

The impact of geographical proximity and technology on firms' R&D-operations

Martin Johanson

Department of Business Studies, Uppsala University

Box 513, 751 20 Uppsala

Martin.johanson@fek.uu.se

and Department of Social Sciences, Business Administration, Mid-Sweden University

Heléne Lundberg

Department of Social Sciences, Business Administration, Mid-Sweden University

Abstract

This paper deals with firms' R&D-operations and how they are influenced by geographical proximity to other firms and organizations and the firm's technology. The paper discusses geographical proximity as geographical distance to business partners like customers and suppliers and to universities and other types of academic research institutes. The firm's technology is analyzed in terms of either an incremental and gradual development in small step or a rapid and step-wise development. A model combining these two aspects are presented in the paper and subsequently applied on a sample of 37 high-technology firms in the Swedish region of Mälardalen. The paper concludes that both these two dimensions have an impact on the firms' R&D-operations, depending on the firm's size, age and industry.

Keywords: geographical proximity, network, technological development, industry, knowledge, research and development

Introduction

That firms tend to aggregate in clusters has been known and discussed for a long time. However, standard agglomeration theory still followed neoclassical economics in regarding even aggregated firms as atomistic competitors. Later on, modern industrial district theory focused on the regional aspect and brought the interdependence among firms into focus stressing flexible firm boundaries, co-operative competition and trust as facilitators of learning and knowledge development (Harrison 1992). Industrial district theory regards spatial proximity as the basic success factor of regional cluster as it facilitates personal interaction. Personal interaction in various circumstances and settings form a social embeddedness that in turn facilitates a development of trustful relationships. Colleagues in related firms are however only one of several potential sources of proximity advantages. A firm may be situated in geographical proximity of related firms: similar firms, complementary firms, customers or suppliers, unrelated firms, universities and research institutes etc. Different kinds of advantages, or disadvantages, can be expected for different categories of geographical proximity. Furthermore, the value of a location in geographical proximity of a certain category may vary across industries. A number of studies have been undertaken regarding the value of different objects of proximity. However, most research has been carried out in one kind of industry at a time.

Empirical studies of industrial districts have focused on two kinds of industries: high technology and crafts (Wilson 1995), but there is a lack of empirical research comparing networking across industries at firm level. A preliminary comparison of the results presented so far indicates that networks in different industries are different but we lack studies looking further into this question (Neergaard 2000). Further research on knowledge spillovers from science to industry that distinguish between different fields of technology has been asked for (Cantwell and Piscitello 2005). We know that industrial contexts differ in terms of velocity of change,

production processes and processes for knowledge development. There is thus reason to believe that the advantages or disadvantages of being in geographical proximity of the various categories of objects will vary across industries.

The IMP tradition argues that relationships with other actors are conducive to the development of technology (e.g. Håkansson, 1987). New technology builds on knowledge of different resources and activities, which implies that access to knowledge is a critical factor for R&D. Interaction and cooperation between both business actors, like customers and suppliers, and non-business actors, like, for instance, universities, can be important mechanisms for development of technology (Håkansson, 1989; von Hippel, 1988, 1994).

This paper aims to discuss effects of geographical proximity, in terms of relationships with customers, suppliers, universities and research institutes, on the firm's learning and knowledge development and hence we focus on the research and development. Moreover, we discuss how the firm's technology is related to the R&D-operations of the firm. We explore findings made in economic geography, which argues that geographical proximity is a critical factor, and combine this with the IMP tradition's key concepts like interaction, cooperation and network in order to apply on R&D activities in high technology industries the Swedish region of Mälardalen*.

Dimensions of proximity

A particular focus in the industrial district theory is given to the value of geographical proximity among related firms for inter-firm learning and knowledge development (Becattini 1991; Lazerson and Lorenzoni 1999; Polenske 2004). However, geographical proximity is relative and its impact on opportunities for interaction is dependent on factors like communications and regulations. For example, two firms located on either side of a border between countries may be very close in spatial terms but if there is no road connecting them and/or if administrative procedures hamper border crossing the time elapsed for moving from one firm to the other may still be greater than for a journey between two more distant but more smoothly connected locations. Geographical proximity is moreover a subjective concept. It is dependent on judgments by individuals based on objective data (km, time, price) but also on subjective perceptions (Torre and Rallet 2005).

