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Christian Schröder

Dynamics in ICT cooperation networks in selected German ICT clusters

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EUROPÄISCHES INSTITUT FÜR INTERNATIONALE WIRTSCHAFTSBEZIEHUNGEN (EIIW)/
EUROPEAN INSTITUTE FOR INTERNATIONAL ECONOMIC RELATIONS
Bergische Universität Wuppertal, Campus Freudenberg, Rainer-Gruenter-Straße 21, D-42119 Wuppertal, Germany
Tel.: (0)202 – 439 13 71
Fax: (0)202 – 439 13 77
E-mail: welfens@eiiw.uni-wuppertal.de
www.eiiw.eu

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Summary: High innovation capability is indispensable for generating economic growth in developed economies. Cooperations in the innovation process are entered into by companies for reasons of risk diversification or costs and often considered to be an efficient strategy to increase a company's knowledge basis. Regional economic literature very often believes that regional agglomeration of companies, i.e. cluster formation, will also lead to increased local networking, i.e. also to cooperations between companies or between company and research institutes in the innovation process. A social network analysis of the two German ICT regions performed with patent data was able to show that cluster formation coincides with a dynamic increase of cooperations measured by joint patent applications. However, the cooperations are characterized by integration of extra-regional companies and research institutes rather than being intraregional.

Zusammenfassung: Eine hohe Innovationsfähigkeit ist eine unabdingbare Voraussetzung für die Förderung des Wirtschaftswachstums in entwickelten Ländern. Kooperationen im Rahmen des Innovationsprozesses werden von den Unternehmen aufgrund der Risiko- und Kostendiversifikation eingegangen und oft als eine effiziente Strategie zur Erhöhung der Wissensbasis eines Unternehmens betrachtet. Regionalökonomische Literatur nimmt sehr häufig an, dass eine regionale Firmenagglomeration, d.h. Clusterbildung, zu einer erhöhten lokalen Vernetzung führen wird, d.h. auch zu Kooperationen zwischen den Unternehmen oder zwischen den Unternehmen und Forschungseinrichtungen im Innovationsprozess. Eine soziale Netzwerkanalyse der zwei deutschen IKT – Regionen, durchgeführt mit Patentdaten, konnte zeigen, dass eine Clusterbildung mit einer dynamischen Erhöhung der Kooperation, gemessen an der Anzahl der Patentanmeldungen, übereinstimmt. Allerdings sind die Kooperationen durch eine Integration der eher extraregionalen als intraregionalen Unternehmen und Forschungseinrichtungen charakterisiert.

Christian Schröder, Institut für Mittelstandsforschung Bonn, Maximilianstraße 20, 53111 Bonn

schroeder@ifm-bonn.org

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1. Introduction

Cluster promotion has been a frequently used business-politics instrument for promotion of regional economy. The term of “cluster” is used as meaning a spatial agglomeration of companies from the same economic sector along the value-added chain in this analysis. They are supplemented by the corresponding complementary companies or facilities, such as specialist suppliers and research facilities. The members are connected via supply or competitor relationships or joint interests. This analysis has a close look at the two clusters of information and communications technology (ICT) in the NUTS-2 regions of Cologne and Karlsruhe in Germany. Both regions are strong in ICT.

The idea is that spatial agglomeration permits generation of competitive advantages. These competitive advantages are created by increased competition, improved access to resources for the companies – in addition to natural resources, e.g. via a pool of specialized human capital and specialized suppliers. Additionally, synergies may result from joint use of infrastructure. A higher number of spin-offs from present companies are expected. The geographic proximity of many companies form the same economic sector leads to voluntary and involuntary, formal and informal channels that stimulate knowledge transfer in particular between companies in the cluster region – as large parts of the corresponding literature claim. In developed economies or high-tech sectors, this so-called knowledge spillover is supposed to play an important role in regional and general economic growth.[1] According to that the idea of knowledge spillovers is the basic concept of the endogenous growth theory and plays a key role in explaining economic growth (see e.g., Romer 1986; Aghion and Howitt 1992, 1997; Howitt and Aghion 1998; Peretto 1998, 1999a,b; Schmitz 1989). The endogenous growth theory highlights unintended knowledge spillovers, which means that business, in spite of patent protection, cannot fully contain the newly acquired knowledge. Since new knowledge cannot be protected comprehensively, other companies that do not conduct R&D will also benefit. These spillovers in addition to public knowledge created by universities and public research institutes, generate constant marginal yields on the macroeconomic level are generated. Lucas (1988) advances similar arguments, but emphasizes investments into human capital. The latter increase productivity by gaining new knowledge, which is then transferred involuntarily to other economic agents, who are also able to workmore productively. Along this view knowledge is a public good as it is created by one or more individuals and can be exploited by another without compensation. Nelson (1990) weakens this viewand creates the term latent public good. The transfer of knowledge from an inventor to an imitator needs the capacity to absorb this knowledge. The imitator has also to invest in resources to apply the new knowledge (Cohen and Levinthal 1990). Therefore the incentive to invest in R&D may remain unaffected or is only less disturbed (Cantner et al. 2009).

Knowledge is a wholly private good if it is incorporated in a person and associated with his talents. This kind of knowledge or a combination of specific resources which is not replicable is called tacit knowledge. Hence one can argue that knowledge as a good is in

[1] Along with Döring and Schellenbach (2006) this paper understands knowledge as comprising all cognitions and abilities that individuals use to solve problems, make decisions and understand incoming information.

terms of exclusivity and rivalry neither a typically private nor public good and should be considered differentiatedly in this regard.

Undesired knowledge outflow is countered by intended or desired knowledge spillovers between different companies, as well as between companies and research facilities. Cooperations permit exchange or joint development, in particular of complementary knowledge to achieve a more valuable and higher innovation output. Politics try to stimulate this networking as an important way of cluster promotion. Simply said, the idea is that high company density also offers a good situation for cooperations. To put this idea into practice and to network companies among each other, cluster managements have been installed and promoted in the corresponding regions. The objective is increasing local knowledge spillover and therefore also regional innovation power.

The following analysis forms the actual cooperation conduct – intended exchange of knowledge - in research and development activities in the timeline of successful ICT clusters. Is there any cooperative behavior and do dynamics actually change? Who are the important players in cooperation networks? Furthermore, in addition to intra-regional cooperation relationships, cooperation networks are also developed between companies from the cluster region and at least one company outside of the region. In how far are there also cooperations between companies that use knowledge generated in the cluster region but are headquartered outside of the region under consideration? These companies “tap” the knowledge in the cluster region. The analysis is to show whether there is actually a large number of local cooperations or whether actors outside of the region are at least as important as innovation partners. Are there any parallels between the successful regions or do cooperation relationships develop very differently?

To add a new component to empiric literature and to gain new insights on the cooperation behavior in the innovation process in clusters, the cooperation conduct of patent applicants in the ICT sector in two German regions, the NUTS-2 region of Cologne and the NUTS-2 region of Karlsruhe. The ICT sector was chosen because it is one of the most important business sectors in Germany. On the one hand, the ICT sector has a high growth and innovation dynamic. On the other hand, it is considered an important cross-section technology. This means that ICT increases production efficiency in nearly all other business sectors. The selected regions show above average ICT knowledge, i.e. a high number of ICT patent applications.

The analysis instrument used is the method of network analysis, as already mentioned. This way, changes in the number of joint patent applications and networking patterns between the cooperating cluster participants can be illustrated and observed in more detail by networking analysis measures. Network analysis is an instrument that is not very common yet in business sciences but used increasingly often for analysis of innovation systems or cluster analyses (see, e.g., the studies by Welfens 2011; Emons 2011; He and Fallah 2009; Graf and Henning 2009; Cantner et al. 2009; Giuliani 2005), because it is very well suitable for visualization of knowledge channels and has some benefits over the previous analysis methods, such as the often-applied concept of the knowledge production function. Two observation periods each are chosen – 10 years before founding of a cluster management in the region and 10 years after.

The following is a brief but also critical treatment of the economic effect of knowledge flows in clusters, i.e. local knowledge spillovers. Existing theoretic and empiric literature on this subject is used as a basis for discussion of how external knowledge influx into the cluster region may play a role, and under what prerequisites companies cooperate in research and development. The third section is targeted at performance of a network analysis of cooperating companies. Business politics implications and further research demand, as well as limitations of this study are phrased in section four of this chapter.
The results show that a successful cluster region shows dynamic development of cooperations. The cooperation networks expand. However, each of the two regions also has some specific features in cooperation conduct. While cooperations with external companies, e.g. at least one registering party on the patent being headquartered outside of the region under consideration, seems important for Cologne, research institutions play a very important role as knowledge intermediaries in Karlsruhe.

In both regions it can be noted that intraregional cooperations between companies have hardly increased and that stronger networking over time is not evident.

2. Cluster, knowledge spillover and cooperation

2.1 The role of clusters and (local) knowledge spillovers for regional growth

Marshall (1920) was probably the first person to emphasize the phenomenon of cluster formation and the concurrent agglomeration benefits. In particular Porter (1990) revitalized the concept in a globalizing economy by further aspects or increased consciousness for so-called knowledge spillovers created by increased spatial collection of business subjects, deriving competitive advantages for these regions. Exogenic knowledge is highly important for the internal innovation process. Innovation is based on the combination or recombination of former knowledge (Schumpeter 1911; Cantner et al. 2009). The creation of new technological knowledge means a cumulative learning process which underlies mainly two components. By the idiosyncratic component the innovator learns through his own experience and knowledge accumulation up to now. The second component means the influence through external factors as the experience and know-how of other innovators (Cantner et al. 2009, p.202).

A high company density therefore should also coincide with high know-how spillover effects (Griliches 1992; Jaffe et al. 1993), and generate so-called Marshall-Arrow-Romer knowledge externalities that increase the companies' abilities to develop innovations. This is supposed to additionally stimulate productiveness and growth of the companies or the region. Empiric cluster research has since tried to document the positive effects regarding innovation output and/or innovation inputs (e.g. Baptista and Swann 1998; Beaudry and Breschi 2003; Falck et al. 2010), productiveness (e.g. Engelsoft et al. 2006; Fontagné et al. 2010), newly founded companies (e.g. McDonald et al. 2006; Delgado et al. 2010) and growth of companies and employment (e.g. Tomokazu et al. 2006; Feser et al. 2008;

Hafner 2008; Maine et al. 2010). The results of these and other studies mainly show that there actually seem to be positive cluster formation effects. However, the effect is very different at the respective height and depends on the sectors under consideration. The precise mechanism that may lead to the positive cluster formation effects remains unclear. Cooke et al. (2007) use selected ICT cluster regions in the UK to show that companies have a higher innovation power in clusters than their counterparts outside of clusters. However, they also show that companies cooperating outside of clusters are more innovative than cluster members that do not cooperate. Cooperations therefore seem to be a decisive factor for innovation activities. It seems that not only own efforts for research and development (R&D) but also cooperation is an important strategy for innovation output in R&D projects.

Breschi and Lissoni (2001) are critical about the concept of local knowledge spillovers and their contribution to unintended externalities that mainly occur from geographic proximity of companies. Their criticism is targeted at studies showing the positive customer effect using a knowledge production function (Griliches 1979). The knowledge production function is based on the assumption that cluster formation happens more in sectors where tacit knowledge is very important. It is stated that tacit knowledge can only be transferred by direct and repeated contact (Audretsch 1998). The knowledge production function differentiates between regional knowledge input (e.g. R&D expenditures) and extra-regional input. Differences in relative knowledge output (e.g. patent applications) are then interpreted as regional knowledge spillover (Breschi and Lissoni 2001). The actual development process of local knowledge spillovers remains a black box in the empiric analyses.

