere in Europe	Has a significant internal IT infrastructure linking company operations on a global basis. Has used e-commerce with partners to which it licenses drugs for sale, mainly for inventory replenishment. Engages in R&D collaboration with external partners, mainly via email.
Large biotech	1,400	Develops biotech products used for various types of disease diagnosis, especially for cancer diagnostics.	Has operations in more than 20 countries, and works with distributors in 50 countries.	Has significant internal IT infrastructure linking company operations. Uses IT to manage transactions with distributors. Supplies sophisticated IT tools for analysis for R&D collaborators, from universities and elsewhere. Also uses the Web to present its products to help find new distributors.
Large biotech research	150	Conducts science to develop chemical and biological compounds that have commercial potential. Creates spin-offs to capitalize on R&D results	Mainly located in Denmark, but is a subsidiary of a large food product producer that sells to a global market. Biotech R&D is mainly in collaboration with local researchers, especially in universities	Has a significant internal IT infrastructure, and facilities to support research. Main external ICT applications are email interactions among research collaborators, but also enable some high speed connections to research tools, especially for collaborators at universities.
Small biotech supplier	4	Produces a blood test product	Manufactures in region, sells globally using distributors. 97% of sales outside Denmark	Uses DSL for always-on Internet access, relies on email to connect with clients, send pdf brochures. Uses Web site hosted externally to provide product information, but not transactions.
Small biotech supplier	1	Produces fermentation equipment, mostly outsources the production to local craftsmen	Manufactures in region, sells globally without distributors	Uses DSL for always-on Internet access, relies on email to connect with clients. Uses Web site hosted externally to provide product information, but not transactions.

Among the small biotech producers, it was noteworthy to see a heavy reliance on local broadband access. Both had DSL lines, and relied on email as a primary form of communication with clients.

"The first [way that customers find us] is by our website…The first contacts are mostly by email [and subsequent contacts] also by email…We have broadband, a very high capacity… We use it quite a lot to learn about the demands of the health authorities, mainly the food and drug administration, but also the European regulations, and of

course we use it in contacts with customers and suppliers… We use a lot of email and fax. People are placing orders using email and fax." (Director, small biotech supplier, June 3, 2004)

These firms were both export-oriented, with one having nearly all sales going to distant markets.

"With this company, we export 97% outside Denmark." (Director, small biotech supplier, June 3, 2004).

One small firm, producing blood test products, noted that despite having some reputation problems within the region, they noted some benefits from the association with Medicon Valley in their global sales efforts.

"Sometimes we say that our quality assurance system was founded by [*name of large pharma company in region*] and made in accordance with their standards and that impresses people." (Director, small biotech supplier, June 3, 2004).

Nearly all interaction with remote clients was email-based. Both of these SMEs used the Web to promote their products, even though their online sites do not support transactions.

"The biggest part of communication nowadays is mainly taking place by e-mail…. I get most of my inquiries by e-mail and I do not have proof of that but I believe that it is mainly because of our web page." (Director, small biotech company, June 14, 2004.

In order to illustrate how remote customers are identified, the fermentation equipment supplier described a recent sale to a customer in China. The customer had found his company after searching online for fermentation equipment suppliers. The customer then emailed to establish communication, resulting eventually in a visit and formal contract. This was a particularly critical sale for the small company, as it represented a significant portion of his revenue for that year.

The companies in Table 3 provide complementary products and services to cluster firms. All highlighted the use of Web-based promotion and email interactions, but a common theme was the importance of in-person communication in the region to obtain clients and provide services, either because the complexity of the products is too high for use of the Web, or the situation requires nuanced information that is better obtained personally.

"The Web site can primarily be used for selling products…[but] because a lot of our solutions are so complicated … it's not possible to sell it through the Web site. Most of the companies, if they really want a solution from [us] then they know [us] and they will not get that kind of information through the Web site and they will get it through our employees. It's possible to get an overview from the Web site, but for more details, they have to contact us in person." (Regional Account Manager, large ICT firm, June 4, 2004)

"We use the Internet for 90% of our candidates….The Internet accounts for 90% of the jobs we advertise. But then there are a number of jobs which are not advertised at all, where we go out and proactively find the candidates…you contact people and have dialogues and they refer you to other people." (Regional Manager, large personnel services firm, June 10, 2004.)