Furthermore, spatial proximity is only one aspect of proximity that may affect relationships. Firms may in addition be more or less close to each other in other dimensions. Several other aspects of proximity/distance have been identified: for instance social, cultural, technological and time distance (Ford 2002) and in addition organizational, and electronic aspects (Polenske 2004). Some argue that the correct measure of proximity is a psychological one and not a physical one (Markgren, 2001) and that distance has advantages in terms of variety and opportunities (Lazerson and Lorenzoni 1999; Markgren 2001). On the other hand there are several researchers who argue that vicinity has a several advantages (Feldman 1999); a line of arguing that is referring back to Marshall (1970 [1923]). It discusses opportunities for cost reduction based on economies of specialization, labor market economies and knowledge spillover effects. Another effect of localized advantages that has been presented is the so-called urbanization effect that takes place when cross-fertilization among technologies and sectors is advantageous for knowledge development and innovations.

The different types of proximities have in common that they reduce uncertainty as well as facilitate coordination, interactive learning and innovation. It is likely that other types of proximity may compensate for a lack of geographical proximity. In business network theory

* The region of Mälardalen consists of the five Swedish counties (län) Stockholm, Södermanland, Uppsala, Örebro and Västmanland. It has a population of approximately three million people, which is about a third of Sweden's total population.

(IMP Group 2002), what is stressed is not geographical proximity which often is more exception than rule in business relationships, but rather relational (organizational, cultural, technological and mental) proximity. Relational proximity is regarded as an important source of competitiveness. It is acknowledged that a development of relational proximity can be facilitated by geographical proximity as face-to-face interaction can take place more often but geographical proximity has not the status of a requirement. The most important aspect of geographical proximity may be to strengthen the impact of the other aspects although too much proximity in any aspect may be detrimental due to lock-in effects (Boschma 2005).

Geographical proximity to other firms and organizations

Co-operation and trust among firms that are co-localized within a particular region cannot be taken for granted. Lazerson and Lorenzoni (1999: p 250, 251) studied the Italian industrial district Castel Goffredo and concluded that:

Cooperation and trust among firms in the district appear to be in large measure an outcome of the process of reciprocal relations that individual firms have constructed over time with each other, much more than it is a resource buried in the district's substratum readily accessible to all of its denizens.

If clusters are analyzed from the point of view of geographical proximity and local environment conditions only there is furthermore a risk that they are portrayed like isolated and self-sufficient entities. Lazerson and Lorenzoni identify advantages of proximity arguing that "proximity produces spontaneous social and professional interaction ... facilitating the diffusion of information". However, they warn against an "over-socialized" view where behavior is regarded as automatic and the result of socialization processes only (Granovetter 1985). Moreover, like for instance Cantwell and Iammarino (2001), they stress the importance of large firms arguing that large firms have several contacts outside the region bringing them in touch with other stimuli than the ones circulating within the community. Having a co-coordinating role in economic activities within the region the large firms will diffuse new knowledge and ideas to their sub-contractors in the community. Without such external influences there is a risk of inertia, stagnation and eventually decline. These observations bring Lazerson and Lorenzoni to the conclusion that:

[I]f successful industrial districts are as much a product of large firms diffusing technology and knowledge at the local level as they are of historical path dependencies and imagined cultural communities, then the promise of reproducing them tomorrow in economically underdeveloped areas is all that much greater (p. 259).

However, in theories on agglomeration, geographical proximity among related firms is mostly supposed to be advantageous in terms of knowledge spillovers in informal networks (Saxenian 1994) in addition to economies of specialization and labor pooling (Maskell 2001). On the other hand, there may also be a negative side of this as knowledge is spread in spite of attempts to prevent information leakage and losing key employees to competitors may be disruptive for a focal firm.

The advantages of proximity to a university may be twofold. First, firms may profit from access to students in search of future employers. Universities may thus contribute to a development of a common and well-educated labor pool. Second, presence of a university may imply formal or informal access to researchers and research data. It has furthermore been argued that public research organizations favor open access and thus act more like "sprinklers" irrigating a broader community whereas information transfer within partners in a business relationship may be more closed to the parties in question (Owen-Smith & Powell 2004).