In spite of objections, e.g. by Breschi and Lissoni, the production knowledge function was used for most of the studies named to measure unintended knowledge spillovers. Breschi/Lissoni suspect that the actual effect of local knowledge spillovers is clearly overestimated. The patent trend increases in cluster regions to better protect against knowledge spillover (Kim and Marschke 2005). This is another reason why the patenting method that is also often used in studies is likely to lead to distorted results. Breschi and Lissoni argue that epistemic closeness is more important than physical limits. This means that technical and scientific information that have the character of tacit knowledge become codifyable knowledge, since there is a dedicated language in small groups of scientific and technical researchers that is only understood by them and develops by extended cooperation and joint experience (Lawson and Lorenz 1999). These things can be transmitted across distances without externals being able to understand these messages. Only fruitful cooperation and subsequent research agreements cause the cooperation partners to get closer in a spatial respect. Accordingly, physical proximity follows epistemic proximity rather than vice versa (Breschi and Lissoni 2001, p. 989). Furthermore, they argue that the role of tacit knowledge in general is overestimated, since this knowledge is often only interesting for other companies if the lab or development conditions are identical. This applies for most high-tech sectors at least. This means that procurement of new knowledge is often connected to high investment costs. The risk for the company is high, since it does not know the real value of the new, non-codifyable knowledge for the company. The inventor will not easily surrender his knowledge, since this would mean dispensing with his “special” skill and reducing his “market value”.

Additionally, companies are able to create incentives, e.g. by issuing share options or other contractual instruments, to at least reduce an outflow of employees or knowledge.

In addition to the protective mechanism named, there are possible other reasons for increased patent activities in spatial proximity of research centers. Small and medium-sized businesses often do not have their own resources for development work, leading to a strong incentive for cooperation with local research organizations (Rodríguez-Pose and Refolo 2003). This explains the increased patent output in the region but is not due to unintended local knowledge spillovers. Malmberg and Power (2005) note that questioning of decision-makers in companies on the question of where the most important suppliers or customers for the companies are regarding knowledge and innovation showed that spatial proximity has no influence. High distances prevailed over spatial proximity of relationships (Angel and Engstrom 1995; Almeida and Kogut 1999; Waters and Lawton-Smith 2006).

2.2 Knowledge spillover induced by cooperation

Research and development activities can be organized differently by companies. Research and development may take place in the own company by subcontracting or deliveries, or by research cooperations with other companies or research facilities. Often, research and development work are implemented by a combination of these options. Entering into research and development cooperations is likely the most risky method of this, since transfer of specific knowledge to a potential competitor may be consciously risked. Nevertheless, the benefits from the resulting risk diversification in a cooperation may be more important. Risk diversification takes place by the shared development costs and higher chances of success of the innovation project. A cooperation is most likely entered into if the two companies offer complementary knowledge. Complementary knowledge means that combination of the knowledge stock of cooperation partners leads to new or improved knowledge innovation output (Sakakibara 2003). In particular in the ICT area, ICT goods or services are often complementary to a value in another sector. Since ICT is a cross-section technology, it is embedded in nearly every high-tech product. Often it forms a product's "core". Research cooperations between ICT companies and companies requiring ICT as an input component therefore are more logical than in most other sectors. Cooperations mainly take place between companies on different levels of the production chain, and less between companies horizontally connected (Schmitz 1999). Of course, cooperations will also lead to "unintended" knowledge spillover towards third parties. Even though third parties are not directly integrated into the research cooperation, they still profit via the channels already named – even more, since the cooperations tend to cause a stronger increase of the knowledge stock than would be the case without cooperation. Malmberg and Power (2005) provide an interesting summary of empiric literature on creation of knowledge by companies in clusters. It becomes clear that empirical studies clearly indicate that companies in a cluster mainly profit from cooperation with partners outside the region. This means that local knowledge spillover plays a rather subordinated role. Kalasky and MacPherson (2003) show that cooperations of cluster companies with external companies correspond to a high performance of companies. Local connections are rather characterized by the exchange of sample goods and services than R&D knowledge (Brown 2000). In contrast to what is suggested by the abundant theoretic literature, it seems that there is actually not much empiric evidence that cooperations in research and development within the clusters are more frequent than in regions not characterized by cluster formation (Angel 2002). A manageable number of studies shows that there may be a higher number of company cooperations, but that this will be limited to a small number of highly innovative companies (Lyons 2000) or small and medium-sized companies (Arndt and Sternberg 2000) or local companies (Gertler et al. 2000). Therefore it seems that the willingness to cooperate is influenced by sector and company-specific factors (Malmberg and Power 2005). Hendry et al.'s (2000) study on companies in the opto-electronics industry showed that national and international company relationships were much stronger than local ones. Kearns and Gorg (2002) show for Irish regions that the electronic industry does form clusters. However, the leading companies in the cluster performed their research activities abroad and there were no or only low spillover effects on local companies. The studies by Simmie (2002) looking at innovative companies in South-East England and Mota and de Castro (2004) show that successful companies show a mix of local and extraneous cooperations or connections (Malmberg and Power 2005, p.415). The heterogeneity of the empiric results regarding local knowledge spillover led to the motivation to consider cooperation conduct in the innovation process in more detail in this work.

2.3 Role of cluster management to stimulate knowledge spillovers

The following analysis considers two periods each. The founding year of the cluster initiatives in the selected regions determines t_0 and t_1. The periods t_0 and t_1 describe the periods 10 years before and 10 after founding of the cluster initiative. Picking a period before and after the founding date seemed sensible for cooperation network analysis because the ICT cluster initiatives consider it one of their most important tasks to link (ICT) companies or (ICT) companies and research facilities among each other. The action range of the respective cluster initiatives is not determined precisely. However, the member lists of the networkers show that their member companies almost all have their headquarters in the respective NUTS-2 regions. The cluster organizations under consideration in the NUTS-2 regions are members of the network initiative *Kompetenznetze Deutschland*, initiated by the Federal Ministry of Economics and Technology. The initiative covers altogether nine topics, among them information and communications technology. Federal Government currently sponsors 15 networks in the field of information and communication technology. According to the Federal Ministry of Economics and Technology (BMWi 2010a, b, c), these I(C)T networks of competence across Germany aim to increase the interconnectedness between industry and research and to accord greater visibility to the advantages of Germany as an innovation-friendly location. While the initiative Networks of Competence offers specific assistance in cluster management to members, which are accepted according to determined criteria, its primary aim is to enhance the interconnectedness and external visibility of these networks for potential investors.[2]

Empirical studies that analyze the performance of cluster managements are still very scarce in the literature which is surprising as the establishing of such teams has become a very popular instrument in economics policy. Therefore, it can hardly be estimated how efficient the work of cluster organizations actually is. Lawton-Smith (2003) shows that cooperation networks between local actors should be an important foundation for cluster formation. In particular for young companies, cluster organizations should serve as contact points for finding suitable cooperation partners; whether cluster management actually successfully acts as intermediary here is hard to measure, since the quantity of success cannot be easily recorded. Often, soft indicators like provision of useful information and creation of formal and informal contacts are the most important part of the daily work of a cluster office. The following analysis also presents how member companies of the cluster organizations have integrated into the network within the period t_1, even if network analysis based on patents is only able to provide very limited results here, since the analysis method is not perfect. The following analysis focuses on the cooperation behavior of innovators (in ICT cluster regions).

3. Network analysis – cooperation network of patent applicants in selected German ICT cluster regions

3.1 Method procedure

The following network analysis is based on the patent database PATSTAT offered by the European patent office. Since these are merely raw data, they were implemented using a database management system.[3] The advantages and disadvantages of patents as innovation indicators are often discussed in literature. A lot of innovations are never patented. A patent application does not always have a relevant market value. Additionally, the patent trend is different from sector to sector, and also depends on country-specific factors. Still, the interconnection between inventions and patents is very high. Patent data deliver detailed and standardized data for all business sectors and across a long period.

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[2] A minimum size of 10 actors is required and a corporate share of at least 50 %. In addition, the involvement of a research institution must be ensured. Among the parties involved there should also be service providers, in particular financial services providers and basic and further training facilities. The BMWi also requires that the network focuses on a specific field of innovation and that it has specific unique features setting it apart. The organizational degree of the network is also of great significance. Next to "branding," this is the focus of the second pillar of sponsoring. The organization unit of the network or the cluster management will receive specific support, for example, for conducting workshops and industrial fairs. Further assistance is provided by the publication of trend reports, network-specific short studies, online newsletters, joint internet presentations, exchange and development of cooperation projects, internationalisation, i.e. the development of strategies for corresponding activities and the organization of group study visits (BMWi 2010b).

[3] For the precise implementation process, see Mahmutovic (2011). Together with Oliver Emons, Zafir Mahmutovic implemented the patent database EIIW-Netpat in the scope of the research project *EU structural change, regional innovation dynamics and cluster formation options in the knowledge societies* for the European Institute for International Economic Relationships (EIIW) at the Bergische University of Wuppertal.

Additionally, this analysis is dedicated to one country and one sector only, so that comparison is sensible at least between the regions under consideration. The analysis also focuses on networking patterns and less on innovation quality. The ICT sector in the NUTS-2 regions of Cologne and Karlsruhe is examined. Both regions have above-average patent applications in this sector as compared to the natural average. The cities of Karlsruhe and Aachen[4] are considered successful ICT cluster regions. The cooperation network was constructed as follows:

Every patent has the address of the inventor or inventors. Furthermore, the address of the applicants is written on the respective patent. The applicants are involved in the innovation process and are therefore described as innovators. The inventors are natural persons while the applicant is often a company for which the inventor works.
The first criterion is that only ICT patents are considered on which at least one inventor has his permanent place of residence within the region under consideration. It is assumed that this is also the place of knowledge production. The OECD REGPAT database is used for assignment of the addresses of applicant and inventor to the NUTS regions. The second criterion is that at least two applicants are stated on the patent so that a cooperation can be assumed. This means that an inventor from the respective region under consideration worked for innovators A and B, who then registered a patent.

The networks developed are so-called total networks, showing the type of relationship between the actors of a specified examined group of actors to every other actor of this group, or the lack thereof. For personal networks, in contrast, the relationship types between the different actors and a specific examined group of other actors are examined – no matter if they are part of the examined group or not. This means that there is no selfcontained group of actors for personal networks, which is, however, the case in the following networks (Emons 2011, p.333). In rare cases, a applicant may occur twice in a network. This is the case if two different addresses are indicated on two different patents. However in the case of a firm as an applicant the address on the patent is usually equal to the address of the firm's headquarter in the country. Generally, cooperation networks are presented with knowledge at least partially generated in the cluster region under consideration. They are differentiated by the applicant's address indicated on the patent. Networks were drawn up in which the applicants are headquartered within the region, as well as networks where at least one applicant is headquartered outside of the region. The third option was construction of networks in which all applicants have their address outside of the NUTS-2 regions under consideration according to the patent letter (see networks in the appendix). Now I want to show how external applicants "tap" the knowledge regions to increase their knowledge basis or how the cooperations develop interregionally over time.

The IPC classes that define the ICT sector are listed in the appendix. It is essentially based on OECD classification for ICT. All isolated applicants were removed from the networks. Differing node sizes (applicants) and connection thicknesses between the notes to display intensity of cooperations was waived for the benefit of a clear structure. This is made clear by the network analysis measures for every network and therefore the respective position of the innovator in the network. The placement of nodes that represent the applicants does

[4] Aachen is located in the NUTS-2 region of Cologne.

not correspond to any spatial order that represents the geographic position or distance between the companies.

3.2 Network measures

The analysis lists three networking measures (the following explanations are in part based on Emons 2011, p. 337 et seqq.).

The *density* of a network offers information on the ratio of actual relationships as compared to the possible relationships in a network, it is a measure for how closely a group is linked. If g is the number of actors, the number of possible relationships (indegree and outdegree) is:

$$g*(g-1) \tag{1}$$

However, this does not consider the actual relationships a. The density, i.e. the number of actual relationships in the respective network, results from:

$$a/g*(g-1) \tag{2}$$

Density is a simple measure and therefore only suitable for comparison between identically sized networks. *Centrality* helps making statements on the inner structure of the network. There is a difference between the *degree centrality* and the so-called *betweenness centrality* (Freeman 1978). Degree centrality makes a statement on the position of a single actor, in this case the innovators, in the network. It is a value describing the number of relationships that every actor in a network has to the other actor and is formally phrased as follows:

$$C_D(i) = d_i/(g-1) \tag{3a}$$

With D(i) being the number of all adjacent items of the applicant i. Therefore, not the overall network properties, but the properties of the individual actors are taken under consideration. This represents the number of the incoming and outgoing relationships of an actor. The centrality degree of the entire network can be calculated as well:

$$C_D = \sum_{i=1}^{g} (\max(C_i) - C_i)/g - 2 \tag{3b}$$

In contrast to density, degree centrality can be used for differently sized networks. For comparability's sake, we calculate the *average degree centrality*, which provides information on how many relationships every actor maintains on average. Furthermore, the so-called *betweenness centrality* (according to Freeman 1978) is calculated as follows:

$$C_B(i) = \sum_{j \neq i \neq k} \frac{g_{jk}(i)}{g_{jk}} \tag{4a}$$

g_{jk} indicates the number of points that connect applicants j and k along the shortest path.
g_{jk} (i) designates the number of such paths that also include applicant i. 1 means a star shape, 0 indicates that all actors have the same degree. Betweenness centrality indicates

how centrally an actor is located regarding information exchange within a network. A applicant with a high betweenness centrality holds an important role when exchanging information within the network. The network betweenness centrality results from

$$C_B = \frac{2\sum_{i=1}^{g}\left[\max(C_B(n)) - C_B(i)\right]}{(g-1)^2(g-2)} \quad (4b)$$

where max(CB(n)) is the highest value of betweenness centrality of a node and g is the number of nodes in the network (Wasserman and Faust 1994).