Finally, the critical role of the member financed, not-for-profit association, the Medicon Valley Academy (MVA), was widely recognized by interviewees.

"The Medicon Vally Annual Meeting is an important event for networking." (Regional Manager, large personnel services firm, June 10, 2004.)

"There are a lot of activities in the cluster, the Medicon Valley Academy, there are a lot of foreign speakers in the region with which it is easy to get in contact with, there is scientific knowledge exchange in these meetings that might lead to collaboration." [Development Director, large biotechnology research firm, June 9, 2004]

Many MVA activities involve the use of an ICT infrastructure, including the development of an extensive Website that promotes the region, disseminates regional and biotech news and reports, lists companies in an online directory, and provides online job listings. Additionally, the MVA organizes many offline activities, including seminars and educational services, conferences and biotech events, and regular member meetings. They also provide substantial support services for firms considering moving to the Medicon Valley, for biotech workers relocating to the area, and for entrepreneurs seeking legal and financial advice. In large part, these are activities that capitalize on the proximity of members in order to benefit the cluster.

Table 3: Descriptive Information on Biotech Industry Support Firms Interviewed

Type of Company	Main products	Market Focus (local vs. non-local customers)	ICT applications
Large ICT firm	Develops ICT solutions for pharma and biotech companies	Danish subsidiary of large global IT supplier. Sells many products to other industry sectors in Denmark, but also selling specialized IT solutions to firms in region	Has a significant internal IT infrastructure, including global network linking operations. Also has extensive Web site, but sees IT solutions for biotech as too complex for Web sales. Mainly used for company information, overview of product line to potential clients to support in-person sales efforts. Sees market for security applications for biotech R&D.
Large personnel services firm	Provides recruitment services, especially for helping recruit scientific staff	Local division of large global employment services company. Emphasis is on recruitment services for biotech firms in the region	Internet used extensively for filling jobs, accounts for 90% of jobs filled. Many portals with CVs. But high level and very specialized jobs filled through personal channels. Relies extensively on email, but only after initial in-person contact to help market services to companies in region, complementary to job fairs, attendance at events like Biotech Forum.
Business Consulting Firm	Provides range of business consulting services, emphasis on strategy, economic issues	Has offices in several countries, small group located in Medicon Valley focusing on gov't and private sector firms region	Internal ICT usage, but limited to email, and traditional communication system connections to clients in region. Extensive use of Web, dissemination of reports online, use of client sites for highlight results of consulting reports. Customer acquisition largely through word of mouth referral, however.
Medicon Valley Academy	Member-financed. Provides range of support services to promote region, including networking, legal advice, events, education, business directory, on and offline publicity	Located in the region, with offices in Lund, Sweden and Copenhagen, Denmark to enable close ties to government affiliated venture capital and support agencies in both countries.	Uses the Web extensively to promote Medicon Valley, maintains an online database of firms in the Medicon Valley, and publishes online newsletters and reports to help publicize regional activities. Has email contacts with members and helps connect members with each other and with external constituents. Also offers job listings online.

5. DISCUSSION

In this section, we revisit the two basic research questions, as well as the expected roles for the ICT infrastructure in clusters generated by our review.

5.1. How do firms embedded in a cluster use public ICT infrastructures?

In the case of Medicon Valley, as expected, all firms benefited from the presence of high quality, broadband Internet access. For the larger firms, fully capable of implementing their own private data communications infrastructure, the public infrastructure clearly supported their ability in the region to support research collaborations with scientists at other smaller firms and at universities. It further enabled better access to research facilities from home, which might, in fact, improve the attractiveness of the firms in the region to biotechnology professionals. We clearly saw that an important aspect of biotech cluster competition is competition for human resources – the clusters that can attract the scientists have an advantage.

Smaller firms heavily depended upon low cost, broadband Internet access. One company reported paying the equivalent of approximately $65 per month for "all the broadband they wanted." Each described the importance of a network connection for business. It enabled low cost and timely communication with distant partners, and facilitated company presentation and promotion online.

