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Sidonia von Proff, Anja Dettmann

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Inventor collaboration over distance – a comparison of academic and corporate patents

SIDONIA VON PROFF[a,*]

ANJA DETTMANN[a]

[a]Philipps-University Marburg, Department of Geography, Deutschhausstrasse 10, 35032 Marburg, Germany

*corresponding author: e-mail: vonproff@staff.uni-marburg.de

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Abstract

Patenting is often done in collaboration with other inventors to integrate complementary and additional knowledge. The paper takes a spatial view on this issue and analyzes the distances between inventors of German patents. In particular, we compare the collaboration distances of three groups over a time period of 14 years: academic, corporate and mixed teams. Due to their different institutional backgrounds different types of proximity guide their spatial search for partners. The distance between collaborating inventors of corporate patents exceeds that of inventors of academic patents, but the largest distances can be found on science-industry collaborative patents. The collaboration distances have not increased over time and regional collaboration clearly prevails.

JEL: R12, O34, L14

Keywords: inventor networks, Germany, academic patents, research collaboration

1. Introduction

During the last two decades the concept of clusters, first of all that one of Porter (2000), became very popular for explaining the importance of collocation for economic and regional growth. In that context, knowledge is usually seen as sticky and specific to the individuals located in the cluster. Because of observing each other, interacting and collaborating they start joint learning processes, absorb knowledge spillovers, and improve and recombine their knowledge. This increases the likelihood of innovations (Feldman 1994; Cooke 2001; Boschma 2005). In that sense, innovations emerge from a local knowledge base created by actors of the cluster. But often external knowledge flows into a cluster via 'pipelines' (Bathelt et al. 2004). These pipelines are relationships of individuals in the cluster to external contacts. Different types of proximity help individuals to maintain these relationships over spatial distance (Boschma 2005, Agrawal et al. 2006) and to include external information into the cluster's knowledge base. These pipelines are assumed to avoid the lock-in of a cluster (Grabher 1993; Visser and Boschma 2004).

The paper at hand investigates how often inventions (as a prerequisite for innovations) stemming from collaboration are exclusively the result of a regional knowledge base. How often are external partners included in collaborative inventions? Did the distance between collaborators increase over time because of an increasing use of ICT?

In order to answer these questions, German patent applications of collaborative inventions are analyzed with regard to the distance between the inventing team members. For this purpose, the inventor's home address written down on the patent is used. A route planning system calculates the distance between the postal codes (two-digit level) and therewith the real reachability (time to get in contact face-to-face) is generated between the single team members. The patent data base covers a time period from 1993 to 2006, what enables to see changes in the average and largest distance between inventing team members over the time period ICT established oneself. Finally, the data base is separated into two main groups of inventor teams in order to control for the influence of the applicators professional environment on the spatial choice of partners: a) patents invented by academics and b) patents invented by corporate inventors. Of course, by using patent data, we exclude a lot of inventions done in the business services and creative industries, but a database about copyrights is still missing. For that reason we focus on industries patenting their inventions.

Questions about local or global knowledge sourcing have been posed by Frenken et al. (2009) and Hennemann et al. (2010) who investigate the distance between collaborative scientific publications. Regarding the corporate side, some studies exist about the type of collaboration partners (e.g.

suppliers and customers) and the regional embeddedness (cf. von Hippel 1988, Owen-Smith and Powell 2004,). D'Este and Iammarino (2010) investigate different factors influencing the distance between universities and firms in a UK-specific form of research partnership. Only few of the earlier studies actually look on the distance between inventors; instead, they often use a certain definition of region and look whether collaboration partners are located within the same region. Additionally, there are already a few studies about the influence of proximity or distance respectively on working groups aiming at innovations (Kraut et. al 1988, Payne 1996; Schunn et al. 2002, Frenken et al. 2009), but the concrete measurement of the distance in units of length between the team members, considering the different professional environments and the general change over time, was never done in one study. We get deeper insights in the relationship of the professional environment inventor teams collaborate in and their partner choices in a spatial sense. From a geographical point of view, we will shed light on the questions, how often inventions stem from a local community, how influential ICT actually became during the last 17 years in cooperative projects aiming at inventions and whether there are differences between academics and corporate inventors.

Most of the literature about the influence of proximity on working groups distinguishes at least indirectly between two main stages. The first is the stage where a working group is formed including the finding of partners and the development of group goals, norms and routines (Tuckman 1965; Kraut et al. 1987; Dutton et al. 1996; Guirdham 2002). The second stage is the performing of a working group implementing that the first stage was successful (Kiesler and Cummings 2002; Kraut et al. 2002; Olson et al. 2002). By using only patent data, we always deal with successful working groups in the sense that they had an innovative output. Because of the fact, that the performing stage lasts longest and the studied working groups always passed the first stage successfully, we will focus in our paper on the influence of proximity in the performing stage of working groups. Furthermore, we will focus on the influence of spatial proximity, because this is the only type we can measure with our methods. Of course, the strand of literature about other types of proximity will be considered in our discussions.