3.3 Descriptive statistics

NUTS-2 region Cologne:	NUTS-2-region Karlsruhe:
Seize: 7364.61 Sqkm	Seize: 6919.09 Sqkm
No. of Inhabitants (on average from 1984 to 2007): 4.30 Mio.	No. of Inhabitants (on average from 1984 to 2007): 2.74 Mio.
Name of the Cluster Initiative:	Name of the Cluster:
REGINA e.V. (REGionaler INdustrieclub Informatik Aachen)	Initiative : CyberForum
Start of the Initiative: 1993	Start of the Initiative: 1997
Domicile of the cluster office: Aachen	Domicile of the cluster office: Karlsruhe
No. of cluster member in 2011: 110	No. of cluster members in 2011: 930

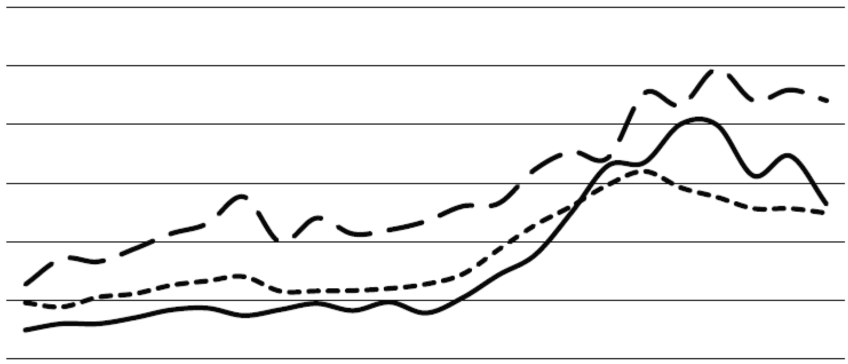
The following figure shows the patent applications in relation to the number of residents. The NUTS-2 region of Karlsruhe is clearly above the national average in the period under consideration while the region of Cologne only exceeds the national average at the end of the 1990s after being below it previously. The figure 3.2 shows the R&D expenses for the region of Cologne drop over time and adjust to the national average. The region of Karlsruhe is clearly above the German overall average and even manages to clearly increase the distance over time (Figs. 1, 2, 3, 4, 5 and 6).

3.4 Results

3.4.1 Results for the NUTS-2 region cologne

The number of cooperations has clearly increased from 643 to 1993 as compared to the previous period, showing very dynamic development. This becomes visually clear in the cooperation network figure. The network measures confirm this first impression.The network degree centrality CD and network betweenness centrality CB increase as compared to the previous period (t0). The average number of connections between the applicants has also increased from 2,375 to 2,596. The Vaillant Group, in t0 still the most central applicant in the cooperation network, lost its central position. The dominance of Vaillant across several companies in the period t0 is distributed to several companies like Philips, Bosch, NXP, Daimler, Volkswagen and BMW in period t1. Similar results are shown in betweenness centrality. Betweenness centrality values for the most important innovators have clearly increased and the order has changed. Large groups from the automotive sector are important – among them Deutsche Telekom AG and Siemens. The research institutes Forschungszentrum Jülich and Fraunhofer were able to maintain their positions as knowledge intermediaries (in the sense of betweenness centrality) as compared to period t0. To achieve this, they clearly increased their centrality values from 0.112 and 0.067 respectively to 0.677 and 0.516 respectively.

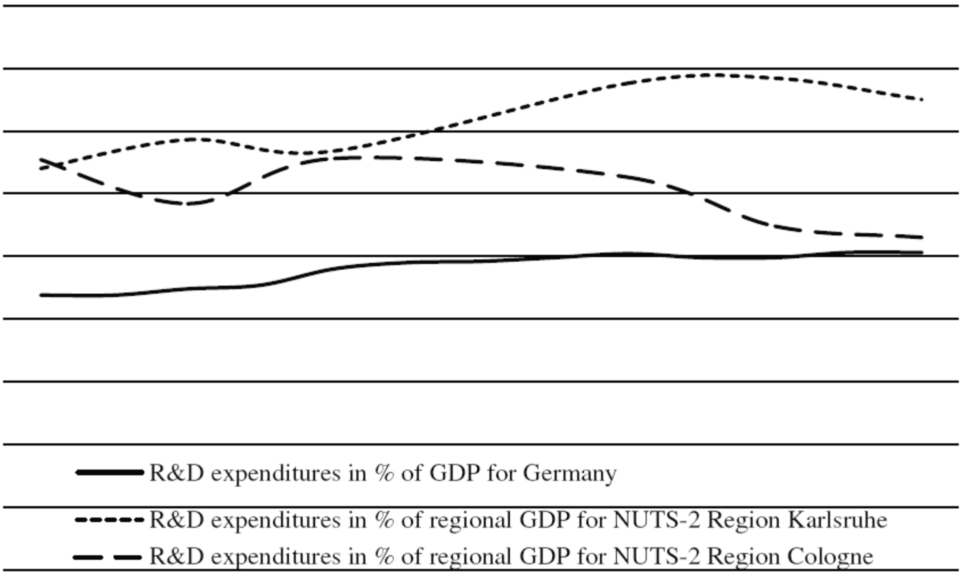
Fig. 1: Number of weighted iCT patent applications (for the period 1984-2006)



Number of weighted ICT patent applications (per million inhabitants) at the EPO for the NUTS-2 Region Cologne
Number of weighted ICT patent applications (per million inhabitants) at the EPO for the NUTS-2 Region Karlsruhe
Number of weighted ICT patent applications (per million inhabitants) at the EPO for Germany

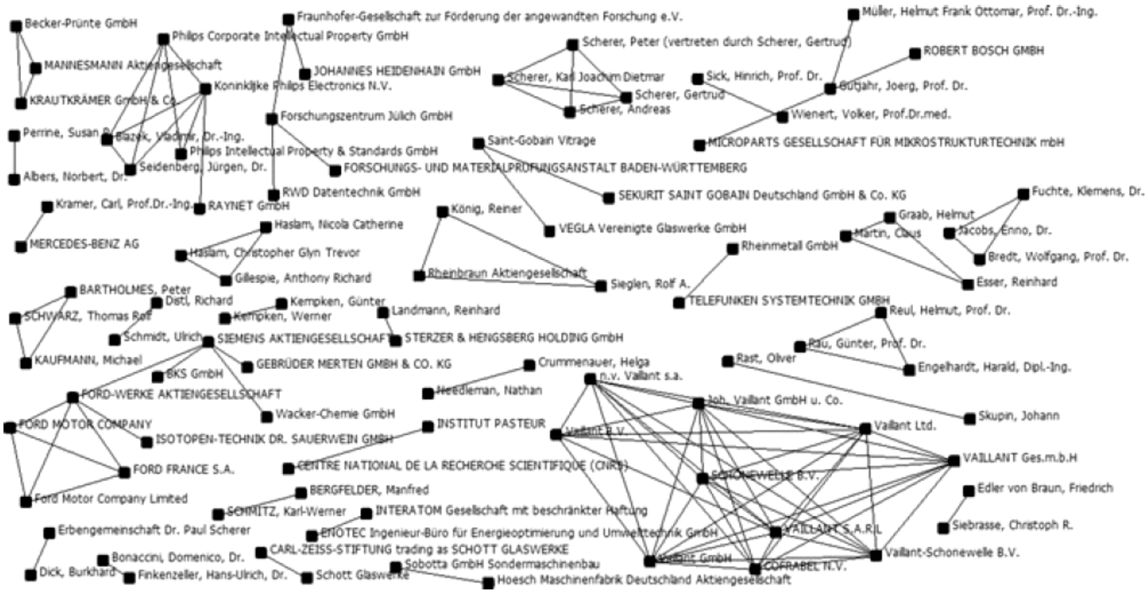
Source: PATSTAT (Own calculations and illustration) (Definition for ICT patents see appendix)

Fig. 2: R&D expenditures in % of (Regional) GDP (No data available for the time before 1995 concerning the NUTS-2 regions) (for the period 1995-2007)



Source: Eurostat/Own Illustration

Fig. 3: Cooperation network for the NUTS-2 Region of cologne for the period of 1984-1993 (t_0)

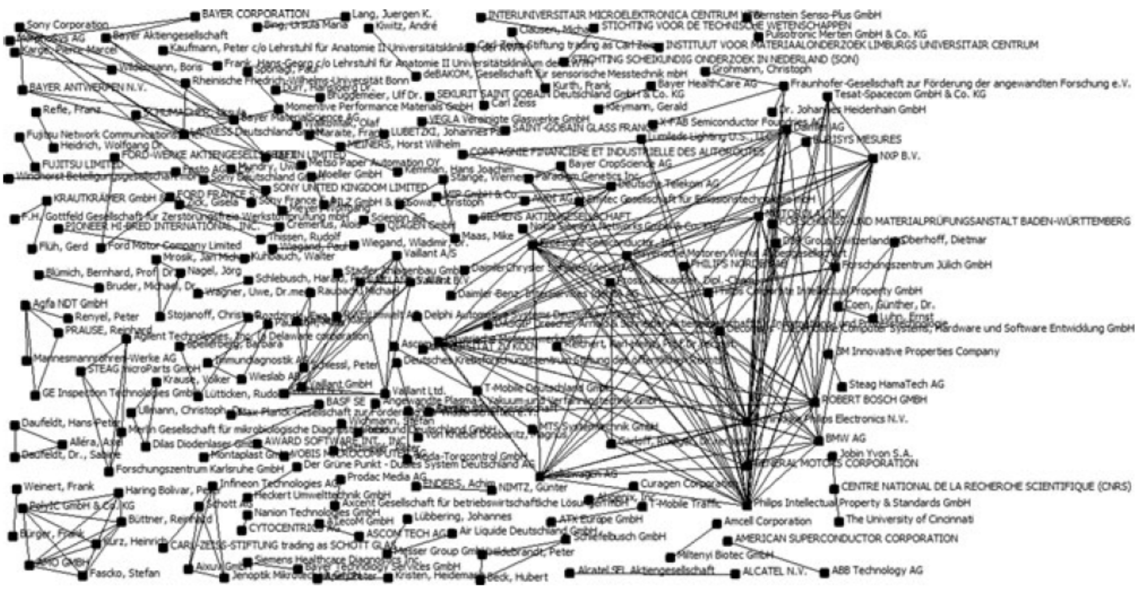


Source: Own Illustration

It is noticeable that research holds an important position in ICT research cooperations nearly at all times and in every network. Looking at the partial networks for Cologne in a more differentiated analysis (see networks in the appendix), i.e. by the address where the applicants are headquartered, shows that in particular companies headquartered outside of Cologne act as intermediaries of cooperations or knowledge. Betweenness centrality of the entire network and individual leading innovators increases most clearly here. The betweenness centrality of the network for applicants headquartered in Cologne increased from 0 % to 0.17 %, staying low. It is clear that almost all applicants in this network are private persons, for both periods t_0 and t_1.[5] (Tables 1 and 2)

In general, it can be said that the importance, i.e. centrality, has moved towards large companies and research facilities headquartered outside of the NUTS-2 region of Cologne over time. The number of companies from outside the region nearly tripled. This also applies for cooperations where at least one cooperation partner comes from the region, while cooperating innovators completely outside of the NUTS-2 region of Cologne only increased from 24 to 36 in absolute figures. This is also represented in the example of the Forschungszentrum Jülich, which is headquartered in the region of Cologne and is often represented as an important player in the different networks. Only in the network that considers only companies headquartered in Cologne it is merely subordinated in importance in t_1. Three companies that are members of the Clusterinitiative REGINA e.V. are part of the overall network in t_0.

