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INNOVATION CLUSTERS: COMBINING PHYSICAL AND VIRTUAL LINKS

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ABSTRACT

Innovation is increasingly seen as a collective action which involves many different actors operating in a cluster context. These clusters are usually conceived as local agglomerations. In this paper it will be argued that they are an important tool to study innovation, but the globalisation of companies and markets and the specific requirements of innovation processes require the expansion of cluster concepts towards virtual dimensions. It will be shown that the combination of local and virtual cluster links improves access to essential resources in innovation. An examples taken from the automotive component sector will illustrate the concept.

Introduction

A rapid rate of technological change, high intensity of competition and an increasing integration in international markets determine the rhythm and forms of innovation activities in many modern economies. In ever more complex technological, organisational and governance scenarios successful innovation requires to cooperate in systemic configurations that transcend industry and country boundaries. One way of analysing the nature and dynamics of these configurations is a cluster approach. So far, innovation research has used cluster concepts based on the local or regional agglomerations of actors that combine resources to gain a competitive advantage in realising the innovation. In the present paper we will argue that cluster relations are essential to cope with the challenges of technology, organisation and knowledge management, but that they do not necessarily have to be locally defined entities.

In this paper we propose to use 'clusters' as a specific systemic approach to innovation. When using a cluster concept, one has to be aware, however, of the focus of analysis. Clusters that provide a contribution to regional development have to emphasise other elements than clusters that enhance the competitiveness of companies, or clusters that support innovation. In processes of innovation the crucial element is the creation and sharing of knowledge, which implies reaching high levels of technological, organisational and managerial competence. It will be argued that this requires to abandon the strict location-oriented approach to clusters.

Two factors drive this opening-up of clusters towards non-local links: the growing globalisation of processes of production and the complexity of knowledge creation, distribution and implementation in innovation. Information technology can be seen as an enabler which is essential for the efficient functioning of co-operation schemes between distant entities.

The present paper is based on the empirical analysis of the innovation cluster in the automotive component sector in Germany. An exploratory analysis of processes of innovation in these two cases has provided the basis for a definition of clusters which takes into account the essential features of innovation processes in general and of the two industries in particular. The resulting cluster concept uses interaction as the constitutive element of clusters, not location. While cluster partners are interacting, they generate path-dependent benefits which are similar to those claimed for agglomeration-based clusters, such as trust, knowledge spillovers, and competence building. The efficiency of these clusters is dramatically enhanced through the use of advanced information and communication technology.

1. Innovation in a systemic perspective

Innovation clusters follow a fundamentally different rationale from production or value chain clusters. It is therefore worthwhile to point out the specific features of innovation that are determining cluster configuration and dynamics. Understanding innovation requires to look at company activities through a series of different analytical lenses. The decisive contributions of innovation research over the past two decades were the introduction of systemic features in innovation models and the integration of non-firm actors, such as research organisations, technology transfer agents or innovation policy actors.

All the more recent lines of thought stress both the diversity and number of actors involved in the innovation process, which is, thus, no longer considered the result of the Schumpeterian heroic entrepreneur's activity (Kline and Rosenberg 1986, Padmore, Gibson and Schuetze 1998), but innovation emerges as a collective action. These models also stress the interdependency of actors and the systemic character of the relationships among them. The basic features of knowledge creation and the channels of knowledge transfer are crucial to understanding the complex interactions among different actors and the functioning of the system generated by these interactions. Individual and organisational learning becomes the key element for the connectivity of a system. These systemic contexts are essential for the performance of each of its members, i.e., the efficiency of any single actor would drop dramatically, if isolated from the system.

While innovation systems refer to countries as their framework of reference, other strands of research have concentrated on further disaggregated entities, such as regions, industries or cities. They underline the relevance of an agglomeration of similar or of co-operating firms or organisations for economic development. A great deal of studies have examined the features and the development of agglomerations of firms, some with reference to Marshallian industrial districts (Sabel 1989, Becattini 1989, Brusco and Paba 1997 and Porter 1998) or to Francois Perroux's notion of growth poles (Perroux 1955), others with reference to more recent concepts like the innovative milieu (Maillat 1995, Ratti et al. 1997) and inter-firm production networks (Batten 1994). The revived attention to issues of economic geography recognises the essential importance of knowledge externalities and points out the increasing returns of spatial concentration of economic activity and growth.

In an almost paradoxical scenario, the tendency for firms in related lines of business to locate and operate in close physical proximity is accompanied by the globalisation of economic activity. Globalisation, thus, has not dissolved the meaning of local orientation of firms, but it has been shown to be consistent with a strong commitment to local sources of competitive advantages in various industries and activities. Hence, a strong emphasis on the embeddedness of firm strategy in global markets, which has dominated analyses of economic development for some time, has now given way to a more balanced view which also takes into account the importance of the local context.

Innovation requires access to codified and un-codified knowledge, but also to specific production capacities and qualified labour. Increasingly competitive market conditions have led to an acceleration of innovation cycles and to the need for firms to react very flexibly to newly emerging technology trends or customer demands, and, hence, to new knowledge. Clusters supporting processes of innovation, therefore, have to show the necessary flexibility in the provision of knowledge and expertise as well as other inputs. The specific features of successful innovation clusters will be subject of the following chapter.