The remainder of the paper is structured as follows. In the next section, we will give an overview of the theories about collaboration in R&D, present hypotheses based on the literature and explain our considerations. After presenting the datasets in section three we will estimate a model which investigates in how far the institutional background of the inventors influence the physical distance between the collaborating individuals and how this developed over time. Finally, we discuss our results and their implications.

2 Theory

2.1 Collaboration for inventions

Analyzing patents implies focussing on technical inventions. In contrary to the term “innovation” (see definitions in OECD 2005; West and Farr 1996), the term “invention” excludes the step of a successful implementation to the market. Therefore, the paper studies the successful output of inventor teams after an invention process and before a commercialization. To understand the role of spatial proximity between the members of academic, corporate and mixed inventor teams, it is important to clarify the characteristics of such an invention process, what the following section does.

The difference between a joint invention process and formal business collaborations (like supply contracts, shares, etc.) is that it is a very difficult and complex activity. A frequent face-to-face contact between the team members is needed over a long time period to trigger common learning processes whereby individual’s knowledge is combined to something new (Kirat and Lung 1999; Nooteboom 2002). Myers and Marquis said, it is “…a complex activity which proceeds from conceptualisation of a new idea to a solution of the problem…” (Myers and Marquis 1969 as cited in West and Farr 1996). To enable frequent contacts face to face, lot of resources from each team member is required in terms of time, organizational and financial efforts. The higher the distance between team members and the more complex the common activity is the higher are the required resources.

Furthermore, invention is a risky activity with the power to leapfrog competitors when it is done successfully. Thus, the development of trust between team members before the invention process starts is very important (Kraut et al. 1987; Hinings and Greenwood 1996; Gersick et al. 2000). To make sure that shared information is not misused by team members, they either have to have a supportive and good willing team cohesion – what requires a longer time of personal interaction – or a strong organizational and formal framework including norms and rules has to bind the team.

To transfer the complex process of invention into a spatial context, Boschma (2005) distinguishes between different types of proximity namely social, cognitive, organisational, institutional and geographical proximity. Social proximity refers to mutual social relationships between individuals like friendship or kinship. The "... establishment and maintenance of a personal relationship is the glue that holds together the pieces of a collaborative research effort. Often it is at least as important as the content itself" (Kraut et al. 1987, p. 53). With cognitive proximity “… it is meant that people sharing the same knowledge base and expertise may learn from each other. [...] [A]ctors need cognitive proximity in terms of a shared knowledge base in order to communicate, absorb and process new information successfully" (Boschma 2005, p. 63). Cognitive proximity is a pre-requisite for common learning processes. Organizational and institutional proximity display a joint framework or basis to exchange knowledge and to organize the invention process. Because of common structures, routines and rules it makes collaborative work efficient and less risky. Geographical proximity by definition is the physical distance between team members in units of length. The role of spatial proximity for invention processes is rather indirect, because it facilitates the team members to observe each other and to share tacit knowledge, what is important for a common learning process. Furthermore, it reduces the organizational, financial and time efforts to get in touch with each other, what is often required during an invention process (Dettmann and Brenner 2010). Boschma (2005) stresses that different types of proximity can partly substitute each other. That means the social, institutional, organizational and cognitive proximity are linked to geographical proximity to different degrees. Hence, it depends on which of the different proximity types a team's performance bases on and as a consequence how important spatial proximity in their invention process is. We assume it depends on the occupational context how the invention process is organized and therefore which proximity type is the most influential. That reasons a difference in the distance between team members in academic, corporate and mixed teams. The following section introduced the studied groups and gives explanations about the importance of spatial proximity in each of them.

2.2 Proximity and distance in inventor teams

To explain possible differences in the importance of spatial proximity between academic and corporate inventor teams, it is necessary to characterize their occupational context.

Corporate inventors work in project structures focusing on specific problems concerning new products, services or sometimes processes. They have a clear stated mission and often they involve the client or at least they are client-specific, what limits uncertainties because the customer is well known and research is directed. These projects are limited in time and resources are allocated and combined for them. Often that constellation disperses after the project is finished (Payne 1996; Becker et al. 2007; Jansen 2008). Hence, in most of the cases the inventors work in a framework with given goals, resources, structures and deadlines determined by their firm depending on the customer.

The conditions of *academic inventors* are quite different. The teams (or parts) are more permanent, because university structures are ongoing and long-lasting. In contrary to the corporate project teams, the scientist's career depends rather on the team and structures in the education system than on specific projects, what makes success and failure for specific projects less important. What counts is to produce constantly good research results in an area over a long time, than quick results in one project. Furthermore, academic research is often open concerning goals, methods and directions because a specific client does not exist – sometimes a concrete demand is not even known. Hence, academic research is often undirected and independent from fixed deadlines and demands, what creates "… a considerable managerial challenge for the research team leader" (Payne 1996, p. 103). Without a fixed and given framework and a concrete customer, projects become more uncertain. Furthermore, academic teams sometimes have to work for years or even decades together and mostly they are not recombined after a single project. Hence, the decision to collaborate for an invention is influenced strongly by the need to create a long lasting work relationship (Hinings and Greenwood 1996; Gersick et al. 2000). It gets more difficult for collaborations between academics that are not part of the same university or research institute, because that relationship has to work without any formal structures per se. The only institutional and formal structures academic inventors have are within the team and the institute.