Is knowledge transferability related to geographical proximity?

It is often argued that one of the most significant cluster advantages is that knowledge can be more easily transferred among co-localized firms within a cluster than over large geographical distances. Within clusters, the knowledge transfer may be purposely undertaken or an involuntary or even unwanted spillover effect of co-localization, labor mobility and social interaction (Albino, Garavelli and Schiuma 1999; Boari and Lipparini 1999; Maskell 2001). Labor mobility may contribute to knowledge diffusion by rendering possible new combinations of knowledge and benefit a diffusion of tacit knowledge, in particular when individuals, who are central to knowledge development processes change locus of employment.

It has however been questioned whether knowledge is freely available in the form of spillovers to all firms in the cluster or restricted to certain epistemic communities that may go beyond the cluster: for instance including test customers outside the region (Breschi and Lissoni 2001; Lissoni 2001). However, Lissoni (2001) admits a lack of data on indirect links among the community members. Breschi and Lissoni furthermore argue that knowledge spillover effects often are used as explanations for patterns of strong geographical concentrations of innovative activities on loose grounds. They suggest alternative explanations in the form of "pecuniary" externalities like contractual arrangements. For instance, they argue that increased innovative activities in the vicinity of universities does not have to emanate from spillover effects; there may be contractual arrangements among the universities and certain firms in the surrounding area governing the knowledge exchange on a pecuniary basis.

In a recent study Cantwell and Piscitello (2005) found that intra- and inter-industry spillovers were highly region specific, and thus declining with distance, while the distance effect was less for science-technology spillovers from universities and other sources of publicly funded R&D. This finding give rise to the question if the information transmitted from the university is of a different character than intra- or inter-industry spillovers or if the relationships underlying the spillovers make the difference?

Like Lazerson and Lorenzoni (1999), Bathelt (2005, p. 109) underlines the importance of firms having contacts that are external to the region. He uses the term pipelines in accordance with Owen-Smith and Powell (ref) for trans-local contacts and the term buzz for local interaction giving rise to intended and unintended learning processes in organized and accidental meetings, arguing that "the actors contribute to and benefit from this buzz by just 'being there'". However, he points out that local buzz is no automatic response to co-location, nor is all buzz equally relevant to the firms in the region. Furthermore, he argues that some industries may benefit from more local buzz while other may be more dependent on pipelines for relevant information. The reason presented is that the knowledge flows and interactions differ between the two channels as trans-local pipelines are planned in advance and targeted towards certain, often predefined goals while local buzz is spontaneous, automatic and non-specified.

It may be tempting for a firm to rely on local buzz only as it is more easily accessible, and therefore less costly, than trans-local pipelines. However, while a single firm may rely on the local buzz as a conveyer of information about region-external development, the region as a whole cannot. According to Bathelt (2005), some firms in the region have to establish pipelines in order to facilitate and stimulate an inflow of external information. Otherwise there will be a risk of over-embeddedness, lock-in effects and eventually a risk of stagnation.

The impact of geographical proximity and the technological development of the firm on the R&D activities

There are thus reasons to assume that a firm's R&D-operations in different degrees are contingent on the geographical proximity to other firms and organizations, but also on the firm's own technology. Proximity is here defined as the geographical distance, and we would like to

underline that it is not only a question of being co-localized, but to which extent the firm performs joint projects and to which extent the firm has relationships, which are important for R&D. We mean that a firm's R&D can be more or less locally embedded in relations to customers, suppliers, research institutes, universities and other organizations, which are instrumental for the firm's R&D.

A firm's R&D does not take place independent of what technology the firm possesses and how it develops. The firm's R&D is path-dependent of its existing knowledge, competence, production process and products and how fast they are developing. One can here divide technologies in two categories; the first one is the technology, which develops gradually and in small and incremental steps evenly distributed over time. This concerns both products and production technologies. On the other hand, a firm's technology can also undergo rapid and step-wise changes. In the light of this discussion, we propose four R&D-situations, based on, on the one hand, the degree of geographical proximity to other firms and organizations and its importance for R&D, and, on the other hand, the firm's technological development, which can be described and be placed on a continuum stretching from incremental and gradual to rapid and step-wise (see figure 1).