Few firms in the cluster had elaborate ordering and payment software systems as expected in a knowledge intensive cluster and. Yet e-commerce of a sort was practiced, even by smaller firms. They received inquiries from non-local customers who saw their Website. They initiated transactions and sometimes took orders via email.

A concern from the review of literature is that better network access might stimulate greater interaction with firms outside the cluster, to the detriment of the cluster. The literature on cluster types (Gordon & McCann, 2000) suggests that this type of effect might be less of an issue with agglomeration clusters, which mainly arise as companies and professionals locate in a place to take advantage of such pooled resources as labor supplies and cultural amenities, and which are not based on stable in-cluster exchanges. This effect should also be limited in social network clusters where close proximity, trust, and prior relations form the basis for exchange. Conversely, it might be more of an issue with classical industrial clusters built on a stable pattern of in-cluster economic exchange, where the primary reason for clustering is to minimize transaction costs. To the extent that improved access to a broadband Internet infrastructure and other ICT applications reduces costs of exchange with distant partners, the cluster is threatened. Our case study only involved one cluster, and discussions revealed that the cluster is oriented towards exporting products – with only a small fraction of output of these firms stays in the region. And clearly, access to a high quality ICT infrastructure supports non-local transactions, even if largely handled in non-automated fashions. Interviewees also stressed the importance of the highly skilled labor force as a reason for the vitality of the region, and mentioned the amenities of the Copenhagen area as a prime factor in attracting biotechnology professionals seeking a high quality of life. It thus has attributes of an agglomeration cluster. However, through the MVA, there are substantial efforts to build social networks within the regions. Hence we might consider the cluster to be something of an agglomeration type, with some aspects of social network clusters., and thus should not be threatened by ICT use.

Indeed, our interviews suggest that the widespread penetration of broadband, and consequent greater use of various Internet based ICT applications poses little danger to the Medicon Valley. There was no evidence of a weakening of the cluster due to increased ICT use. Interestingly, although the ICT infrastructure is used for distant transitions, much ICT use was for the purpose

of local interactions, particularly between the support service organizations and the producers, and between research institutions and the producers. Furthermore, interviewees often described the importance of in-person contact to initiate relationships and generate referrals. Moreover, ICT use with distant suppliers and customers appeared to strengthen the cluster. Larger firms could maintain connections to foreign biotechnology expertise, and as well as to distributors and their own decentralized operations, all while keeping critical research and management staff in the region. Smaller firms also with ties to the region could successfully generate business without having to move closer to their customer bases. These findings are consistent with the findings from cluster researchers who argue that connections to global markets and sources of knowledge strengthen the cluster and ensure a healthy mix of firms and increased innovative capacity (Hicks & Nivin, 2000; Simmie, 2003; Zaheer & Manrakhan, 2001).

The internal benefits of an ICT infrastructure were further highlighted by the role of the MVA, illustrating the interaction between online activities and geographic proximity. Members of the cluster support the MVA in their efforts to promote the cluster. The MVA has helped to build the brand name of the region – The Medicon Valley- and promotes it extensively throughout the world. Their use of ICT serves both a local and distant audience. It encourages connections locally, through online job listings and announcements of events and seminars. But it does not substitute for in-person events and meetings, through which personal connections are made that can lead to research collaborations.

5.2. Under what conditions do small firms benefit from Internet usage in a cluster?

Our second question focused specifically on small businesses and asked whether they benefited from the use of a public ICT infrastructure when located in a cluster. The findings reported here are suggestive of a cluster legitimizing effect that has not been discussed widely in previous cluster research. It was rather surprising to hear that small businesses were able to rely on a crude form of electronic commerce – static presentation of their firm via the Web in order to generate business from customers in other countries. Prior research on e-commerce use by small firms would not lead to this prediction, and instead suggests that such companies - except for those selling niche products otherwise unobtainable in other markets - find it difficult to generate sales online (Steinfield & Klein, 1999; Steinfield *et al*., 1999). The lack of a brand name, technical and financial resources to produce a professional looking online presence, and limited resources for marketing and promotion of their Website all should mitigate against success in attracting remote customers. However, when embedded within a cluster that has become well known in a given industry – essentially the cluster brand is established (Yukawa, 2004) – such remote e-commerce appears feasible for small firms. *Clients find and trust them, and are willing to initiate transactions using the Internet because these small companies are in an established cluster with a strong reputation for excellence in the given industry*.