Fig. 4: Cooperation network for the NUTS-region cologne for the period of 1994-2003 (t_1)



Source: Own Illustration

3.4.2 Results for the NUTS-2 region Karlsruhe

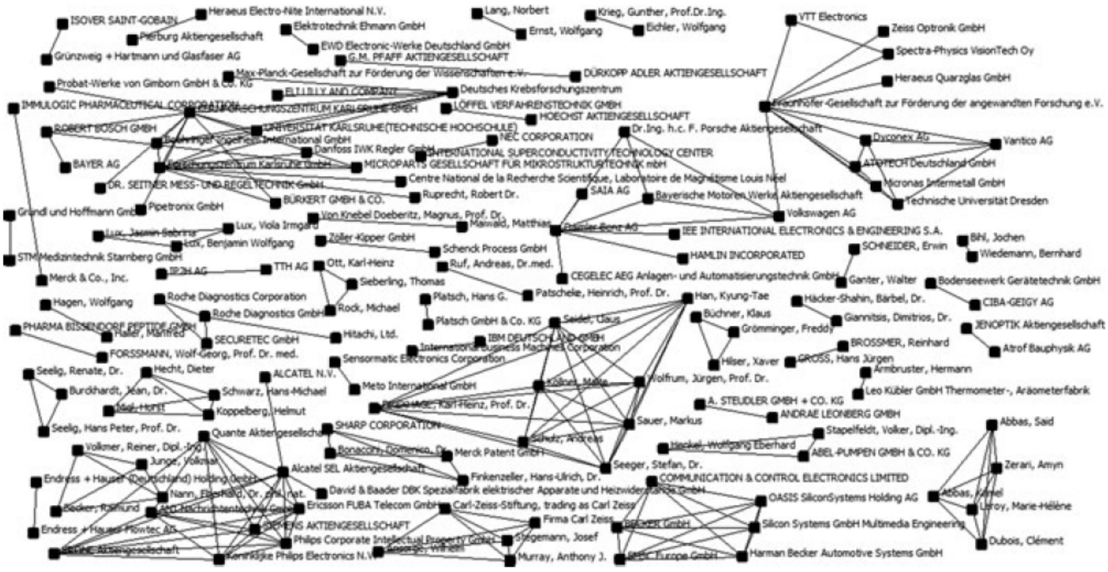
Similar as in the region of Cologne, the number of ICT research cooperations clearly increased from 1273 to 2103. Even if the relative increase is lower, observe that the initial level is much higher in the region of Karlsruhe. Development is in parallel to the region of Cologne. Again, the centrality measures for the cooperation network have increased over time. While network degree centrality increases slightly, the value for betweenness centrality clearly increased from 0.82 % to 1.81 %. The importance of knowledge intermediaries in the scope of research cooperations has therefore clearly increased. With a

[5] It must be noted that natural persons with a professor's title very often can be assigned to research institutions. Until 2002, German patent law permitted university professors to register a patent in their name rather than the university's name.

view to the overall network, but also the differentiated networks (see appendix) for the region of Karlsruhe it becomes clear that the research institutions always hold a central position. Many research institutes like Fraunhofer, Forschungszentrum Karlsruhe, Deutsches Krebsforschungszentrum, Kernforschungszentrum Karlsruhe, Max-Planck-Gesellschaft, etc. are involved in periods t_0 and t_1. A high ratio of research institutes comes from the region or has at least an important site there. Expansion of the cooperations is obviously due to the many cooperations of research companies. They seem to cooperate less with each other, as is shown by the innovator network only headquartered in Karlsruhe, but rather with companies from the outside. Research institutions are important in the Cologne network, and extraordinarily so in their function as knowledge intermediaries or innovators here.

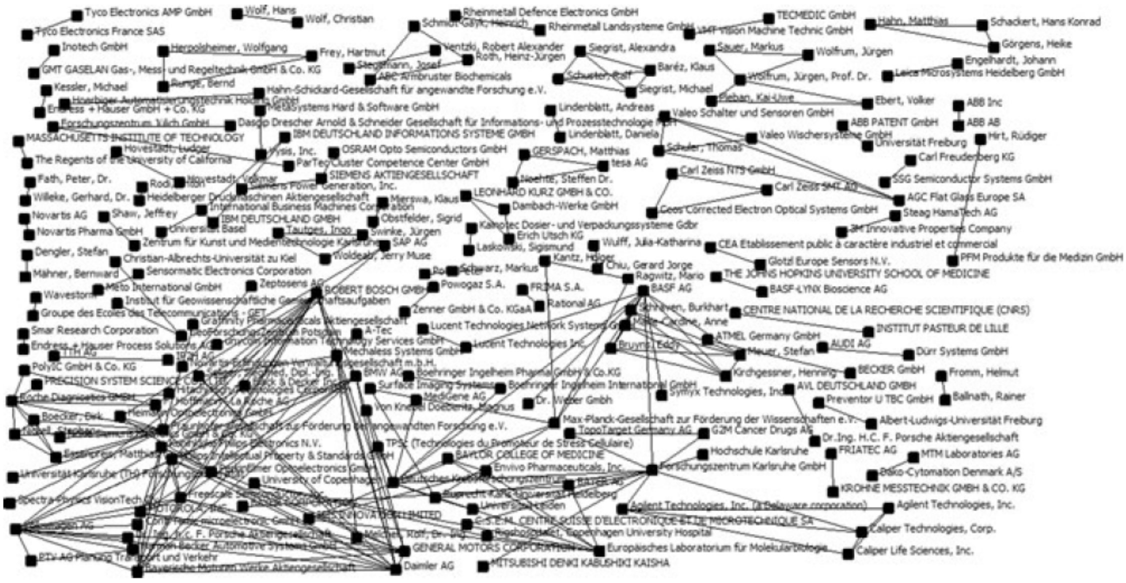
The knowledge region of Karlsruhe is not tapped by cooperating companies, headquartered only outside of it as in the case of the region of Cologne. The number of cooperations in which all cooperation partners are headquartered outside of Karlsruhe increased only from 69 to 91 joint patent applications. It is notable that the most important companies from the outside include Bosch Volkswagen, Daimler, BMW and Philips, the same ones as in the region of Cologne. Five companies are members of the regional cluster initiative CyberForum.

Fig. 5: Cooperation network for the NUTS-2 region of Karlsruhe for the period of 1988-1997 (t_0)



Source: Own Illustration

Fig. 6: Cooperation network for the NUTS-2 Region of Karlsruhe for the period of 1998-2007 (t_1)



Source: Own Illustration

4. Summary of results and conclusions

A network analysis was performed in the German ICT cluster regions of Cologne and Karlsruhe, on the NUTS-2 level. It was targeted at examining the cooperation conduct of innovators. The data basis was the patent database PATSTAT. The raw data provided was prepared so that all ICT patents with at least one inventor resident in one of the regions were filtered out. In a second step, the patents from this data volume with more than one innovator (applicant) were analyzed. It may be assumed that the patent applicants know each other and that they cooperate within a joint research project. Cooperation networks were generated for networks or network measures and their development was illustrated and analyzed for two periods of 10 years each for either region. The objective was showing how cooperation behavior dynamics develop in an economic sector in which successful cluster formation has taken place at the same time. Who were the important actors in this process, and what was the role of inter-regional cooperations? How are external innovators integrated into the network? Did the regions go through parallel development? The results show that the cooperation behavior in the cluster process also developed dynamically. In both regions, the network expanded and continued to diversify, while also enhancing its structures. This becomes clear by the analytic measures, as well as the graphic network mappings. The overall networks in the two regions show that cooperation intensity has continued to increase, at concurrent increase of the number of cooperating innovators. Only Karlsruhe showed some small relative reduction of the average number of cooperation relationships. In both regions there are several important innovator cooperations regarding number and intensity. There is no danger of cooperation networks breaking apart due to loss of one innovator. The clear increase of betweenness centrality in both networks is notable. Knowledge intermediation has clearly increased. Knowledge transfer between innovators with a third party integrated has clearly increased. It is not surprising that the most important innovators are large companies. In particular multinational ICT companies and automotive groups are central actors in the cooperation networks. The differences between the regions become clear here as well. While the overall networks develop dynamically in parallel over time, drivers for cooperation conduct in the region of Cologne are cooperations with external companies. They often tap the knowledge region. This means that they cooperate with inventors from the region while being headquartered outside of it. Additionally, there is a strong increase of cooperations between regional companies and external companies in Cologne. The interregional cooperations developed much less dynamically in both regions. In the region of Karlsruhe, many research institutions are involved in cooperations or serving as knowledge intermediaries, in addition to large multi-national groups that are, interestingly, often the same ones as in the region of Cologne . This is the case of the region of Cologne as well, but Karlsruhe often has more than five different research institutions as most important players in the network and therefore is extraordinarily strongly placed here. On the other hand, cooperating external companies do not play the important role for network expansion that they do in the NUTS-region of Cologne. Network expansion in the region of Cologne therefore was driven more strongly by companies from the outside, and in the region of Karlsruhe by research cooperations with at least one research institute from the region as innovator. Three and five companies respectively among the cooperating investors in

Table 1: Cooperation network measures of NUTS-2 region Karlsruhe

NUTS-2 region cologne for the period of	1984–1993	1994–2003
Number of all weighted ICT patent applications:	643	1993
Number of applicants >1 per patent (Nodes)	96	225
Ratio of applicants >1 per patent (cooperations)	14.93 %	11.28%
Number of applicants that are also members of the cluster initiative		3
Network Density	0.025	0.0116
Network Degree centrality C_D	7.04 %	10.09%
Network Betweenness Centrality C_B	0.42 %	1.47 %
Average Ties per Actor	2.375	2.596
Inclusion of Research Institutes	Yes	Yes
	Most Central Applicants/C_D(i) in % (Degree-Centrality)	
1984–1993	1994–2003	
n.v. Vaillant s.a./9.474	Philips Intellectual Property & Standards GmbH/ 11.161	
VAILLANT p.A.R.L/9.474	Koninklijke Philips Electronics N.V./10.714	
Vaillant GmbH/9.474	ROBERT BOSCH GMBH/6.696	
Joh. Vaillant GmbH u. Co./9.474	NXP B.V./6.250	
VAILLANT Ges.m.b.H/9. 474	Daimler AG/6.250	
Vaillant Ltd./9.474	Volkswagen AG/5.804	
SCHONEWELLE B.V./8.421	BMW AG/5.357	
COFRABEL N.V./8.421	Decomsys - Dependable Computer Systems, Hard ware and	
Vaillant-Schonewelle B.V./8.421	Software Entwicklung GmbH/5.357	
Vaillant B.V./6.316	GENERAL MOTORS CORPORATION/5.357	
FORD-WERKE AKTIENGESELL-	Freescale Semiconductor, Inc./5.357	
SCHAFT/5.263	Bayerische Motoren Werke Aktiengesellschaft/ 5.357	
Koninklijke Philips Electronics N.V./5.263	MOTOROLA, INC./5.357	
SIEMENS AKTIENGESELLSCHAFT/4.211	Forschungszentrum Jülich GmbH/4.018	
Philips Corporate Intellectual Prop. GmbH/4.211	Bayer MaterialScience AG/3.125	
	Most Central Applicants/C_B(i) in % (Betweenness-Centrality)	
1984–1993	1994–2003	
FORD-WERKE AKTIENGESELL-	Deutsche Telekom AG/1.413	
SCHAFT/0.426 Daimler AG/1.497	Philips Intellectual Property & Standards GmbH/ 1.217	
SIEMENS AKTIENGESELLSCHAFT/0.403	Koninklijke Philips Electronics N.V./1.041	
Koninklijke Philips Electronics N.V./0.112	Forschungszentrum Jülich GmbH/0.677	
Forschungszentrum Jülich GmbH/0.112	Fraunhofer-Gesellschaft zur Förderung/der angewandten Forschung e.V./0.516	
	T-Mobile Germany GmbH/0.348	

Table 1 (continued)

Deutsches Krebsforschungszentrum/0.240	Volkswagen AG/0.581
ROBERT BOSCH GMBH/0.124	Daimler AG/0.437
Alcatel SEL Aktiengesellschaft/0.124	Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V./0.430
MICROPARTS GESELLSCHAFT FÜR	
MIKROSTRUKTURTECHNIK mbH/0.033	Roche Diagniostics GMBH/0.319
Roche Diagnostics GmbH/0.017	Lucent Technologies Inc./0.173
	Boehringer Ingelheim International GmbH/0.173

Own calculations

networks are members of the cluster initiative. To assess the role of cluster organizations, supplementary quality analysis is indispensable. Measuring the networking success in the innovation process by patent analysis without any further information on the members only would be insufficient and would not meet the requirements of evaluation of cluster organization activities. However, supplementary qualitative analysis would be highly interesting to look more closely at the cluster initiative's role. This analysis indicates that individual cluster promotion is required and that a strategy customized for the region in question should be pursued. While the region of Cologne has developed from a below-average to an above-average ICT knowledge region at least regarding ICT patent applications by, e.g., increased cooperation between regional companies and external companies, integration of the research institutes as knowledge intermediaries or cooperation partners in R&D was likely a decisive factor for further development of Karlsruhe as an ICT site. In any case, cooperations and successful cluster formation seem to coincide. Networking appears to be relevant. If these networking activities are promoted by third parties (e.g. a cluster organization), external companies should in any case be considered as potentially matching partners in the innovation process for regional companies.