2. Clusters and innovation

2.1 The geographical approach

The origins of cluster research go back to studies of *industrial districts* that have been presented by Alfred Marshall as early as 1890 (Marshall 1952). The idea of specific synergies deriving from the physical proximity of similar and cooperating firms in industry-specific agglomerations has been taken up much later by Piore and Sabel (1990) and by Krugman (1991). These analyses emphasised the benefits to be gained from a sufficient supply of specialised labour and industry-specific intermediate inputs. In addition industrial districts offered favourable conditions for knowledge spillovers.

In contrast with the industrial districts approach which took mainly the perspective of securing inputs necessary for production at favourable conditions, cluster approaches start from the perspective of generating optimal competitive conditions for firms. Central to this strand of research is the work of Michael Porter. He deduces the relevance of clusters as a conceptual tool which explain the competitive advantage in a global economy (Porter 1998). By pointing out the paradox of global links and the apparently diminished meaning of distance and location on the one hand, and the obvious agglomeration of industries and firms in specific regions on the other, he emphasises the importance of strategic resources which are typically generated in physical encounters as a result of informal flows of information and require a certain degree of geographical proximity. However, the features that made location an important factor in gaining a competitive advantage (cheap inputs because of ample supply: coal mines and steel mills; easy access to resources: ports and universities) have been substituted by more complex elements. The core of company performance nowadays lies in “making more productive use of inputs” (Porter 1998). Companies achieve this by being innovative. This requires efficient management of internal resources and, certainly, of external relationships. The function of clusters in this rationale is to guarantee privileged access to knowledge, to enhance productivity and the ability to innovate and form new businesses.

Studies of regional clusters have been conducted in a whole number of countries (see Bergman and Feser 1999, DenHertog and Roelandt 1999). These studies that mainly emerged as a result of an initiative of the OECD (OECD 2001) do not share a common notion of cluster and use a whole variety of concepts. This is typical of the explorative phase of studying a new phenomenon, and, thus, these studies are helpful to grasp the essential characteristics of innovation clusters. Another strand of cluster research explains the role of clusters in innovation in the tradition of studies on innovative milieux (see, for example, Keeble and Wilkinson 2000).

What is common to the different concepts is that clusters are usually seen in a spatial perspective, i.e., they refer to groups of firms or actors which are located in close proximity. As a consequence of the emerging knowledge economy, some authors have developed concepts of virtual clusters consisting of cooperating partners that are linked via electronic networks and develop cluster characteristics independently from their location (Passiante and Secundo 2002¸ Kaufmann, Lehner and Tödtling 2002). Assuming a ‘global virtual learning environment’ Passiante and Secundo claim that learning which is at the core of innovation processes, increasingly takes place in virtual networks. They conceive virtual innovation clusters as a further development of industrial clusters specific to a global information economy. After the strictly spatially defined Marshallian industrial districts and an evolutionary approach which emphasises collective learning in environments or milieux, virtual clusters are identified as a new competitive space for innovation processes (Passiante and Secundo 2002, p.9).

The present paper argues for a combination of spatial and virtual cluster configurations. Empirical evidence suggests that distance still matters, and some cluster advantages clearly rely on close proximity between actors, but flexible access to essential resources, economies of scale and specialisation in technological resources and a general widening of the geographical scope of markets may require to open cluster concepts to include virtual links (Preissl and Solimene 2003).

2.2 The rationale of innovation clusters

A definition

Considering the variety of cluster approaches and the lack of a commonly acknowledged definition, it might be useful for the purpose of this paper to start with a very basic definition:

> "A cluster is a set of interdependent organisations that contribute to the realisation of innovations in an economic sector or industry".

As simple as this definition is, it contains a number of important settings: there is no geographic orientation, the decisive criterion is that the relevant actors take part in the same activity, an innovation. The definition is essentially industry-specific. As such, it assumes that some cluster actors typically specialise in a technology, in services or other resources which are often used in an industry. Firm-specific clusters are a sub-group of industry or sector clusters.

Clusters in this definition comprise *all* actors that contribute to an innovation, thus they also include service and manufacturing firms that are not R&D intensive, such as suppliers that provide new parts according to designs delivered by the innovating company or an advertising company that promotes the new product.

Cluster characteristics

A very general explanation for the existence of clusters is that they provide economic advantages against other forms of organisation, such as independent actors, networks or firm co-operation. Some of these advantages are linked with the spatial proximity of cluster members and are typically associated with the agglomeration of actors and activities in a well defined region. Others are due to economies of scale that are (partly) subject to critical mass phenomena. A third group results from interaction in the cluster and becomes more and more relevant as the cluster matures and develops path-dependent specificities (see Table 1).

Agglomeration. The presence in close proximity of actors that are actual or potential partners in business and, thus, to a certain extent share the same interests, favours communication. Often this communication is informal or linked to procedures other than innovation. In any case, it inevitably leads to the *exchange of knowledge*. While codified knowledge can easily be transferred via any means of communication, informal knowledge is spread rather accidentally, because neither the sender nor the recipient might know about its relevance, before it is communicated (Macdonald 1996). This kind of *knowledge spillovers* typically results from casual encounters or demonstration effects in local agglomerations (Fritsch and Schwirten 1999, Kash and Rycroft 1994, Saxenian

1994, Feldman 1994). R&D results as specific types of knowledge are transferred from one company to another through various formal and informal mechanisms that all accelerate technological advancement in a region and/or in the economy as a whole (see Audretsch and Feldman 1996). The informal exchange of knowledge is one of the features from which Porter deduces the advantages of cluster structures: " .. personal relationships and community ties foster trust and facilitate the flow of information. These conditions make information more transferable." (Porter 1998).