We now summarize our findings by restating our exploratory propositions, and our tentative conclusions in the context of the Medicon Valley cluster. Proposition 2, suggesting that ICT strengthens rather than weakens a cluster, was supported in the Medicon Valley case over the opposing view in proposition 1. Proposition 3, which proposed that personal interaction in a cluster is a primary form of coordination and collaboration rather than ICT-based automated transactions, was also supported by the interviews in this case. However, given the nature of the products in a biotechnology cluster – where products are not commodities easily bought and sold via electronic commerce, we recognize that this was not the best type of industry in which to test this proposition, so this proposition is clearly in need of further exploration. Our Proposition 4, which proposed that small enterprises in a cluster may experience benefits that might otherwise

not be associated with companies of this size also received support from our interviews in this case. Finally, proposition 5 proposed that there is a role for ICT usage in cluster promotion and development by support agencies. Given the activities of the MVA and other support agencies we identified in the Medicon Valley, this proposition was also supported.

6. CONCLUSIONS

This case study has highlighted the critical role of the ICT infrastructure for industrial clusters, and yielded new insights into how small businesses in particular may benefit. In this particular cluster – a knowledge intensive cluster that does not involve extensive intra-cluster economic exchange - our research supports the proposition that ICT use does not threaten, but rather enhances cluster viability and vitality. It has a centripedal effect in the language of Maignan *et al*. (2003). It further suggests that ICT infrastructure alone would not have the same effect. Rather, it is the interaction between cluster dynamics and ICT infrastructure that produce the types of benefits highlighted above. The research reported here suggests that small firms would not gain as much from the use of the ICT infrastructure if not located in a cluster with a strong reputation. Presence in a branded cluster appears to help remote clients find small companies, and trust them to perform the kinds of activities needed.

These findings are merely suggestive of hypotheses that require further investigation. Nonetheless, such preliminary results, if confirmed in subsequent research, should be encouraging to policy makers who are working hard to ensure high quality broadband infrastructures for economic development. However, the analysis here also warns against isolating the question of ICT infrastructure from other business development policies, and especially from policies designed to encourage the development of clusters in targeted sectors like biotechnology and high technology. The two work in concert, and may not otherwise yield the same benefits.

Our study is clearly limited, in that it is merely one case of one type of cluster, and we were able to conduct only a relatively small number of interviews. As such, we recognize the speculative nature of the findings, and realize that we are merely presenting an opportunity for additional research to confirm the types of effects encountered in this study. Much better tests would involve a contrast of the gains from the use of improved ICT infrastructures obtained by isolated firms with those in established clusters, as well as to explore the differential effects of ICT use among agglomeration, classical industrial districts, and social network oriented clusters.

7. REFERENCES

Andersen, K.V. & Bjørn-Andersen, N. (2001). Globalization and e-commerce: Growth and impacts in Denmark. (http://crito.uci.edu/GIT/Publications) Accessed the 31st of October 2007.

Asheim, B., & Isaksen, A. (2002). Regional innovation systems: The integration of local 'sticky' and global 'ubiquitous' knowledge. *The Journal of Technology Transfer, 27*(1), 77-86.

Audretsch, D. (2001). The role of small firms in u.S. Biotechnology clusters. *Small Business Economics, 17*(1,2), 3-15.

Audretsch, D., & Stephan, P. (1996). Company scientist locational links: The case of biotechnology. *American Economic Review, 86*, 641-652.

Auger, P., & Gallaugher, J. (1997). Factors affecting the adoption of an internet-based sales presence for small businesses. *The Information Society, 13*(1), 55-74.

Bakos, J. Y. (1997). Reducing buyer search costs: Implications for electronic marketplaces. *Management Science, 43*(12), 1676-1692.

Bakos, J. Y. (1998). The emerging role of electronic marketplaces on the internet. *Communications of the ACM, 41*(8), 35-42.