Geographical proximity to other firms and organisations	High	3	4
	Low	1	2
		Incremental	Fast, step-wise

Technological development of the firm

Figure 1. Four combinations of geographical proximity and technological development

Cell 1 reflects a situation where low geographical proximity to other firms and organizations is important for the firm's R&D, while, at the same time, the firm's technological development is incremental and gradual. In this situation, several reasons can be singled out. One reason could be that improved transportation facilities and information technology makes interaction across regions increasingly fast and smooth. Firms can therefore form co-operative relationships over long distances when needed. R&D processes are thus undertaken in cooperation with customers outside the region. However, since the technological development is slow and gradual, R&D is a question of long-term processes. It is likely that one here can find firms with mature technologies, where it takes a long time to acquire the skill and experience needed to do R&D. People and departments involved in R&D therefore tend to be highly specialized, which, in turn, excludes a lot of potential R&D-partners. A big part of the R&D takes place in house.

Cell 2 is a situation where low geographical proximity and fast, step-wise technological development prevail. Disadvantages of distance like decreased opportunities for face-to-face interaction and co-ordination can partly be overcome by integrating rules and practices of the organizations, supported by personal interaction when needed as the staff may travel for shorter or longer periods to other locations. Knowledge may furthermore be fairly easily exchanged even over long distances. In this situation knowledge related to R&D can relatively cheaply be codified and packaged, which, in turn, means that the firm's R&D can be dispersed over big areas. This combined with the fact that the technological development is rapid and step-wise

stimulates the firm to search for R&D-partners far away. Moreover, critical customers and suppliers can be localized remote from the firm's R&D-operations. ´

A completely different situation is represented by *Cell 3*, where there is a high geographical proximity to firms and organizations, which are important for the firm's R&D-operations and that firm's technology, can be described as undergoing an incremental and gradual development. This situation resembles a lot of studies made in the tradition of industrial district and cluster theory. Usually, the firm is still localized to the place, where it has its roots, which could, for instance, be related to raw material, or specific and beneficiary transportation or communication. Another reason could be a big and dominant firm, which have a few or several local suppliers, which are involved in the R&D-operations.

Cell 4, finally, is a situation, where high geographical proximity to other firms and organizations is important for R&D and where the firm's technology is developing in a fast and step-wise process. As the technology is developing fast the firm's own knowledge is not enough, but instead a regular influx of new, and sometimes unexpected, knowledge, are favorable for the R&D-operations. Another aspect in this situation is need of constant interaction between the firm and other organizations, which is much easier to secure if the organizations are co-localized.

Research method

Results from a study of 37 firms are presented. Firms were chosen by means of a strategic selection procedure, 25 from the Stockholm County and 12 from 4 surrounding counties. The study was part of a larger study, undertaken with a broad area of research questions in mind. The aim was therefore to get a heterogeneous sample with firms of varying size and age, from various industries and with different kinds of ownership and markets. However, the majority of firms represent IT, electronics, pharmaceutical industry and manufacturers of instruments for the pharmaceutical industry (see Table 1). These industries are often called high-technological or R&D-intensive. The interviews have been carried out in Sweden. Swedish proprietary laws give researchers at academic institutions the patent rights to their discoveries while in the USA the rights stay with the university. This difference may affect the generalizability of the results.

Table 1. Sample of the study

Industry	Size	Small	Medium	Big
Biotechnology		Cyto Genomics, Neuronova, Radi Medical	Biovitrum, Medivir, KaroBio, Biotage	AstraZeneca, Amersham, AGA-Linde
IT / Electronics		Senseboard, Activio PrintDreams, Olsbergs,	Micronic Laser Systems, Note, CC Systems	Ericsson
Chemistry				Casco/Akzo Nobel
Engineering			SPM, Aura Light Group, EMBA	Scania, Seco Tools, Bombardier, Metso
Wood, paper and pulp				Hallsta
Food				Cerealía
Energy		Cellkraft, Solibro, Seabased Energy		Vattenfall
Construction				NCC
Services		Ergonomidesign, BEPAB		Folksam
Raw material				SSAB

The majority of the interviews were carried out with managers of research and development, but in some cases, managing directors, production managers and a human resource manager were interviewed depending on the situation at hand. In total 40 interviews were completed. The interviews were guided by some prepared questions, ranging from general to more specific subjects. However, the form of the interview was a dialogue that allowed for departures from the prepared set of questions. We did not use tape-recorders, but instead, we took notes and the interviews have been fully transcribed. Some quotes are presented in the paper as an illustration of characteristic views. The quotes are however not word-by-word cited but encompass the substance of the stand taken.