Of course, this thesis is a rather descriptive analysis that provides an additional component for the German ICT sector created by network analysis, an analysis instrument not very widely used in business sciences yet, in the light of the many cluster analyses today. In addition to the disadvantages of patent analysis already named, this method cannot easily empirically analyze causative interrelations. Additionally, there are the usual limitations resulting from the administrative and therefore artificial thresholds, such as the NUTS-2 level for a cluster analysis. However, it appears obvious that successful regional ICT cluster formation by cooperations with external companies and integration of research institutions are important factors for success. It remains unclear, in how far local knowledge spillovers in the form of cooperations play a role and whether other factors like lower transaction costs or a specialized local labor market would offer better explanations for a spatial agglomeration of companies from the same sector. Interregional cooperations develop much less dynamically in both regions, in any case.

Apprendix

Table 2: Classification of (OECD) ICT sector

IPC 4 classes

'B07C','B41J','B41K','G01B','G01C','G01D','G01F','G01G','G01H','G01J','G01K','G01L','G01M','G01N', 'G01P','G01R','G01S','G01V','G01W','G02F','G03G','G05B','G05F','G08C','G08G','G09B','G09C','G09G',' G10L','G11B','G11C','H01L','H01P','H01Q','H03B','H03C','H03D','H03F','H03G','H03H','H03J','H03K', 'H03L','H03M','H04B','H04H','H04J','H04K','H04L','H04M','H04N','H04Q','H04R','H04S','H1S5','H1'

IPC 8 classes

'G02B 6','H01B 11','H01J 11','H01J 13','H01J 15','H01J 17','H01J 19','H01J 21','H01J 23','H01J 25','H01J 27','H01J 29','H01J 31','H01J 33','H01J 40','H01J 41','H01J 43','H01J 45','H01S 3/025','H01S 3/043','H01S 3/063','H01S 3/067','H01S 3/085','H01S 3/0933','H01S 3/0941','H01S 3/103','H01S 3/133','H01S 3/ 18','H01S 3/19','H01S 3/25'

Large IPC4 classes

'G06/G07

Table 3: Cooperation networks with at least one cooperation partner (Applicant) headquartered outside of the region under consideration

NUTS-2 region of Cologne for the period of	1984–1993	1994–2003
Number of all weighted ICT patent applications	643	1993
Number of applicants with at least one cooperation partner (applicant) headquartered outside of the region under consideration >1 per patent (modes)	56	136
Ratio of applicants >1 per patent (cooperations)	8.71 %	6.82 %
Network Density	0.0416	0.0150
Network Degree-centrality C_D	6.88 %	5.95 %
Network Betweenness Centrality C_B	0.73 %	0.96 %
Average Ties per Actor	2.286	2.029
Inclusion of Research Institutes	Yes	Yes
	Most Central Applicants/C_D(i) in % (Degree-Centrality)%	
1984–1993	1994–2003	
Vaillant Ltd./10.909	ROBERT BOSCH GMBH/7.407	
VAILLANT Ges.m.b.H/10.909	Koninklijke Philips Electronics N.V./6.667	
Vaillant s.a./10.909	Daimler AG/6.667	
Joh. Vaillant GmbH u. Co./10.909	Philips Intellectual Property & Standards GmbH/5.926	
VAILLANT p.A.R.L/10.909.	Decomsys - Dependable Computer Systems,	
Vaillant GmbH/10.909	Hardware and Software Entwicklung GmbH/5.185	
SCHONEWELLE B.V./10.909	Bayerische Motorenwerke AG/5.185	
FORD-WERKE AKTIENGESELL-	Freescale Semiconductor, Inc./5.185	
SCHAFT/9.091	GENERAL MOTORS CORPORATION/3.704	
Seidenberg, Jürgen, Dr./5.455	Bayer MaterialScience AG/3.704	
Blazek, Vladimir, Dr.-Ing./5.455	Deutsche Telekom AG/3.704	

Table 3 (continued)

Ford Motor Company Limited/5.455	Forschungszentrum Jülich GmbH/3.704
FORD MOTOR COMPANY/5.455	Sony Corporation/2.963
Philips Corporate Intellectual Property GmbH/5.455	
Forschungszentrum Jülich GmbH/5.455	
FORD FRANCE p.A./5.455	
	Most Central Applicants/C_B(i) in % (Betweenness-Centrality)
1984–1993	1994–2003
FORD-WERKE AKTIENGESELLSCHAFT/0.741	ROBERT BOSCH GMBH/0.984
SIEMENS AKTIENGESELLSCHAFT/0.337	Daimler AG/0.829
Forschungszentrum Jülich GmbH/0.202	Forschungszentrum Jülich GmbH/0.586
Saint-Gobain Vitrage/0.067	Deutsche Telekom AG/0.586
	Koninklijke Philips Electronics N.V./0.287
	Bayer MaterialScience AG/0.133
	Philips Intellectual Property & Standards GmbH/0.094
	Bayer Aktiengesellschaft/0.066
	Sony Corporation/0.066
	Agfa NDT GmbH/0.022
	T-Mobile Germany GmbH/0.011
	SAINT-GOBAIN GLASS FRANCE/0.011
	KRAUTKRÄMER GmbH & Co./0.011

Source: Own calculations

Fig. 7: Cologne (NUTS-2) with at least one cooperation partner (Applicant) headquartered outside of the region for the period of 1984-1993 (t_0)

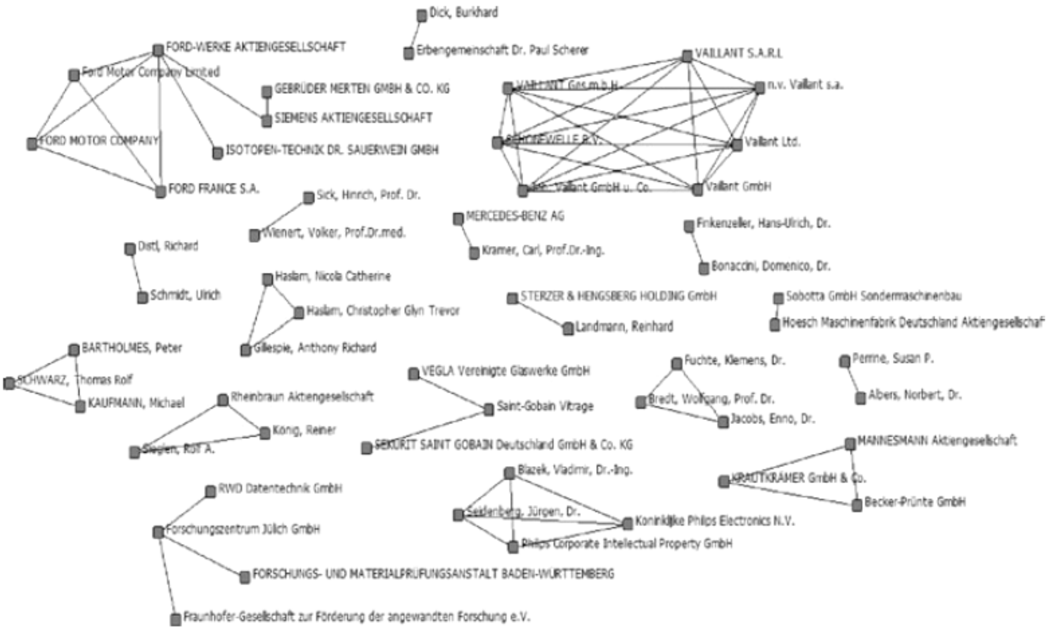
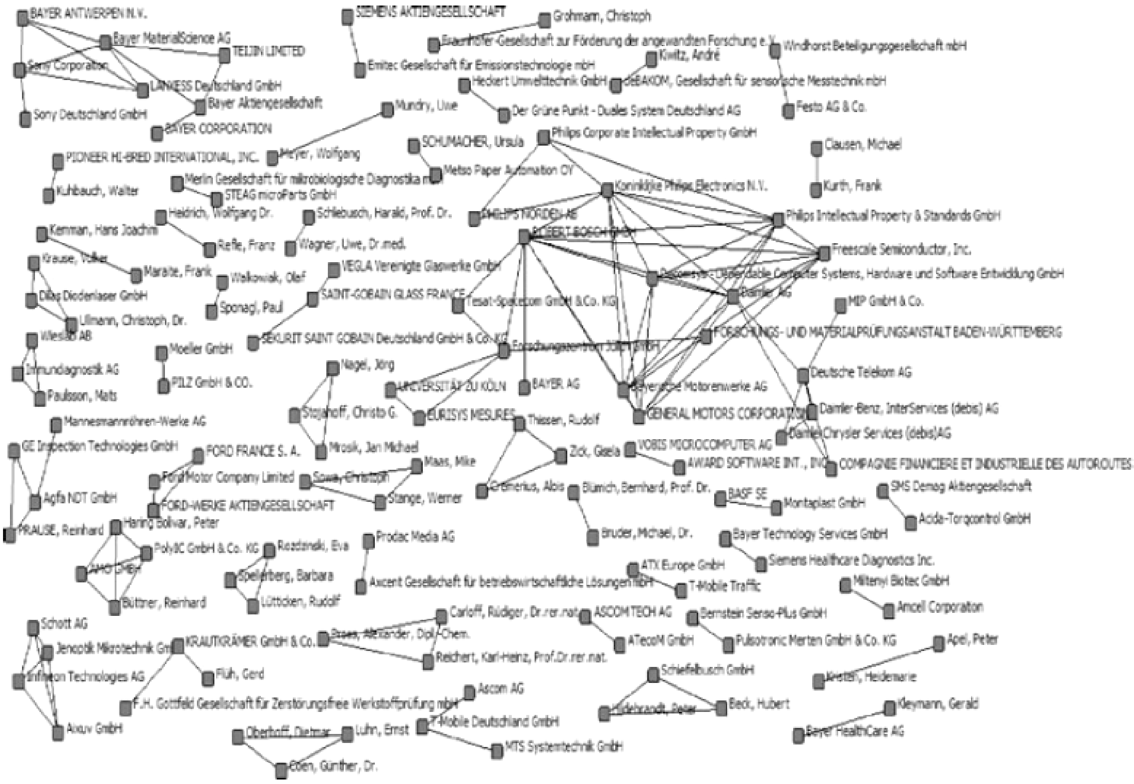


Fig. 8: Cologne (NUTS-2) with at least one cooperation partner (Applicant) headquartered outside of the region for the period of 1994-2003 (t_1)



Source: Own illustration

Table 4: Cooperation networks with at least one cooperation partner (Applicant) headquartered outside of the region under consideration