Table 1: Cluster benefits

Benefits related to …	
Agglomeration	Knowledge spillovers Transaction cost Shared infrastructure
Level of activity	Economies of scale Network externalities Specialisation
Interaction	Tacit knowledge Trust Competition and co-operation

Source: Preissl/Solimene 2003.

Most components of *transaction costs* are affected by the distance of trading partners. The costs of delivery can be reduced by the fact that suppliers are located close to their customers or by the clustering of many customers in a small area. Short ways to suppliers imply low transportation and insurance costs and easy after-sales services. Transactions with local suppliers are characterised by informal relationships and therefore low contracting costs. As a rule, more distant relationships require a higher degree of formalisation of contracts. Search and information costs, an important component of transaction costs, are supposed to be low in a cluster context, because information about cluster members, their specific competencies and reliability spreads quickly. In the age of electronic information systems and internet-based search engines, this advantage looses importance, because information can easily be reached via the internet. However, the vast amount of information available in electronic networks can lead to an increase in search and selection costs which in turn can be reduced by using personal information sources available in a cluster. Here spatial proximity and informal encounters still generate comparative advantages.

Benefits from the shared and combined use of resources are an important reason for clustering. This affects *infrastructures*, such as traffic systems, schools and universities, energy and water supply systems as well as telecommunication facilities that are actually used jointly by many firms and organisations. Requirements of firms for skilled labour might induce governments to establish schools or training centres, if the demand is big enough. Part of these infrastructure facilities are location-sensitive, and most of them have a public goods character. Cluster dynamics create a mutual dependency between infrastructure provision and firm allocation: the presence of a large user community for public facilities will direct resources to these agglomerations. If there are many firms that use the same kind of research results in a certain area, (public and private) research resources will be directed into this area in order to serve this cluster.

Level of activity. The presence of a large number of potential customers means that suppliers can operate at a level of production which allows to realise *economies of scale*. Clusters are likely to generate such a large local market, in particular for suppliers of a certain manufacturing or service industry which is at the core of a given cluster. Economies of scale also occur in the provision of infrastructure which yields higher returns, if the resulting facilities are used intensively (see, for example Ciccone and Hall 1996). Apart from cost considerations, clustering provides advantages in the provision of intermediate goods, qualified labour and knowledge. Large groups of similar actors, whose needs can be summed-up into substantial demand stimulate the allocation of the corresponding suppliers, are a constitutive element of clusters (Enright 1996 and Porter 1998). However, at least temporarily, the concentration of demand for specific resources in certain areas can also lead to a shortage of supply and to rising prices. Each cluster will show particular patterns of power between the various actors. In some cases, suppliers of essential inputs might be in a strong position, since many customers in the cluster compete for access to resources they deliver. In other clusters, ample supply of certain resources might keep their price down. In any case, it might be wise not to completely neglect linkages outside a local cluster that can be mobilised, if needed.

External economies are typical for network organisations. It can be argued that the larger a network is, the more valuable it becomes for an individual member, because more potential partners can be accessed (Katz and Shapiro 1985). This is a benefit which does not cause any costs for individual network participants. The phenomenon has been studied extensively for technical networks, such as telecommunication technology or petrol distribution. These are 'classical' cases of external economies. However, in the context of clusters, the phenomenon has also been discussed in terms of the availability of other infrastructure resources. It has been argued that externalities arise from an education system which provides specific qualifications and a continuous supply of human resources for the advancement of cluster firms (Bergman and Feser 1999). The more potential employers are there to hire qualified personnel, the more likely it is that facilities will be provided in the education system that educate and train people according to the needs of these employers.

Firms in need of specialists will also benefit from the proximity of other firms with people who possess similar qualifications as those required in an innovating firm; these employees might be willing to change employers (especially if the new employer is close by, so that no relocation is necessary). For an individual firm the qualification that happens either in a public education system or in the firms of other cluster members, constitutes an external economy. The overall increased level of qualification and its specificity for cluster purposes are external resources from which a company can benefit without paying for it.

A substantial number of suppliers of a specific asset (intermediate goods, services, knowledge or technology) and high levels of demand favour *specialisation*. Hence, clusters can promote the generation of virtuous circles: the presence of highly specialised manufacturing and service firms attracts others. Specialisation raises the overall quality of output, and generates productivity gains. This phenomenon can be interpreted as 'economies of specialisation'. This aspect is especially relevant for technology development which requires substantial investment in R&D, testing facilities and equipment, which can only be efficiently installed, if there is sufficient demand for the related services.

Interaction. The systemic character of innovation clusters constitutes itself in complementarities and co-ordinated linkages which require interaction and are generated through it. Interaction among cluster members establishes a division of functions which is confirmed or altered with each new communication. In a *system*, synergies develop which result from optimally balanced complementarities and efficient mechanisms of interaction and rules of conduct. Systems develop and become more efficient referring to these mechanisms and rules (Luhmann 1995). Interdependency results in higher performance of each actor in relation to operating as isolated units. Interaction always shows these specific features, regardless of the location of the interacting parties.

Despite the enormous increase in the availability of information due to the automation of search processes and the international linking of information systems, *tacit knowledge* seems to play an increasingly important role in company strategies (see, for example, Bergman and Feser 1999).