Research findings

Geographical proximity and R&D

It usually gathered that since cooperation and interaction with other firms, organizations and institutions is such an important factor for most R&D, being co-located enhances R&D. The firm's revenues come from the customers, which means, that it is essential that the results of the R&D satisfies the customers' needs and from that follows that it should be an advantage to have the customers closely located. Co-localization should enhance the transfer of information about the customers' needs and the suppliers' capabilities. The customers in general are by almost all firms in the study viewed as an important factor for R&D and in this respect three types of customers can be singled out:

1. Customer as a source for identification of needs that R&D can satisfy
2. Customers as buyers of the results produced by R&D
3. Customers as active cooperative partners in R&D

The most important role played by the customers is as an input of ideas. Several firms have developed procedures or routines for how to identify the needs of the customers. Identification of needs that can be transformed into ideas for R&D departments is the most common function fulfilled by the customers. This role is played by the customers in almost any industry and in many cases; the R&D process starts with the customers and ends with the customers, when the results of the R&D process is tested on the customer.

The customers are important for R&D, but they never participate in the actual process. It's a circle, which goes round and round. Input comes from our customers and our sales companies. Our R&D is basically business-driven. The customers are part of the process in the beginning and in the end. No physical representatives from the customers are ever part of our research here. (Big mechanical engineering firm)

The second type of customer was rare in the sample and concerns those customers who appear when the results are achieved. They buy the results in terms of patent or license in order to produce and supply the end-user. This is, for instance, common in the biotechnology industry, but rare in almost all the other industries. The third types of customers are also relatively rare. Irrespectively of industry, firms have not so many customers with whom they run R&D projects and in the case where it happens, most firm keep the customer distant from the concrete R&D operations. For instance, there were quite few firms that actually invited representatives from the customers to physically take part in the R&D and if this happens, it is not customers as a group in general, but one or two very specific and important customer in terms of sales volume, size ort competence.

However, in the sample of the study, most of the firms have an export share of more than 75 %, which means that, in most cases, the firms' market is located far away from the firm. Thus, R&D-intensive firms tend to have few local customers, though the customers are important for

R&D, but they are very seldom involved in the R&D-process, which seems to be the case irrespectively of age, size and type of industry.

Among the firms in the sample R&D cooperation with suppliers was even less common than cooperation with customers, although the suppliers in bigger extent than the customers are located to the Mälardalen region. Suppliers are regarded as rather unimportant for R&D. We see this as an interesting observation since all firms can be viewed as suppliers and since they view customers as a critical source for identification of ideas. This also means that the firms in the sample do not have formal or long-term cooperation with suppliers on R&D. The dependence on local suppliers in general was biggest among firms in the IT-sector or for those firms, which in some respect are dependent on raw material from Sweden, although the data do not indicate that their suppliers, neither with local or more remote located suppliers, are more involved in the R&D activities of the firms.

We have among other things important suppliers of prototypes, models and other services in Stockholm. (Small service firm in the IT-industry).

This region supplies us with a big part of the raw material that we need. It is strength to be close to both our supply and sales market. Localization is thus a question of logistic: The big roads and railways. (Big food-processing firm).

Academic research and the universities, in general, are important for the firms in the sample. Most of the firms have some contacts or cooperation with universities. For some of them, the cooperation consists just of giving guest lectures or recruiting employees from the universities. Several firms give research grants to research projects or specific doctoral students. The biotechnological firms, both producers of instruments and pharmaceuticals, cooperate extensively with the leading universities in the region like Karolinska Institutet and Uppsala University, while the firms which are spin-offs from the universities have cooperation with their home universities, which is especially the case with the Royal Institute of Technology in Stockholm, Uppsala University and Karolinska Institutet. However, for most other firms, universities in other regions of Sweden are more important for R&D. Chalmers University of Technology in Gothenburg, Lund Institute of Technology and Linköping University are for most other firms as important for R&D as the universities in the region of Mälardalen.