Boston Consulting Group. (2002). *Commercial attractiveness of biomedical r&d in medicon valley: The role of r&d in attracting regional investments*. Copenhagen: Boston Consulting Group.

Breschi, S., & Lissoni, F. (2001). Knowledge spillovers and local innovation systems: A critical survey. *industrial and Corporate Change, 10*(4), 975-1006.

Breschi, S., & Malerba, F. (2001). The geography of innovation and economic clustering: Some introductory notes. *Industrial and Corporate Change, 10*(4), 817-834.

Cairncross, F. (1997). *The death of distance*. Boston, MA: Harvard Business School Press.

Chiesa, V., & Chiaroni, D. (2004). *Industrial clusters in biotechnology: Driving forces, development processes and management practices*. London: Imperial College Press.

Coenen, L., Moodysson, J., & Asheim, B. (2004). Nodes, networks and proximities: on the knowledge dynamics of the Medicon Valley biotech cluster. *European Planning Studies*, 12(7), 1003-1018.

Cooke, P. (2001). Regional innovation systems, clusters, and the knowledge economy. *industrial and Corporate Change, 10*(4), 945-974.

Cooke, P. (2002a). New media and new economy cluster dynamics. In L. Lievrouw & S. Livingstone (Eds.), *The handbook of new media* (pp. 287-303). London: Sage.

Cooke, P. (2002b). Regional innovation systems: General findings and some new evidence from biotechnology clusters. *Journal of Technology Transfer, 27*(1), 133-145.

Dunning, J. H. (2000). Regions, globalization, and the knowledge economy: The issues stated. In J. H. Dunning (Ed.), *Regions, globalization, and the knowledge-based economy* (pp. 7-41). Oxford, UK: Oxford University Press.

Feldman, M. P. (1994). *The geography of innovation*. Boston, MA: Kluwer Academic.

Frank, L. (2002). Biotechnology in the medicon valley. *Nature Biotechnology, 20*, 433-436.

Gaspar, J. and Glaeser, E. L. (1998). Information technology and the future of cities, *Journal of Urban Economics*, 43(1), 136-156.

Gibbs, D., & Tanner, K. (1997). Information and communication technologies and local economic development policies: The british case. *Regional Studies, 31*(8), 765-774.

Gordon, I. & McCann, P. (2000). Industrial clusters: Complexes, agglomeration and/or social networks? *Urban Studies*, 37(3), 513-520.

Granovetter, M. (1985). Economic action and social structure: The problem of embeddedness. *The American Journal of Sociology*, 91(3), 481-510.

Grudin, J. (1994). Computer-supported cooperative work: Its history and participants. *IEEE Computer, 27*(5), 19-26.

Hicks, D. A., & Nivin, S. R. (2000). Beyond globalization: Localized returns to it infrastructure investments. *Regional Studies, 34*(2), 115-127.

Howells, J. (1996). Tacit knowledge, innovation and technology transfer. *Technology Analysis and Strategic Management, 8*(2), 91-106.

Hudson, H. E. (1984). *When telephones reach the village: The role of telecommunications in rural development*. Norwood, N.J.: Ablex Publishing Corp.

Ihlström, C., Magnusson, M., Scupola, A. & Tuunainen, V.K. (2003). SME barriers to electronic commerce adoption, Nothing changes - everything is new, in G. Gingrich (Ed.), *Managing IT in government, business and communities*, IDEA Group Publishing, USA.

Johnston, R., & Lawrence, P. (1988). Beyond vertical integration: The rise of the value-added partnership. *Harvard Business Review*, 94-101.

Jussawalla, M., & Lamberton, D. (1982). Communication economics and development: An economics of information perspective. In M. Jussawalla & D. Lamberton (Eds.), *Communication economics for development* (pp. 1-5). Sydney: Pergamon Press.

Keeble, D. & Wilkinson, F. 1999. Collective learning and knowledge development in the evolution of regional clusters of high technology SMEs in Europe," *Regional Studies*, 33(4), 295-303.

Kraut, R. (1989). Predicting the use of technology: The case of telework. In R. Kraut (Ed.), *Technology and the transformation of white-collar work* (pp. 113-133). Hillsdale, NJ: Laurence Erlbaum.