The main scope of tacit knowledge is to put more or less random information in a meaningful context. Since it constitutes part of the assets of innovating companies, tacit knowledge is bound to organisational and geographic locations. This specificity increases circulation of information and the spread of knowledge within the cluster, but prevents external actors from accessing it (Keeble and Wilkinson 1999). Cluster interaction is likely to favour the exchange of tacit knowledge, because it enhances trust between business partners. Trust and the exchange of tacit knowledge are concepts that relate to human beings, not to organisations. Therefore, physical encounters and, thus, spatial proximity, play a major role in making these features become effective (Bergman and Feser 1999).

The interaction of *competitive and co-operative attitudes* in a cluster has been identified as an important element of cluster dynamics (Porter 1998, Bergman and Feser 1999). The cluster combines competing firms of the same industry as well as business partners with complementary competencies. Cluster dynamics are nurtured by the competitive action of rival firms as well as by the confidence created between co-operating units. In the case of innovations, one might say that competition stimulates innovation and co-operation helps to achieve it (Den Hertog et al. 2000). In this sense clusters are ideal incubators for innovation. Close co-operation in technological development stimulates the creation of next generation technology. Competition pushes technological inventions towards product and process innovation. Competitive pressure and reputation in an environment in which visibility is high and mutual observation is part of daily business, are important drivers of innovation. Thus, a strong incentive to improve performance is derived from local rivalry (Porter 1998). Informal information exchange leads to a quick diffusion of new ideas and to dynamic innovation paths, and, therefore, to an intensification of competition, which, in turn, requires to be innovative. However, cluster actors *co-operate* along other cluster links, for example, in supply chains or R&D joint ventures. Complementarities among cluster members enhance the co-operative side of interaction. Thus, some cluster members interact as partners, others as competitors. These roles can change, if market conditions or technical progress require new alliances.

There is considerable overlap between the cluster characteristics descried above; some can be attributed to geographical factors as well as to the fact that a large number of business partners allows to operate more efficiently. Patterns of interaction can constitute clusters, but they are also shaped by the location of partners.

2.3 Combined innovation clusters

The specificity of innovation clusters can be deduced from three essential properties which are crucial for their identification, set them apart from production clusters and take into account processes of globalisation:

- Clusters are identified through a *functional* analysis of processes of innovation.
- Innovation clusters can enhance their performance by combining *physical* with *virtual* links. The constitutive element is interaction, not location.
- Clusters consist of a *potential* of resources that innovating companies can access when needed.

The identification of combined clusters

The definition presented above leads to the question of how to identify and limit innovation clusters. Statistical methods measure the frequency and/or the density of a phenomenon in a given space. They are a typical tool for regional studies or agglomeration analysis; two kinds of cluster studies have emerged from these approaches: those based on a core technology concept (Saxenian 1994), and those based on core industry concepts (Leisink 2000). Whereas in strictly geographical clusters location is the central criterion for deciding whether a firm or organisation belongs to the cluster, in a cluster which is not spatially defined, more complex criteria adopt.

Some authors have used input-output analysis for identifying clusters (see, for example, Maggioni 2002). This technique identifies actors along a value chain and concentrates on routinely present relations between suppliers and customers. The resulting tableaux do not give any information about whether the relations identified are relevant for processes of innovation.

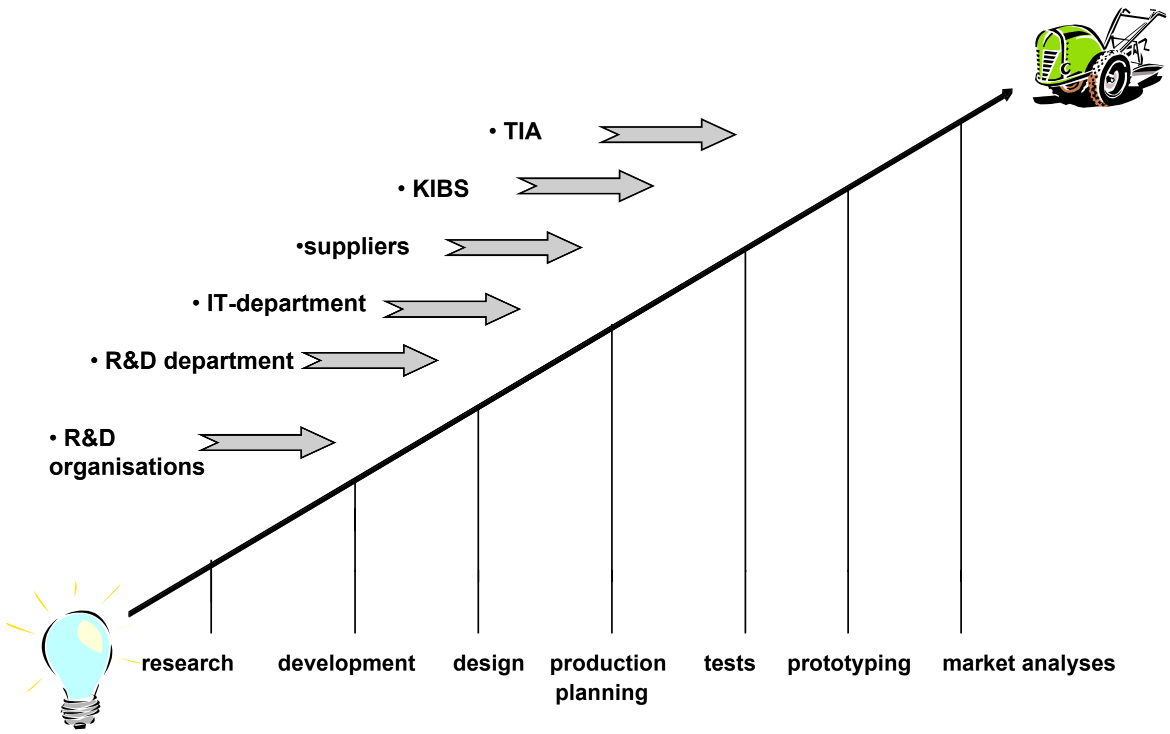
The correspondence approach presented by Spielkamp and Vopel (1998) identifies similarities between firms with respect to the organisation of R&D processes as the distinctive feature of a cluster. It has been used in cluster studies, but seems irrelevant for the type of innovation cluster studied here, because it concentrates on the identification of *similar* actors, whereas the benefits of innovation clusters – as described here - typically rely on *complementarities* of actors.