NUTS-2 region of Karlsruhe for the period of	1988–1997	1998–2007
Number of all weighted ICT patent applications:	1273	2103
Number of applicants with at least one cooperation partner (applicant) headquartered outside of the region under consideration	69	104
Ratio of applicants >1 per patent (cooperations)	5.42 %	4.95 %
Network Density	0.0367	0.0207
Network Degree-centrality C_D	6.73 %	5.75 %
Network Betweenness Centrality C_B	0.78 %	2.65 %
Average Ties per Actor	2.493	2.135
Inclusion of Research Institutes	Yes	Yes
	Most Central Applicants/$C_D(i)$ in % (Degree-Centrality)%	
1988–1997	1998–2007	
Seeger, Stefan, Dr./10.294	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V./7.767	
Seidel, Claus/10.294		
Köllner, Malte/10.294	Roche Diagniostics GMBH/7.767	

Table 4 (continued)

DREXHAGE, Karl-Heinz, Prof. Dr./10.294	BASF AG/7.796
Sauer, Markus/10.294	Forschungszentrum Karlsruhe GmbH/6.796
Schulz, Andreas/10.294	Europäisches Laboratorium für Molekularbiologie/5.825
Wolfrum, Jürgen, Prof. Dr./10.294	Max-Planck-Gesellschaft zur Förderung der
Han, Kyung-Tae/10.294	Wissenschaften e.V./4.854
KERNFORSCHUNGSZENTRUM	Bruyns, Eddy/4.854
KARLSRUHE GMBH/7.353	Deutsches Krebsforschungszentrum/4.854
Forschungszentrum Karlsruhe GmbH7.353	Schraven, Burkhart/4.854
Leroy, Marie-Hélène/5.882	Marie-Cardine, Anne/4.854
Abbas, Kamel/5.882	Kirchgessner, Henning/4.854
Zerari, Amyn/5.882	Meuer, Stefan/4.854
Abbas, Said/5.882	Essenpreis, Matthias/3.883
Dubois, Clément/5.882	Boecker, Dirk/3.883
	Nickell, Stephan/3.883
	F. Hoffmann - La Roche AG/3.883
	Most Central Applicants/$C_B(i)$ in % (Betweenness-Centrality)
1988–1997	1998–2007
Forschungszentrum Karlsruhe GmbH/0.790	BASF AG/2.722
KERNFORSCHUNGSZENTRUM	Deutsches Krebsforschungszentrum/2.322
KARLSRUHE GMBH/0.790	Forschungszentrum Karlsruhe GmbH/1.980
Roche Diagnostics GmbH/0.132	Max-Planck-Gesellschaft zur Förderung der
Deutsches Krebsforschungszentrum/ 0.044	Wissenschaften e.V./1.371
	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V./0.733
	Roche Diagniostics GMBH/0.457
	Europäisches Laboratorium für Molekularbiologie/0.209
	SAP AG/0.209
	F. Hoffmann - La Roche AG/0.105
	Wolfrum, Jürgen, Prof. Dr./0.038

Fig. 9: Karlsruhe (NUTS-2) with at least one cooperation partner (Applicant) headquartered outside of the region for the period of 1988-1997 (t_0)

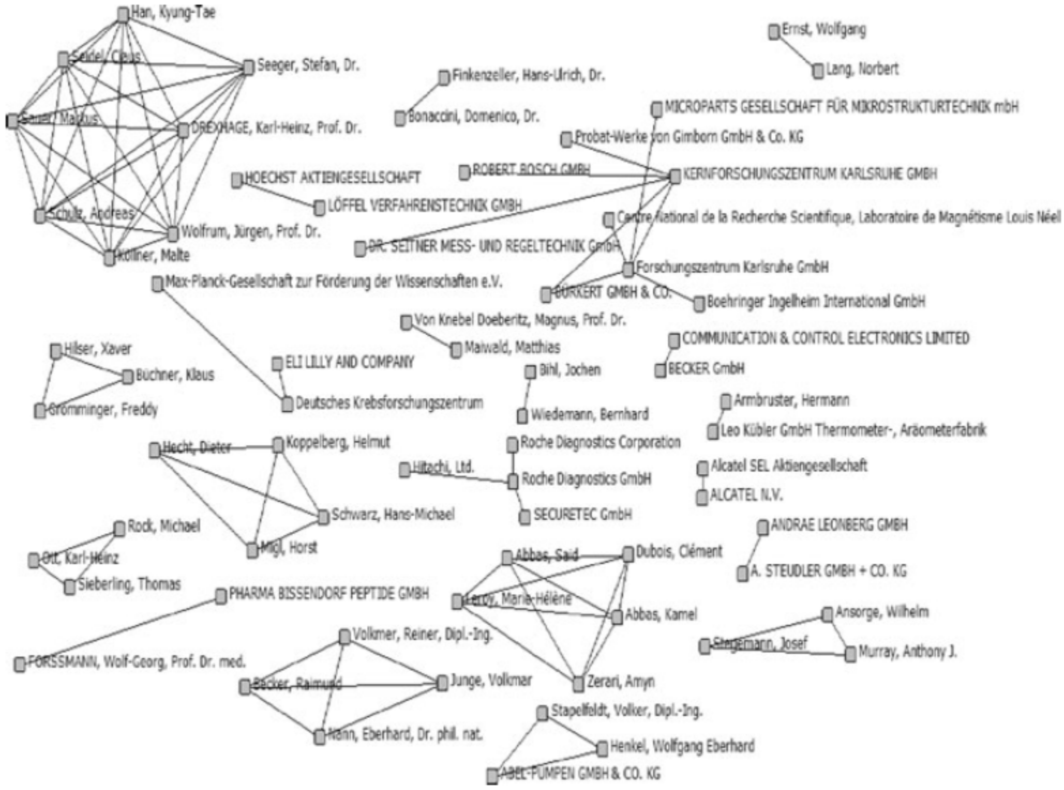


Fig. 10: Karlsruhe (NUTS-2) with at least one cooperation partner (Applicant) headquartered outside of the region for the period of 1998-2007 (t_1)

Source: Own illustration

Table 5: Cooperation networks in which all cooperation partners (Applicants) are headquartered outside of the region under consideration

NUTS-2 region of Cologne for the period of	1984–1993	1994–2003
Number of all weighted ICT patent applications:	643	1993
Number of applicants in which all cooperation partners (applicants) are headquartered outside of the region under consideration	26	75
Ratio of applicants >1 per patent (cooperations)	4.04 %	3.76 %
Network Density	0.1569	0.0418
Network Degree-centrality C_D	21.12 %	20.42 %
Network Betweenness Centrality C_B	0.28 %	2.94 %
Average Ties per Actor	3.923	3.093
Inclusion of Research Institutes	Yes	Yes
	Most Central Applicants/$C_D(i)$ in % (Degree-Centrality)%	
1984–1993	1994–2003	
Joh. Vaillant GmbH u. Co./36.000	Philips Intellectual Property & Standards GmbH/24.324	
VAILLANT Ges.m.b.H/36.000	Koninklijke Philips Electronics N.V./22.973	
Vaillant GmbH/36.000	Volkswagen AG/14.865	
Vaillant Ltd./36.000	MOTOROLA, INC./13.514	
n.v. Vaillant s.a./36.000	Daimler AG/13.514	
VAILLANT p.A.R.L/36.000	NXP B.V./13.514	
COFRABEL N.V./32.000	ROBERT BOSCH GMBH/13.514	
SCHONEWELLE B.V./32.000	Freescale Semiconductor, Inc./13.514	
Vaillant-Schonewelle B.V./32.000	Bayerische Motoren Werke Aktiengesellschaft/13.514	
Vaillant B.V./24.000	GENERAL MOTORS CORPORATION/13.514	
Koninklijke Philips Electronics N.V./8.000	BMW AG/13.514	
SIEMENS AKTIENGESELLSCHAFT/8.000	Vaillant GmbH/6.757	
	Vaillant B.V./6.757	
	Vaillant A/S/6.757	
	Vaillant Ltd./6.757	
	VAILLANT p.A.R.L/6.757	
	Vaillant N.V./6.757	
	Most Central Applicants/$C_B(i)$ in % (Betweenness-Centrality)	
1984–1993	1994–2003	
SIEMENS AKTIENGESELLSCHAFT/0.333	Philips Intellectual Property & Standards GmbH/2.999	
Koninklijke Philips Electronics N.V./0.333	Koninklijke Philips Electronics N.V./2.258	
Joh. Vaillant GmbH u. Co./0.167	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V./1.444	
Vaillant Ltd./0.167		
VAILLANT Ges.m.b.H/0.167	Volkswagen AG/0.740	
VAILLANT p.A.R.L/0.167	Sony Germany GmbH/0.074	
Vaillant GmbH/0.167	AUDI AG/0.037	
n.v. Vaillant s.a./0.167	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (CNRS)/0.037 Messer Group GmbH/0.037	

Source: Own calculation

Fig. 11: All applicants outside of cologne (NUTS-2) for the period of 1984-1993 (t_0)

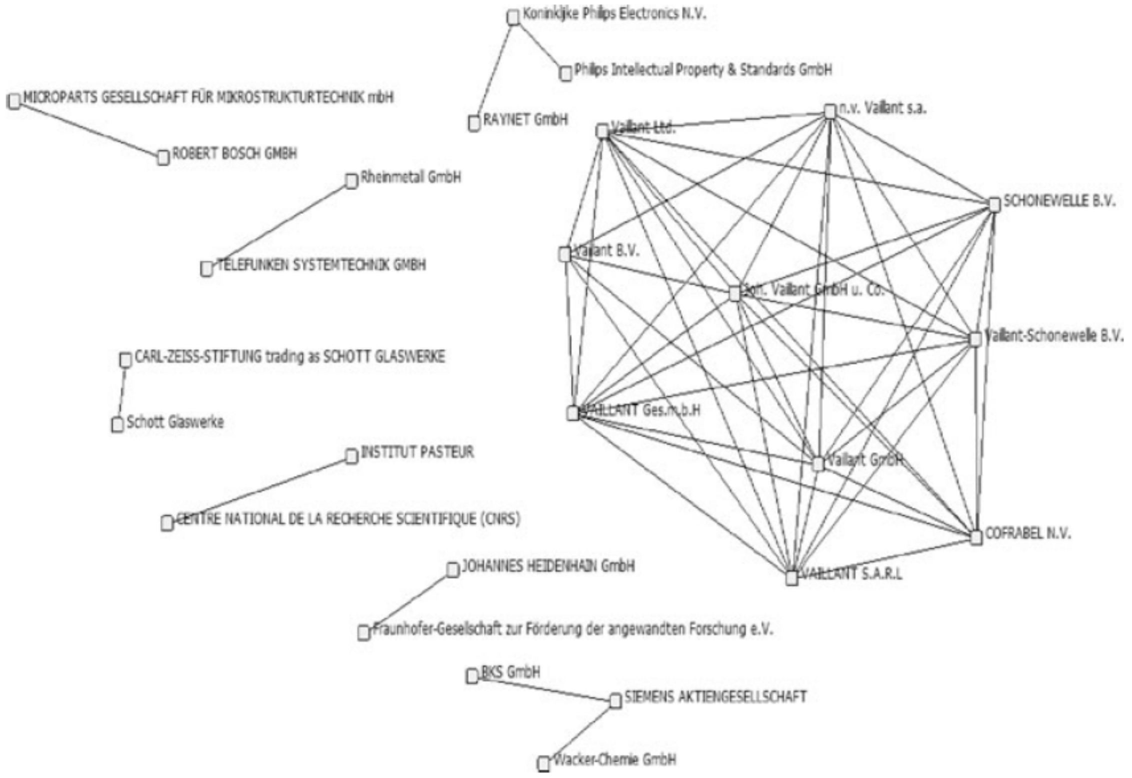
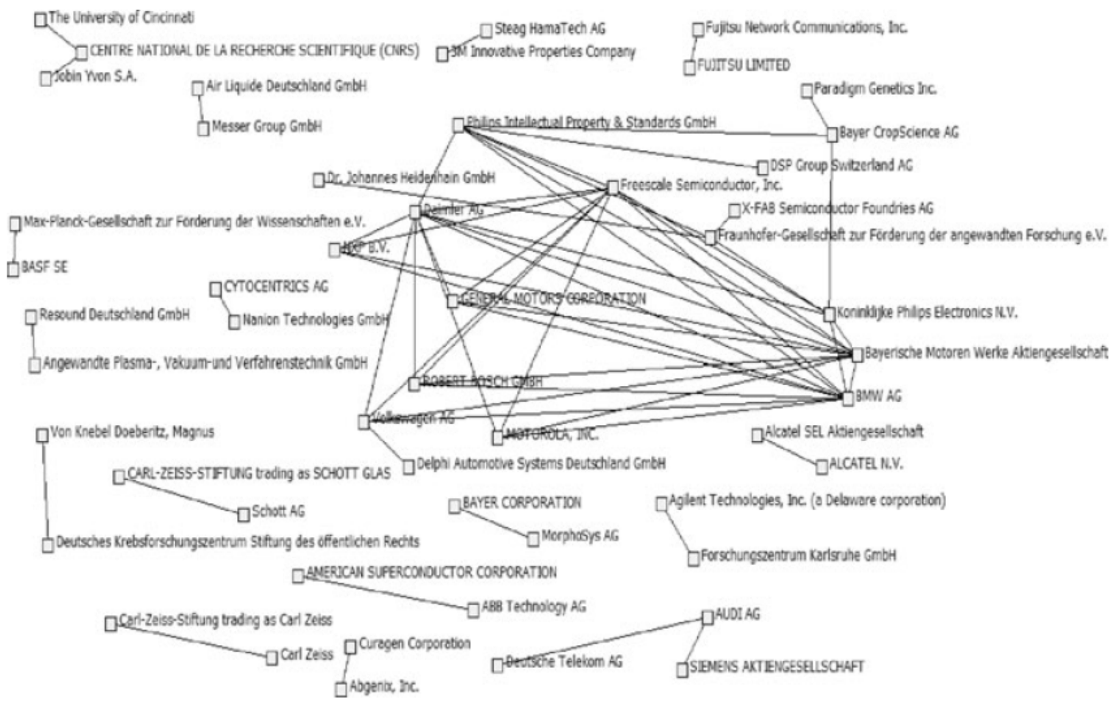