Kraut, R., Steinfield, C., Chan, A., Butler, B., & Hoag, A. (1999). Coordination and virtualization: The role of electronic networks and personal relationships. *Organization Science, 10*(6).

Kumar, K., van Dissel, H., & Bielli, P. (1998). The merchant of prato -- revisited: Toward a third rationality of information systems. *MIS Quarterly, 22*(2), 199-226.

Lam, A. (2000). Tacit knowledge, organizational learning and societal institutions: An integrated framework. *Organization Science, 21*(3), 487-513.

Leamer, E. E., & Storper, M. (2001). The economic geography of the internet age. *Journal of International Business Studies, 32*(4), 641-665.

Lemarie, S., Mangematin, V., & Torre, A. (2001). Is the creation and development biotech SMEs localised? Conclusions drawn from the French case. *Small Business Economics, 17*(1,2), 61-76.

Maignan, Pinelli, D. & Ottaviano, G., (2003). ICT, clusters and regional cohesion: a summary of theoretical and empirical research, Nota di Lavoro, Fondazione Enrico Mattei 2003.58, accessed at http://papers.ssrn.com

Mansell, R., & Wehn, U. (1998). *Knowledge societies: Information technology for sustainable development*. New York: Oxford University Press.

Markusen, A. (1996). Sticky places in slippery space: A typology of industrial districts. *Economic Geography, 72*, 293-314.

Maskell, P. (2001). Towards a knowledge-based theory of the geographical cluster. *Industrial and Corporate Change, 10*(4), 921-944.

Moodysson & Jonsson (2007). Knowledge collaboration and proximity: The spatial organization of biotech innovation. *European Urban and Regional Studies,* 14(2), 115-131

Moss, M. (1987). Telecommunications, world cities, and urban policy. *Urban Studies, 24*(6), 534-546.

NTIA. (2004). *A nation online: Entering the broadband age*. Washington, D.C.: National Telecommunications and Information Administration.

OECD. (2001). *The development of broadband access in oecd countries* (No. DSTI/ICCP/TISP(2001)2/FINAL). Paris: Organization for Economic Cooperation and Development.

OECD. (2004). *Ict, e-business and smes* (No. DSTI/IND/PME(2002)7/FINAL). Paris: Organization for Economic Cooperation and Development.

OECD. (2007). OECD broadband statistics. http://www.oecd.org/sti/ict/broadband. (accessed February 1 , 2008).

Parker, E. B., Hudson, H. E., Dillman, D. A., Strover, S., & Williams, F. (1995). *Electronic byways: State policies for rural development through telecommunications* (2nd edition ed.). Boulder, CO: The Aspen Institute.

Polyani, M. (1967). *The tacit dimension*. New York: Anchor Books.

Porter, M. E. (1990). *The competitive advantage of nations*. New York: Free Press.

Porter, M. E. (1998). The adam smith address: Location, clusters, and the "new" microeconomics of competition. *Business Economics, 33*(1), 7-13.

Porter, M. E. (2000). Location, competition, and economic development: Local clusters in a global economy. *Economic Development Quarterly, 14*(1), 15-34.

Porter, M. E. (2003). The economic performance of regions. *Regional Studies, 37*(6&7), 549-578.

Powell, W. W., Koput, K. W., Bowie, J. I., & Smith-Doerr, L. (2002). The spatial clustering of science and capital: Accounting for biotech firm-venture capital relationships. *Regional Studies, 36*(3), 291-305.

Powell, W. W., Koput, K. W., & Smith-Doerr, L. (1996). Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. *Administrative Science Quarterly, 41*(1), 116-145.

Rogers, E., & Larsen, J. (1984). *Silicon valley fever: Growth of high-technology culture*. New York: Basic Books.

Saxenian, A. (1994). *Regional advantage: Culture and competition in silicon valley and route 128*. Boston, MA: Harvard University Press.

Saxenian, A., & Hsu, J. Y. (2001). The silicon valley-hsinchu connection: Technical communities and industrial upgrading. *Industrial and Corporate Change, 10*(4), 893-920.