An enumerative *institutional* approach which attempts to identify all those organisations which produce relevant output for innovative activity in a sector, such as research organisations, universities or companies along the value chain is too static to grasp the requirements of innovation processes. For example, the relevant innovation cluster for an innovating machine construction company might include a research institute specialising in metal alloying, if an institutional approach is adopted. However, for a specific process innovation, the company might need a software provider to develop a process control system. In this case, the metal alloying institute is not relevant, and the software provider might not be considered part of the cluster. Hence, a functional approach is needed to identify the relevant actors.

Adopting a *functional* perspective on clusters solves this problem; however, it requires a specific concept of innovation: the innovation process can be seen as a series of steps that lead from an initial innovation idea to a marketable product or a new process (see Figure 1). (This scheme might suggest a linear process of innovation, which is not likely to represent a realistic picture of modern processes of innovation. However, back-loops are possible between the different steps, and the functional approach to innovation does not imply that there is a unilateral direct path from one function to the next. In this sense, the graph is open to comprise more complex itineraries towards the final achievement.)

Innovation is, thus, perceived as an interactive process that involves a wide variety of actors (Malerba 2000). Each step can be interpreted as a service that fulfils a certain function in realising the innovation. Examples of such service functions are given on the horizontal axis in Figure 1. Innovation services are provided by in-house or by external actors. Possible actors are represented along the innovation graph leading from the innovation idea to a new machine.

Fig. 1.



The innovation cluster of an industry comprises all actors who deliver services that are relevant to pursue innovations in this industry. Some actors might co-operate only with a small number of companies and for certain types of innovation, others appear more often as protagonists in innovations. As technology develops and market dynamics change, the innovation functions and, consequently the actors will change. For example, the introduction of remote control systems in operating chemical plants requires the installation of telecommunication links. This service function might be provided by an external ICT firm, and, thus, it introduces a new cluster actor. The innovation function approach deduces cluster configuration from the innovation process. It looks at the entire set of services needed and identifies the actors that usually deliver those services. Thus, it goes beyond a strict R&D or technology orientation, covers outsourcing or in-sourcing phenomena, and allows to adapt cluster analysis flexibly to changes in innovations.

Combining physical and virtual links

The distinction between benefits deriving from agglomeration and those that are due to quantitative dimensions (critical mass and bundling) or interaction, leads to the question, whether regional clustering is essential to keep up the cluster notion or whether some elements of clusters can also become effective through virtual links.

The innovation function approach allows us to open the cluster and expand it beyond geographical boundaries. If the cluster is to comprise all actors contributing an innovation service function, these might also be actors located outside a specific area. Empirical cluster studies have shown that firms prefer to work with local or regional partners, but finally it is the quality of the service required that determines the location of the partner (Preissl and Solimene 2003). Involvement of distant partners is facilitated by electronic networks and by technical progress in transportation (Bergman and Feser 1999).

Virtual links can establish a cluster-like environment with its own mechanisms of interaction. Often cooperation with remote partners via electronic channels is based on previous contacts that had an important trust-building function. This, virtual links complement the physical links in a cluster. For example, a closely located cluster member can give information on an electronically accessible service, or trust-building steps between new networked partners can be facilitated if a locally situated cluster member mediates first contacts. In this point, the present cluster concept is clearly distinct from the pure virtual clusters introduced by Passiante and Secundo

(2002) as “Innovation Virtual Systems”, which are conceived as an entirely web-based system of learning and knowledge exchange.

The main advantage of combining physical with virtual links in a cluster is the increase in flexibility. Spatially defined clusters require the relocation of companies to make new knowledge and new resources available in the cluster context. With increasingly short innovation cycles, it may take too long to restructure clusters physically according to the needs of innovation processes in which new types of resources are needed frequently.

Whether cluster benefits can be transferred from spatially defined entities to so-called virtual clusters rests mainly on the question whether tacit knowledge can be exchanged in electronic communication systems. As convincing as the argument of virtual knowledge exchange is in an emerging information economy, the functioning of virtual networks has not been researched yet. This applies to the stability of links based entirely on electronic communication as well as to the substitution of tacit knowledge and trust by mechanisms apt to electronic network. Indeed Kaufmann, Lehner and Tödtling (2002) conclude that knowledge management can never be fully codified and computer-based. They argue that electronic networks can only transmit codified knowledge, tacit knowledge needs to be exchanged in physical encounters.