Fig. 12: All applicants outside of cologne (NUTS-2) for the period 1994-2003 (t_1)



Source: Own illustration

Table 6: Cooperation networks in which all cooperation partners (Applicants) are headquartered outside of the region under consideration

NUTS-2 region of Karlsruhe for the period of	1988–1997	1998–2007
Number of all weighted ICT patent applications:	1273	2103
Number of applicants in which all cooperation partners (applicants) are headquartered outside of the region under consideration	69	91
Ratio of applicants >1 per patent (cooperations)	5.42 %	4.33 %
Network Density	0.0332	0.0252
Network Degree-centrality C_D	11.55 %	10.94 %
Network Betweenness Centrality C_B	4.34 %	1.62 %
Average Ties per Actor	2.261	2.264
Inclusion of Research Institutes	Yes	Yes
	Most Central Applicants/C_D(i) in % (Degree-Centrality)%	
1988–1997	1998–2007	
Fraunhofer-Gesellschaft zur Förderung der	ROBERT BOSCH GMBH/13.333	
angewandten Forschung e.V./14.706	Volkswagen AG/12.222	
Alcatel SEL Aktiengesellschaft/13.235	Daimler AG/10.000	
SIEMENS AKTIENGESELLSCHAFT/10.294	BMW AG/10.000	
ANT Nachrichtentechnik GmbH/10.294	Koninklijke Philips Electronics N.V./10.000	
KRONE Aktiengesellschaft/10.294	Bayerische Motoren Werke Aktiengesellschaft/10.000	
Koninklijke Philips Electronics N.V./10.294	MOTOROLA, INC./10.000	
Quante Aktiengesellschaft/10.294	GENERAL MOTORS CORPORATION/ 10.000	
Daimler-Benz AG/10.294	Freescale Semiconductor, Inc./10.000	
Philips Corporate Intellectual Property	Philips Intellectual Property & Standards GmbH/10.000	
GmbH/10.294	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V./6.667	
Ericsson FUBA Telecom GmbH/10.294		
Volkswagen AG/5.882	BASF AG/4.444	
Vantico AG/5.882		
ATOTECH Germany GmbH/5.882		
Dyconex AG/5.882		
Technische Universität Dresden/5.882		
	Most Central Applicants/C_B(i) in % (Betweenness-Centrality)	
1988–1997	1998–2007	
Fraunhofer-Gesellschaft zur Förderung der	ROBERT BOSCH GMBH/1.648	
angewandten Forschung e.V./4.434	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V./1.124	

Table 6 (continued)

Volkswagen AG/3.073	
Daimler-Benz AG/2.546	Volkswagen AG/0.774
Alcatel SEL Aktiengesellschaft/0.658	BASF AG/0.225
ROBERT BOSCH GMBH/0.044	Lucent Technologies Inc./0.100
	International Business Machines Corporation/0.050
	Forschungszentrum Jülich GmbH/0.025
	SIEMENS AKTIENGESELLSCHAFT/ 0.025
	GeoForschungsZentrum Potsdam/0.025

Source: Own calculation

Fig. 13: All applicants outside of Karlsruhe (NUTS-2) for the period of 1988-1997 (t_0)

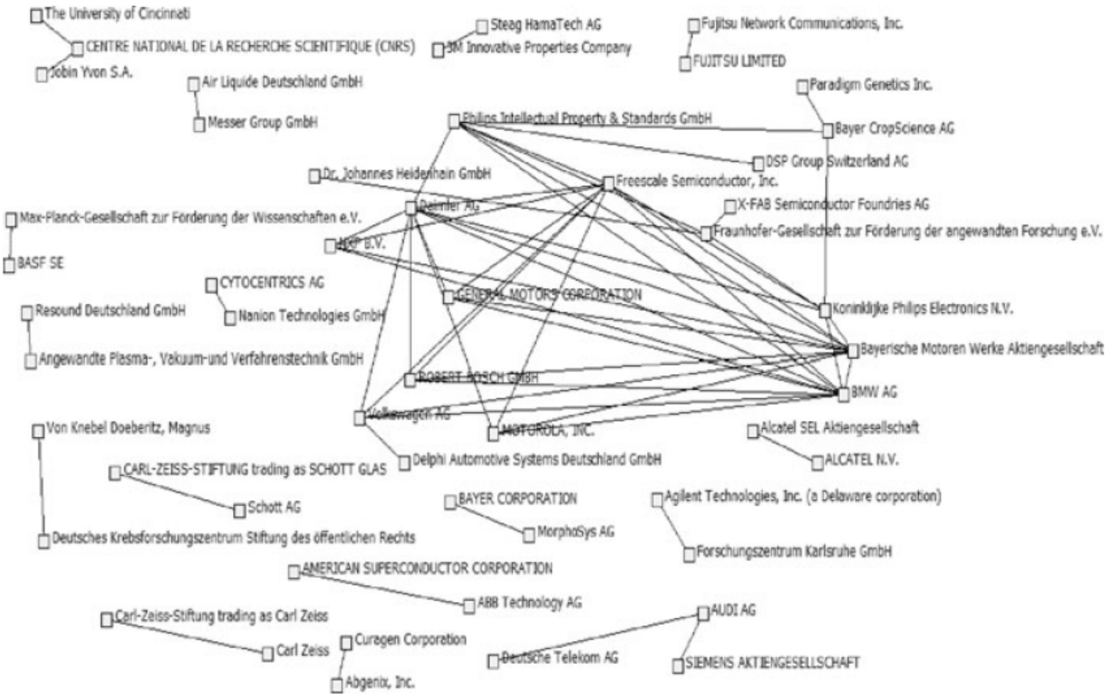
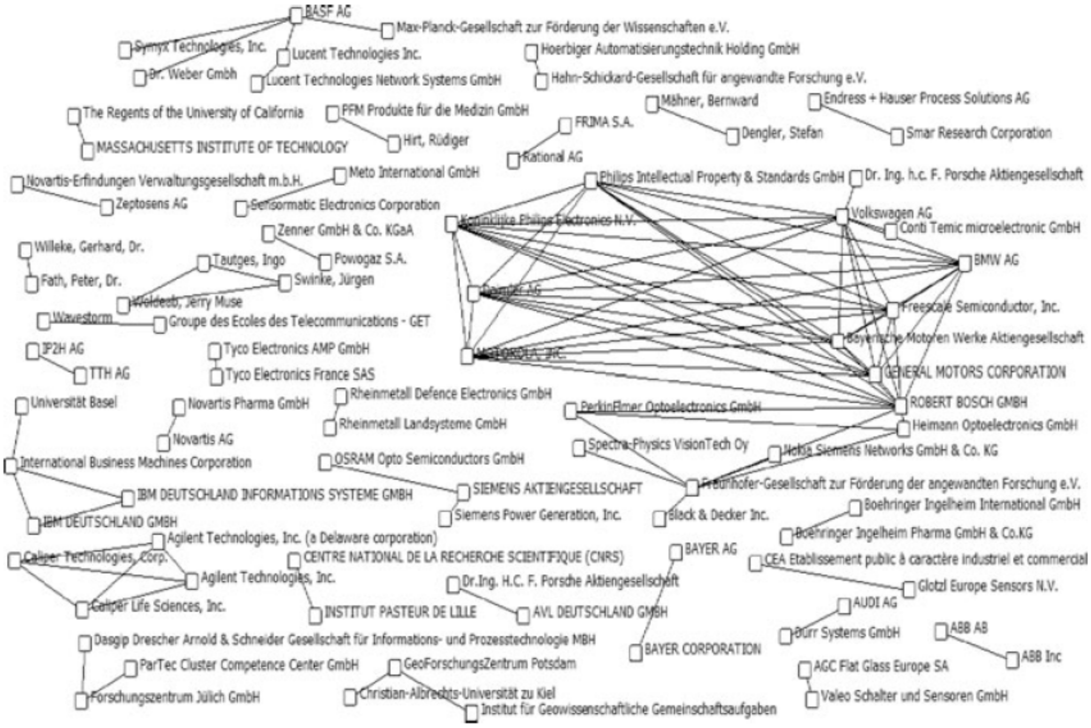


Fig. 14: All applicants outside of Karlsruhe (NUTS-2) for the period of 1998-2007 (t_1)



Source: Own illustration

Table 7: Cooperation networks in which all cooperation partners (Applicants) are headquartered inside the region under consideration

NUTS-2 region of Cologne for the period of	1984–1993	1994–2003
Number of all weighted ICT patent applications:	643	1993
Number of applicants in which all cooperation partners (applicants) are headquartered inside the region under consideration	24	36
Ratio of applicants >1 per patent (cooperations)	3.73 %	1.81 %
Network Density	0.0688	0.0333
Network Degree-centrality C_D	6.43 %	2.45 %
Network Betweenness Centrality C_B	0 %	0.17 %
Average Ties per Actor	1.583	1.167
Inclusion of Research Institutes	Yes	Yes
	Most Central Applicants/C_D(i) in % (Degree-Centrality)%	
1984–1993	1994–2003	
Scherer, Gertrud/13.043	Kollberg, Klaus/5.714	
Scherer, Karl Joachim Dietmar/13.043	Alléra, Axel/5.714	
Scherer, Peter (represented by	Bayer MaterialScience AG/5.714	
Scherer, Gertrud)/13.043	Daufeldt, Dr., Sabine/5.714	
Scherer, Andreas/13.043	Daufeldt, Hans-Peter/5.714	
Engelhardt, Harald, Dipl.-Ing./8.696	Schiessl, Peter/5.714	
Reul, Helmut, Prof. Dr./8.696	Raupach, Michael/5.714	
Graab, Helmut/8.696		
Martin, Claus/8.696		
Rau, Günter, Prof. Dr./8.696		
Esser, Reinhard/8.696		
	Most Central Applicants/C_B(i) in % (Betweenness-Centrality)	
1984–1993	1994–2003	
	Bayer MaterialScience AG/0.168	

Source: Own calculation

Fig. 15: All applicants within cologne (NUTS-2) for the period of 1984-1993 (t_0)