SBA. (1997). *The economic impact of small businesses*. Washington, D.C.: Small Business Administration.

Schultze, U., & Orlikowski, W. (2002, December). *When complementarity is not enough: The implications for unbundling services in the internet era*. Paper presented at the International Conference on Information Systems, Barcelona.

Scott, A. J. (2000). Economic geography: The great half-century. *Cambridge Journal of Economics, 24*(4), 483-504.

Scupola A. & Steinfield, C. (2008) The role of a network organization and Internet-based technologies in clusters: The case of Medicon Valley. In Fuglsang L. (Ed.), *Innovation and the Creative Process* (pp. 193-211). London: Edward Elgar.

Simmie, J. (2003). Innovation and urban regions as national and international nodes for the transfer and sharing of knowledge. *Regional Studies, 37*(6&7), 607-620.

Sinai, T. & Waldfogel, J. (2004). Geography and the Internet: is the Internet a substitute or a complement for cities? *Journal of Urban Economics*, 56(1), 1-24.

Steinfield, C. (2004a). Explaining the underutilization of business-to-business e-commerce in geographically defined business clusters: The role of social capital. In M. Huysman & V. Wulf (Eds.), *Social capital and it* (pp. 209-229). Cambridge: MA: The MIT Press.

Steinfield, C. (2004b). Situated electronic commerce: Toward a view as complement rather than substitute for offline commerce. *Urban Geography, 25*(4), 353-371.

Steinfield, C., & Klein, S. (1999). Local vs. Global issues in electronic commerce. *Electronic Markets, 9*(1/2), 45-50.

Steinfield, C., Kraut, R., & Plummer, A. (1995). The effect of networks on buyer-seller relations. *Journal of Computer Mediated Communication, 1*(3).

Steinfield, C., Mahler, A., & Bauer, J. (1999). Electronic commerce and the local merchant: Opportunities for synergy between physical and web presence. *Electronic Markets, 9*(1/2), 51-57.

Steinfield, C., & Whitten, P. (1999). Community level socio-economic impacts of electronic commerce. *Journal of Computer Mediated Communication, 5*(2).

Storper, M. (1995). The resurgence of regional economies ten years later: The region as a nexus of untraded interdependencies. *European Urban Regional Studies, 2*, 191-201.

Storper, M. & Venables, A. (2004). Buzz: Face-to-face contact and the urban economy. *Journal of Economic Geography*, 4(4), 351-370.

Thong, J.Y.L. (2001). Resource constraints and information system implementation in Singaporean small businesses. *The International Journal of Management Science*, 29, 143-156.

Thong, J.Y.L., Yap, C-S. & Raman, K.S. (1996). Top management support, external expertise and information systems implementation in small businesses, *Information Systems Research*,7 (2), 248-267.

Tornatsky, L., & Klein, K. (1982). Innovation characteristics and innovation adopting-implementation: A meta-analysis of findings. *IEEE Transactions on Engineering Management, 29*, 28-45.

Turner, C. (2003, September 19-21). *New media industries: A quantitative research study*. Paper presented at the Workshop on ICTs and Business Clusters at the International Conference on Communities and Technologies, Amsterdam, The Netherlands.

Uzzi, B. (1996). The sources and consequences of embeddedness for the economic performance of organizations: The network effect. *American Sociological Review, 61*(4), 674-698.

Veltz, P. (1997). The dynamics of production systems, territories, and cities. In F. Moulaert & A. J. Scott (Eds.), *Cities, enterprises and society on the eve of the 21st century*. London: Pinter.

Westfall, R. (2004). Does telecommuting really increase productivity. *Communications of the ACM, 47*(8), 93-96.

Wolff, M., F. (2003). Biomedical cluster blossoms in scandinavia. *Research Technology Management, 46*(4), 2-4.

Yukawa, K. (2004). *Internet companies in japan after the collapse of the internet bubble: An analysis of internet companies and their cluster*. Tokyo: Fujitsu Research Institute.

Zaheer, S., & Manrakhan, S. (2001). Concentration and dispersion in global industries: Remote electronic access and the location of economic activities. *Journal of International Business Studies, 32*(4), 667-686.