It may, thus, be concluded that innovating firms take advantage of local clustering in some steps of the innovation process, but the performance of a cluster can be enhanced by integrating virtual links that give flexible access to more distant resources. Combined clusters benefit from the same mechanisms that make physical clusters attractive; however, they rely on interaction as their constituting element and not mainly physical proximity.

Clusters as potentials

Clusters as configurations of innovation service providers can offer resources needed in innovation processes in a specific sector. However, not every actor is involved in every innovation, and not all actors are linked among each other. The use of cluster resources does not even require direct contact between actors, since knowledge can be accessed via public channels. This is the case, for example, if a research institute publishes results that enter the R&D process of an innovating company. Thus, from the point of view of an individual innovator, clusters are a potential of heterogeneous resources that can be activated and accessed as needed. The relevant cluster is then constituted through innovation activities. Thus, it is the individual process of innovation that defines the configuration and dynamics of individual innovation clusters as a sub-group of the industry specific cluster.

Whereas networks require continuous contact, efforts to maintain the links as well as quite a strong commitment by each member, clusters offer a much looser contact, where occasional contacts suffice to establish membership. This makes them less costly and time consuming than networks. Networks are confined to a small group of actors, and if an innovation requires the use of resources not available in the necessary quality within the network, it might be difficult to look for these resources outside because this might threaten network relationships. The less committed relationships in a cluster offer more variability and flexibility. In a cluster context, relationships can be 'dormant', i.e., they are based on communication at some point in the firm's history and will be activated in the event of a new innovation that makes them relevant.

3. Clusters in action: Innovation in the German automotive component industry

4.

The following chapter presents an application of the cluster concept presented above to the automotive component sector in Germany. The sector has been chosen because of its high innovation and R&D intensity, (Legler, Beise et al. 2000). and because of some interesting features with respect to innovation patterns and cluster configuration. The sector comprises different industries and a whole range of relevant technologies. (for a detailed analysis see Preissl and Solimene 2003).

3.1 Trends in component supply

Over the last decade organisational innovations and new governance models in supply chains have resulted in a reorganisation of the division of labour between car manufacturers and their suppliers (Hancké 1997, Lay and Wallmeier 1999a, 1999b, Peters 1997). The dynamics of innovation and growth in the automotive component sector has been determined to a large extent by these processes. This has a strong impact on how innovation opportunities are identified and how new products are brought to the market in the suppliers' industries. Innovation cycles, features of competition, regulatory issues of the transport system and changing tastes of car drivers become immediately effective at component supplier level.

The internationalisation of German car manufacturing implies an internationalisation of supply sources. As a result, component suppliers are expected to follow car producers to foreign markets; suppliers might work for a client who transfers his development department to another country, and, as a consequence, the supplier has to develop international links as well; or cost reduction and system supply strategies make car manufacturers look for suppliers that can serve their branches in different countries with standardised parts (Hancké 1997).

3.2 The cluster

Identifying the cluster

In the case reported here, cluster analysis started with interviews in innovating firms in various component supplier industries. By identifying their partners in innovation, a picture was gained of firm-level clusters, relevant for this particular component supplier. However, this technique would not allow us to identify the relevant cluster for the sector as a whole. Therefore, publications on automotive manufacturing, R&D and innovation activities in the car manufacturing industry and its supply chain have been consulted, and industry representatives, such as the Association of Automotive Industries (Verband der Autmobilindustrie, VDA) and experts in the field have been interviewed. As a result, more organisations (companies, research institutes and other actors) were found which do not directly cooperate with all the firms in the sector at any time, but, nevertheless, play an important role for innovation.

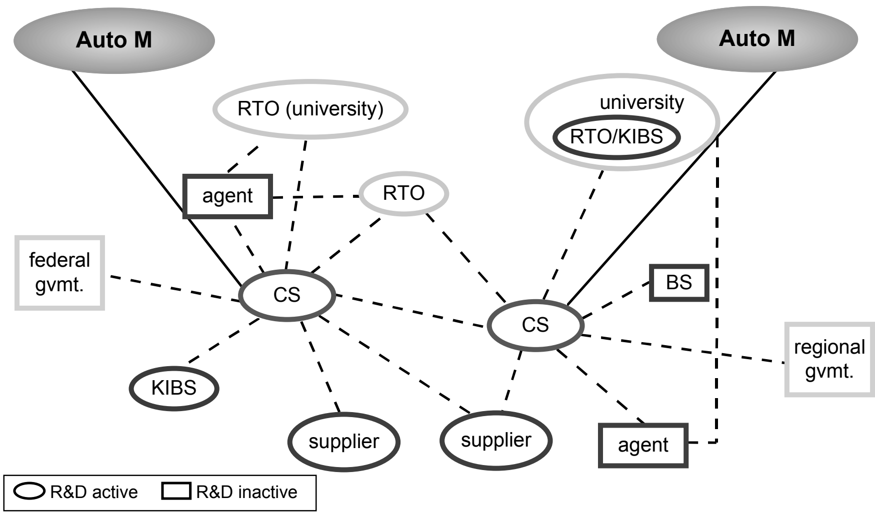
In the following step, all institutions/firms and other actors listed by participants of the first round of case studies were contacted and interviewed. This approach allows us to reconstruct cluster configurations *and* to analyse cluster activities in innovation from different perspectives.