For researchers in the pharmaceutical and biotechnology spheres of interest, their personal networks at the local universities were reported to be of outmost importance. Several informants stated that frequent contacts with university researchers were necessary for their research process. However, these firms also tend to have a larger international spread of R&D than the firms in heavier industry.

75% of our cooperation with academic institutions is within Sweden. When you're cooperating it's essential to have frequent contacts and to create personal ties to other researchers. If one of our researchers has a problem that he can not solve, he can check if other researchers have useful knowledge and contact them. Research-cooperation with counterparts in USA is mainly done through "cherry-picking": you identify certain researchers and research groups that you would like to cooperate with. In Sweden we try to secure recruitment during longer periods of time. (A large biotech firm)

The university hospitals are important for us. They are researchers and customers at the same time. They are also important references when we are selling large systems. (Medium-sized producer of medical instruments).

The place is very important for research and development. Here has Alfa-Bio been an important driving force. The University is also of great importance. We have been cooperating with both. We also have an accepted entrepreneurship; large, strong networks of competence; technical

and business experience. Taken together, there is a critical mass of humans and companies, which make it live its own life. (Medium-sized producer of medical equipment)

While the pharmaceutical sector has experienced rapid knowledge development in close contact with academic research, the mechanical engineering industry and automotive industry seem to be characterized by incremental knowledge development with less connection to academic research.

Our contacts with the academic society are limited to employing Masters of engineering. (Middle-sized mechanical engineering firm)

This difference in using academic research may partly be explained by the difference in technology. The informants from the mechanical engineering industry and the automotive industry stressed that up-scaling from laboratory research to industrial production is a problem and that development rather takes place incrementally.

It is hard to transfer laboratory experiments to large scale trials within production industry. Large scale trials are very costly and the cost acts as a barrier for trying. (A large mechanical engineering firm)

In contrast to the impact of geographical proximity to customers and suppliers, where the importance were low among all firms, the situation concerning the impact of geographical proximity to academic research differed among the firms in the study. Their importance differed depending on the size of the firm, type of industry and age of the firm. The firms, which seem to be mostly dependent on geographical proximity to academic research, were small and young start-up firms in the pharmaceutical and biotechnology industry. Among the firms studied in this sample there was furthermore a relationship between firm size, technological change and cooperation with academic research. The smaller the firm and the more dynamic the industry the more important was cooperation with other actors for R&D. Several of the smaller firms in medicine and biotech were founded by academic researchers. For them the links to the academy were of utmost importance as sources of information and knowledge but also as a way to improve legitimacy. Legitimacy increases when firms are able to refer to well-known and respected academic researchers thereby improving opportunities for funding and gaining acceptance for a new technology. Furthermore, small firms lack the resources necessary for conducting the necessary R&D in house. Firms from other industries and not so newly started tended to be less dependent on academic research. The firms in mechanical engineering, automotive, paper and pulp industries, which had close relationships with academic research, were cooperating more extensively with universities in other parts of Sweden than in the Mälardalen region.

Technology development and R&D

Most firms could be divided into two main categories: firms representing industries characterized by incremental technological development and firms representing industries characterized by rapid, step-wise technological development. Moreover, it seems that this difference also has a consequence on the link between R&D and production. Two typical quotations, representing the incremental technology development, are the following:

It is all about successive improvements regarding toughness, hardness, evenness and other characteristics worth striving for. Hand in hand goes process development, a prerequisite for better and more even products. Our own development is often about improving the performance of our own equipment, for instance regarding precision. (A large raw material-based firm)

Our products are based on established construction techniques. There are rarely any large amounts of innovative thinking involved. (A small electronics firm)

Despite the increased formalization of R&D in the Swedish economy, the data show that it is not a homogeneous activity. Instead, it seems that the character of R&D depends on the character of the technology used in the firms. The dynamics of the firm's technology influences the nature of R&D. Several firms emphasize patience and the gradual development as the most typical aspects of their technology. Small components of knowledge are added to the already used knowledge, while informants from other firm mean that the development is characterized by rapid and big steps combined by unplanned and unexpected events and discoveries. Moreover, there is a strong link between the technology used and R&D, which means that production and R&D are not separated activities, but integrated and interdependent. However, also in this respect it seems that there are differences between industries. For instance, in the biotechnology industry the link between production and R&D seems to be much weaker than in, for instance wood-processing and paper and pulp and engineering. On the other hand, the data propose that R&D in the biotechnology is closer linked to academic research than almost all the other industries.