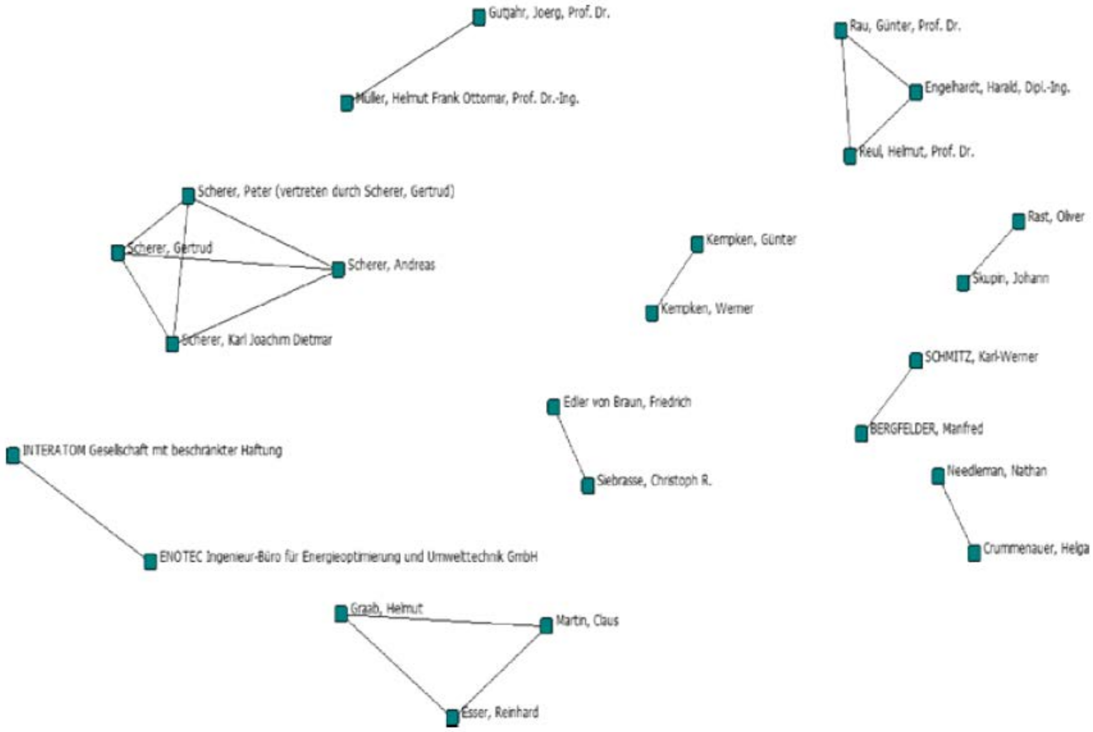
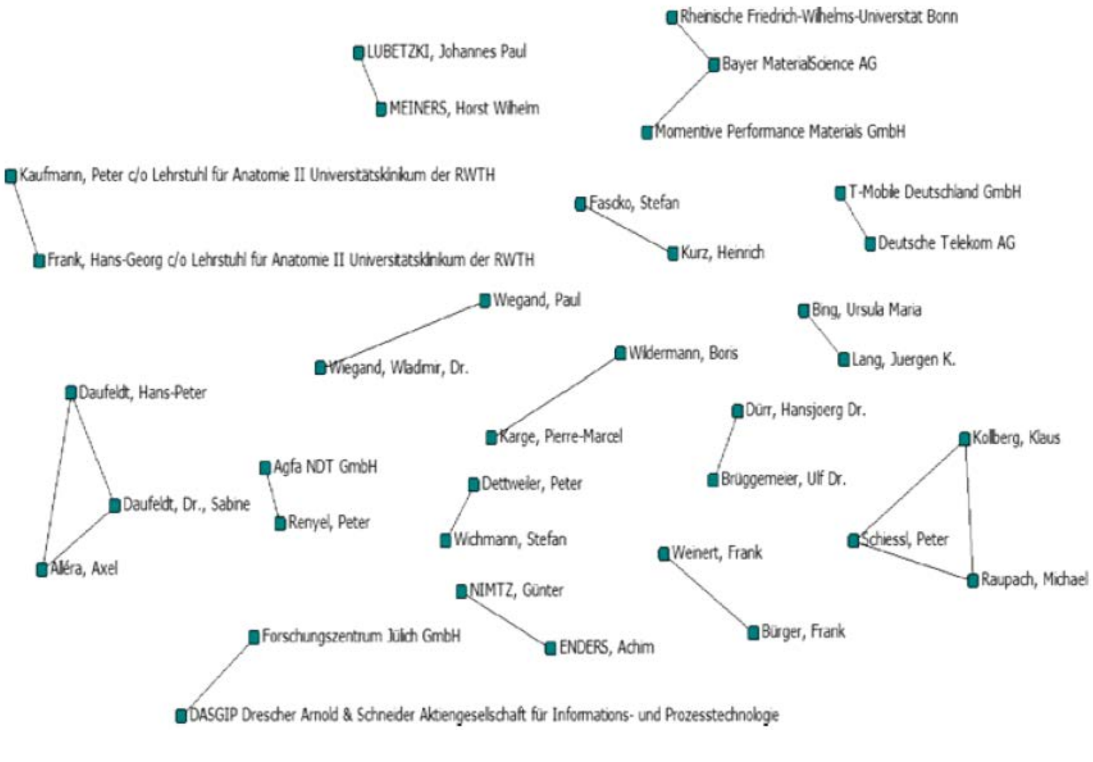


Fig. 16: All applicants within cologne (NUTS-2) for the period of 1994-2003 (t_1)



Source: Own illustration

Table 8: Cooperation networks in which all cooperation partners (applicants) are headquartered inside the region under consideration

NUTS-2 region of Karlsruhe for the period of	1988–1997	1998–2007
Number of all weighted ICT patent applications:	1273	2103
Number of applicants in which all cooperation partners (applicants) are headquartered inside the region under consideration	30	38
Ratio of applicants >1 per patent (cooperations)	2.36 %	1.81 %
Network Density	0.0713	0.0341
Network Degree-centrality C_D	10.46 %	4.82 %
Network Betweenness Centrality C_B	2.17 %	0.45 %
Average Ties per Actor	2.067	1.263
Inclusion of Research Institutes	Yes	Yes
	Most Central Applicants/$C_D(i)$ in % (Degree-Centrality)%	
1988–1997	1998–2007	
Forschungszentrum Karlsruhe GmbH/17.241	Schuster, Ralf/8.108	
Harman Becker Automotive	Siegrist, Alexandra/8.108	
Systems GmbH/13.793	Baréz, Klaus/8.108	
BECKER GmbH/13.793	Deutsches Krebsforschungszentrum/8.108	
OASIS SiliconSystems Holding AG/13.793	Siegrist, Michael/8.108	
SMSC Europe GmbH/13.793		
Silicon Systems GmbH Multimedia		
Engineering/13.793		
KERNFORSCHUNGSZENTRUM		
KARLSRUHE GMBH/13.793		
UNIVERSITÄT KARLSRUHE		
(TECHNISCHE HOCHSCHULE)/10.345		
Deutsches Krebsforschungszentrum/10.345		
Lux, Benjamin Wolfgang/6.897		
Lux, Viola Irmgard/6.897		
Burckhardt, Jean, Dr./6.897		
Seelig, Hans Peter, Prof. Dr./6.897		
Seelig, Renate, Dr./6.897		
Lux, Jasmin Sabrina/6.897		
	Most Central Applicants/$C_B(i)$ in % (Betweenness-Centrality)	
1988–1997	1998–2007	
Forschungszentrum Karlsruhe GmbH/2.217	Deutsches Krebsforschungszentrum/0.450	
KERNFORSCHUNGSZENTRUM		
KARLSRUHE GMBH/1.232		

Source: Own calculation

Fig. 17: All applicants within Karlsruhe (NUTS-2) for the period of 1988-1997 (t_0)

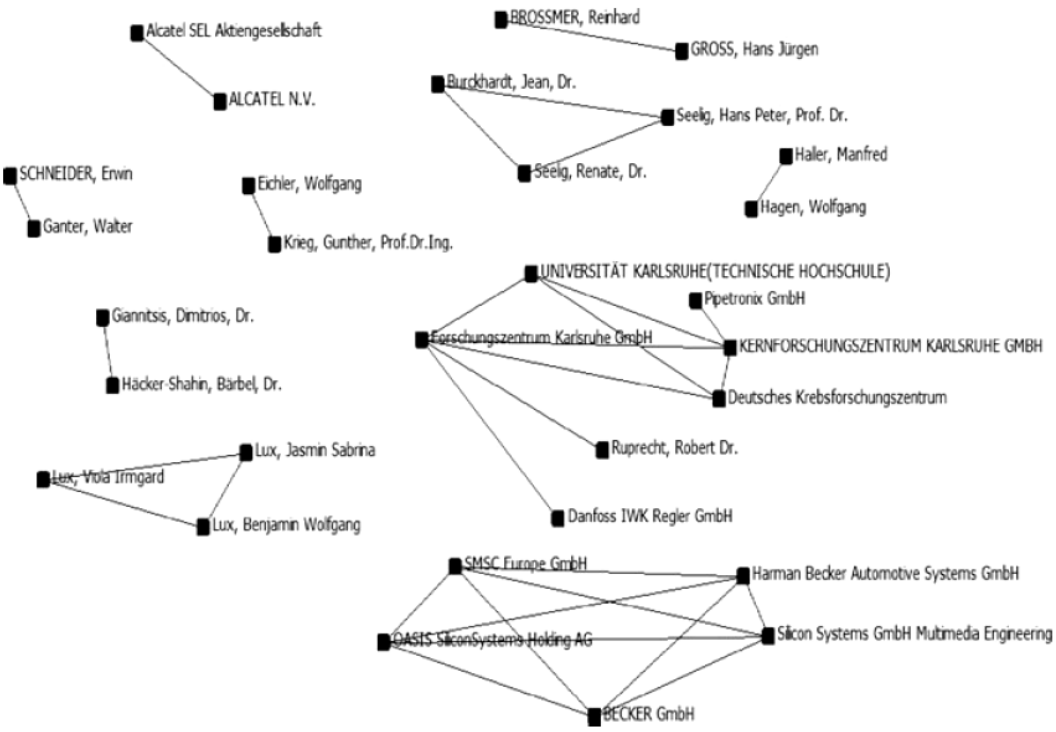
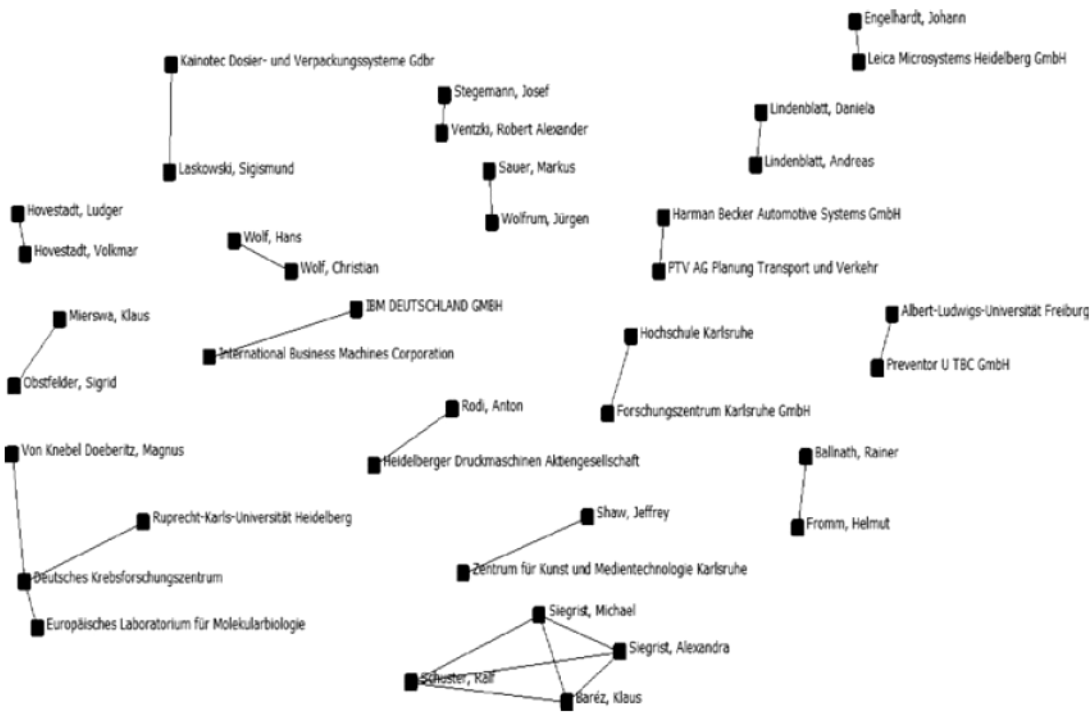


Fig. 18: All applicants within Karlsruhe (NUTS-2) for the period of 1998-2007 (t_1)



Source: Own illustration

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