Cluster configuration

Innovations in the cluster are the result of interaction between specific groups of actors (see Fig. 2). They vary with respect to the intensity of their impact in innovation processes, R&D intensity, service functions and institutional arrangements. The heterogeneity of the sector implies that the range of research and technology organisations (RTOs), knowledge intensive business service firms (KIBS) and other partners in innovation is as broad and as heterogeneous as component suppliers' innovation projects.

The entities in Figure 2 represent groups of actors in the cluster. Hence, each group can consist of several (or many) actors. The groups of actors can be quite heterogeneous: for example, suppliers comprise small as well as large firms from a vast range of industries, and RTOs can specialise in various fields of technical expertise. There is a particularly strong link between component suppliers and car manufacturers. All links can be either activated by physical encounters or refer to virtual exchanges. Stability and intensity of links depend on the characteristics of actors and the innovations taking place at a certain point in time. Whether links are physical or virtual depends on the innovation functions actors are involved in, the phase of an innovation (preparatory, research or implementation phase) and the location of actors.

Fig. 2 The automotive component suppliers' innovation cluster



RTO = Research and Technology Organisation; BS = Business Services; KIBS = Knowledge Intensive Business Services; gvmt. = Government; CS = Component Supplier; Auto M = Auto Manufacturer; R&D = Research and Develpment; agents = VDA, FAT, UBA, BAST, Project Management.

Source: DIW 1999

The *innovating company (or component supplier, CS)* is at the centre of the cluster; it organises the innovation process and largely determines procedures and the division of functions among the participating actors. However, it is itself bound to evolution in car manufacturing and thus to its clients' strategy.

The *clients in the automotive industry (represented here by automotive manufacturers, Auto M*[1]*)* often share the function of developing an innovation idea with the component suppliers. They also play an active role in determining the innovative capabilities of component producers by attributing them R&D functions. Patterns of interaction in innovation, styles of communication and functional division of labour may vary from case to case between clients and their suppliers. Innovation in component supplier firms usually relies on an expression of interest by an automotive manufacturer. A series of personal meeting serve the confirmation and specification of this interest. During the process of developing the innovation co-operation may be organised in the form of

[1] Since many component suppliers do not exclusively sell to the automotive industry, this is an approximation. The cluster picture could also show a category called 'clients' which has been omitted here in order not to confuse the picture.

electronic communication, but physical encounters are also used to keep track of each other's activities. Meetings rather than electronic communication is the means for agreeing about new projects, whereas more routine communication takes advantage of virtual links.

Suppliers of parts and raw materials (in short: suppliers): Often the realisation of innovations in component supplier firms requires new inputs. Suppliers may enhance the innovation process by investing in the development of these inputs. On the other hand, innovations may be impeded by a lack of adequate inputs and reluctance of suppliers to generate them. The typical form of interaction is physical, based on common experience of the delivery of reliable inputs. However, in the process of transition to newly defined inputs virtual links are activated and intensively used. This allows to develop innovative goods and services, even if an established supplier is located at a distance.

Two groups of *RTOs* can be distinguished, (a) institutes specialising in automotive technology and (b) institutes specialising in certain technological fields relevant to car or component manufacturing, such as metal forming, laser technology, microelectronics or plastic materials. RTOs in the first group cover the whole range of knowledge required to construct and improve vehicles. RTOs in the second group specific knowledge which might be adopted in many different industries.

Of particular relevance are combinations of *RTOs and KIBS firms* that are located in one organisational setting, usually a university. Typically, the KIBS firms are private spin-offs of the RTO; usually, however, the resulting KIBS firms remain in close contact with the RTO they belonged to in the past. RTO/KIBS organisations combine basic research competence with directly applicable knowledge of high relevance for car manufacturers and suppliers. In-depth expertise and system competence have made RTO/KIBS conglomerates highly successful. Their expertise comprises all parts of cars, and often they hold important patents.

The expertise RTOs accumulated in RTOs is a particularly scarce resource in the process of innovation. Hence, RTOs are involved that are highly specialised and offer unique sets of knowledge. In order to fit the pieces of knowledge delivered by the RTO into the innovating company's R&D and production facilities, close co-operation is required. This co-operation can range from medium- to long-term stays of RTO personnel in the innovating company to frequent meetings and intensive electronic communication, depending on the nature of the project and the phase in the innovation process.

'KIBS' comprise engineering firms, software and IT consultants as well as management consultants. However, in this cluster, they only play a role as contractors for smaller development tasks in construction and design, mainly for larger component suppliers.

'BS' firms (for *business services*) are service providers who contribute to the innovation process but do not transmit any significant innovation-related knowledge into the innovating firms (tax consultants, banks, patent lawyers, marketing firms, etc.).

'University' is a short form for university chairs, i.e., professors and their assistants who are fully integrated in the university. Their links with component producers are generally based on personal contacts between the holder of the chair and engineers in the companies.

'Agents' communicate policy targets from the political to the economic system. Some agents are private, usually managed by industry associations and serving the interests of all companies in an industry. Their work has been greatly enhanced by the introduction of electronic means of communication which allow for an individually selected distribution of information and a customised set of services for innovating companies. These services can be delivered over larger distances, which increases the efficiency of operations of agents.

Federal and regional governments act as sponsors of R&D and technology transfer as well as drivers of regulatory changes that induce innovative activity. They stimulate research and support technical and structural change. Governments are also responsible for the establishment and financing of institutes for basic and applied research within the national innovation system. In this function, they can be active supporters of cluster generation.