Informants representing firms from the automotive industry, mechanical engineering, paper production and the packaging industry stressed the link between existing technology and research. Continuous interaction between technology in use and research generates an iterative process, often referred to as "long-term and patient work in small steps". In these firms research takes existing production, technology and markets as a starting point and research findings have to fit in with existing structures of technology, products, productions methods and human resources.

Our industry is based on traditional, established technique. Customer requests are extremely stable and it concerns a 100 years old product. There are no great leaps but a gradual development. Still, within the slow movement there are thousands of product changes per year. This is all very complicated and takes large systems to handle. It would be a given failure to separate R&D from production, we do not even think about it. (A large mechanical engineering firm)

Incremental development of technology makes production dependent on the character of R&D, which, in turn, ties R&D locally to production. It thus seems that in certain sectors of industry, like the mechanical engineering industry, knowledge is largely experience based, local and tacit: hard to articulate and transfer. A newcomer then needs a long time for learning the logic of a specific workplace. On the other hand, there are sectors, like the pharmaceutical and biotech industries, to a large extent building on received cumulative knowledge known to everyone in the business. These differences may be an effect of industries and technologies being in different stages of development, needing different kinds of knowledge and knowledge development processes for future development.

Discussion

Geographical proximity to a research centre had a varied importance for the firms in the study. For the firms in industries with a rapid technological development, geographical proximity to a research centre is regarded as being of importance. The specialization of academic researchers is regarded as an advantage since the firms cannot be at the research frontline of all subjects that may be useful components of their R&D. These firms furthermore saw an advantage in co-location with related firms within the same region. However, for the firms in industries with rapid, step-wise changes these advantages of co-location are not enough. They need both local buzz and long-distance pipelines. In additions to their local relationships they identify and cooperate with suitable partners world-wide .Long-distance relationships can here be viewed as

“cherry picking” while local relationships are undertaken at a broader scale. This indicates that long-distance relationships are more resource demanding to uphold and therefore need to be more deliberately and selectively chosen. They are used, when needed, to complement the knowledge that is locally available. It does not have to imply a choice between tacit or codified knowledge so that a transfer of tacit knowledge is dependent on face-to-face interaction. If what you need is available close by, that is the most convenient and cost-efficient solution. The lack of geographical proximity is manageable for researchers within a particular discipline (Cowan, David and Foray 2000). Within the community the common background form a tacit base that allows for knowledge exchange over long distances. Other aspects of proximity like cultural proximity, relational proximity or technological proximity may compensate for a lack of geographical proximity (Ford 2002; Polenske 2004).

The firms representing gradually developing industry form a striking contrast. They saw no major advantage in being co-localized with academic research as they regard academic findings too specialized and theoretical to be applicable in their processes. They regard thorough knowledge own their own products, processes and logics as essential. Their learning and knowledge development takes place in interaction and is based on thorough knowledge of present conditions. To develop this knowledge is time-consuming and the investment is lost when an employee leaves the firm. Instead they get most of their input for R&D from customer requests. Except for the pipelined of customer relationships they seem to be self-sufficient, unaffected by local buzz and in no need of additional pipelines. Nevertheless, the proximity of a university was appreciated as a source of qualified potential employees.

Tacit knowledge may still be transferred between specialized researchers (Breschi and Lissoni 2001; Brown and Duguid 2001; Lissoni 2001). Face-to-face interaction may be indispensable for certain kinds of interaction but the need for it varies during a knowledge development process and the value of geographical proximity will diminish with time (Torre and Rallet 2005). It has furthermore still not been shown that interaction between specialized researchers would be of a more tacit nature when performed locally. The geographical distance may therefore be less of an obstacle in these industries than in other contexts. The division between local buzz and long-distance pipelines is thus not fully appropriate as both may fulfill the same needs. Information exchange and R&D cooperation may take place on a personal level as well as in more formal agreements, locally as well and long-distance.

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