Cluster actors and location

Cluster actors show a certain concentration around large component suppliers or car manufacturers. This agglomeration sometimes emerges in the course of time, sometimes it is the result of outsourcing practices or strategic firm decisions. Examples for regional clustering in automotive production and innovation are the Zwickau area and the Köln/Aachen area, as well as Frankfurt/Rüsselsheim and Stuttgart. However, there are important RTO/KIBS combinations allocated in Berlin, in Stuttgart and in Aachen that serve the automotive and the component industries in the whole of Germany and beyond. Their expertise is typical for innovation resources which might be allocated within one local production cluster, but is shared by all component manufacturers in Germany. Virtual links with these organisations are typical for the expansion of local innovation clusters into a virtual dimension described above.

In addition, component suppliers emphasise that the search for new qualifications or new service inputs often forces them to refer to resources that are located outside the local environment. The resulting restriction in communication is often compensated by meetings with space for 'social encounters', longer stays for experts in the partner firm, long-term co-operations on subsequent projects, or the selection of partners based on previous acquaintances. Thus, cooperation in innovation processes generates, reinforces and re-establishes a cluster context not bound to a particular location.

Functional division of labour in the cluster

The cluster shows a specific functional division of labour. Figure 3 gives a list of functions and the respective actors. The actors that are involved in most innovation functions are the innovating component suppliers themselves. Company interviews have shown that external service inputs in innovation played a minor role, compared with the functions provided in-house. However, internally, some functions were jointly provided by the R&D or product strategy department and the production or purchasing units.

Often a clear attribution of functions to actors is difficult, since many functions are assumed jointly by partners in innovation. Sometimes it is not an entire function that is delegated to an external partner, but only segments of it, such as the construction of a small part of a new device, or the development of some software elements. The existence of virtual links allows remote partners to assume functions which require intense co-operation, high reliability and trust, characteristics that are usually attributed to the interaction of actors in close proximity.

Table 3. Service Functions and Actors in the Component Supplier Innovation Cluster

Functions	innovating firm, CS	customer, car manuf.	supplier	RTO	KIBS	agent	partner	others
basic research	++	o	o	+++	+	o	+	universities
applied research	+++	o	o	+++	o	o	o	
innovation idea	+++	+++	+	++	o	++	o	production units, literature
information gathering	+++	o	o	++	+	+	o	
feasibility studies	+	+	o	++	o	+	+	production/pur-chasing units
product development	+++	o	+++	+++	o	+	+	
process development	++	o	+	+++	+	o	+	software firms
technological advice	o	+	+	o	o	+	+	
planning	+	o	o	o	o	o	o	
implementation	+	o	o	o	+	o	+	
training/HRM	+	o	o	++	+	+	o	
quality control	+	o	o	o	+	o	o	students
testing	+	o	o	++	++	o	+	students
prototypes	+++	o	+	+	+	o	o	universities
documentation	+	o	o	+	+		o	
certification	+ +	o	o	o	o	+	o	service firms, public authorities
marketing	+	+	o	o	o	+	o	

project management	+	o	+	+	+	o	o	service firms
financing	++	+	o	+	+	+	o	government

+++ strong role ++ active role + moderate role o not active in this function

Source: Preissl/Solimene 2003.

3.3 Central features of the component supplier innovation cluster

- Cluster dynamics reflect the dynamics of automotive and automotive component manufacturing in an international context. However, the evolution of the cluster will also be shaped by the difficult balance of power in the supply chain.
- The development of new technological solutions for car manufacturing determines the configuration of actors in the cluster and their relative importance.
- Internationalisation of car manufacturing will further open up the component suppliers' cluster to foreign actors. The virtualisation of cluster links, thus, will become more important in the future. The global cooperation and global sourcing strategies of car manufacturers will lead to a new international division of labour in R&D.
- according to statements of researchers in the component supplier industries, the strong emphasis on fast results and direct applicability of research output in production will lead to a lack of basic research in a few years' time. It will also increase the need to refer to resources which are not readily available in local clusters.
- Interaction and knowledge transfer in the cluster will continue to be strongly based on human communication, but they will increasingly be supported by electronic means. Joint research and innovation projects, mobility of researchers and informal contacts will establish a basis for activating cluster benefits in electronic links.
- The allocation of innovation competencies in the cluster will shift more decisively to component producers, together with their close cooperation partners in system development networks.

4. Concluding remarks

The analysis presented above suggests a number of careful conclusions:

- Innovation clusters follow a different rationale than production clusters, because their essential components – knowledge and expertise are not the result of routine procedures.
- Local clustering still bears important advantages and fosters competitiveness; it is, thus, innovating firms are widely aware of its benefits.
- However, innovation clusters need to rely on favourable conditions for knowledge transfer in *local and non-local* settings.
- Hence, virtual links enhance the possibility to establish such conditions at a distance, and firms are increasingly adopting virtual cooperation techniques in innovation.
- Empirical evidence suggests that combined clusters rely on physical encounters to establish trust and to allow for the exchange of tacit knowledge;
- The exact mechanisms of the emergence of cluster bonds in virtual links has still to be studied; virtual communities in research might be an instrument of the future, but the difficult balance between the benefits of sharing knowledge and the necessity to appropriate it still seems difficult to handle in a virtual environment.
- Methodological improvements concern mainly cluster identification methods. The technique adopted in the two cluster studies makes it difficult to reach statistically significant levels.
- Central difficulties are the measurement of interactions as the constitutive element of clusters and the construction of indicators for the performance of combined clusters.

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