Referring to Boschma (2005), the two types of inventor teams are supported by different types of proximity. Corporate teams share organizational and institutional proximity that can span huge geographical distances, because rules, norms, goals and structures can be communicated in codified ways. Being part of the same research project that usually bases on strong contracts means to share the same framework and being embedded in the same structures – no matter where in the country or world. We assume that quite often firm collaborations for research happen between related firms what strengthens the institutional and organizational proximity. Academic research as explained above can only draw on strong organizational and institutional proximity within their team or institute, what might limit the distance between team members strongly. Quite often research teams acquire their members from the institute's environment namely well known students or trainees, because of the long lasting perspective and uncertainties such a team faces. Hence, social proximity becomes very important for working effective and successful. The importance of spatial proximity increases, if academic researchers co-operate with people from other universities or research institutes. The reason is that formal structures are not available and therefore a personal trustful relation is needed as a substitute, namely social proximity. Because of social-psychological processes required to build up those relationships, social proximity is strongly related to spatial proximity in the sense of having the chance to interact together and observe each other (Kraut et al. 1988; Nardi and Whittaker 2002; Olson et al. 2002). Beyond their institutes, academic teams are restricted concerning norms, rules, goals and structures in a codified way. They have to substitute that by trust and personal relations that enable the team members to develop their own project framework requiring personal interaction, thus spatial proximity. That situation is strengthened by the different resources both groups have. The bigger the distances are the team members have to overcome to meet face-to-face, the more resources in terms of time, money and organizational effort they need. We assume that firms who are able to do research, are bigger firms with higher amounts of resources and supportive structures. Academic inventors face a limit budget for traveling and deal with a lot of different time consuming tasks concerning their job profile (like teaching). Additionally, they face bureaucratic structures when it comes to business travels. That finally leads to our first hypothesis:

H1: The distance between the members of corporate inventor teams exceeds the distance between members of academic corporate inventor teams.

Our database supports the aspects that patents quite often are invented by mixed inventor teams, meaning a combination of academic and corporate inventors. They face the challenge to overcome the institutional differences described above and therefore they present an own group of inventing teams which we will distinguish in the empirical analysis. We draft the following conceptual framework about the influence of proximity on such teams.

To overcome the institutional difference, mixed inventor teams create organizational proximity in forms of contracts for their project. In that point the mixed type of inventor teams is rather similar to the corporate one. The problem with contracting is that it is hard to foresee such an uncertain process like invention, especially for a team whose members have got very different backgrounds (Nooteboom 1999). Thus, the share of social proximity could be very helpful in mixed teams, but as mentioned above that is strongly related to high geographical proximity. Concerning the literature, two scenarios are possible. On the one hand, universities and likewise headquarters of large companies tend to be located in urban areas due to (among others) the greater availability of high-qualified staff. Furthermore, important R&D sites are often close to the headquarters (Feldman and Florida 1994) and Fritsch et al. (2007) found regional boundaries for collaborations between academic scientists and companies with necessary face-to-face contacts. Hence, it is likely that team members might know each other from former times and share social proximity, although they work for different firms or institutes today (Agrawal et al. 2006; Breschi and Lissoni 2009). On the other hand, larger companies do have university contacts over greater distances because it is unlikely that firms always have neighbored universities that fit in terms of content. Hence, as soon as the research fields of a university do not match the industry structure of a region, collaboration is only possible over a certain distance. This happens certainly more often in university cities with few company sites. Since empirical studies (Fritsch et al. 2007; Ponds et al. 2007) suggest a regional limitation of cross-institutional collaboration, we assume hypothesize that purely corporate collaboration takes place over larger distances than mixed collaboration:

H2: The distance between the members of mixed inventor teams exceed the distance in academic inventor teams but falls below the distance in corporate ones.

Besides the spatial differences between different types of inventor teams, the paper deals with the question whether or not the importance of geographical distance in inventor teams decreased over time due to the improvement of ICT.

A lot of studies during the last two decades were made to find out, whether teams, whose members are geographically spread, can work as efficient and successful than local teams (Durnell Cramton 2002). The results are quite similar for teams facing the challenging and complex tasks. Powell and Giannelli (2010) find an increase in the geographic dispersion of US patent inventors when comparing patents from the 1970s and today. They argue with the need to access distant knowledge and lower communication costs. Other studies do not analyze data going back so far and find that ICT cannot substitute face-to-face communication due to the importance of social relationships in teams working on complex tasks as explained above (Kraut et al. 1987; Hinings and Greenwood 1996; Mannix et al. 2002; Nardi and Whittaker 2002) or organizational respectively managerial problems (Kraut et al. 1988; Armstrong and Cole 2002; Cummings and Kiesler 2007). Of course ICT makes it possible to get in contact more often because of high speed communication systems facilitating video conferences, messenger systems etc. But a common learning process and the development of trust, norms, rules and common goals can only be done by personnel interaction and observation. This is the truer, the longer a team has to work together and the more complex and risky the common task is. Usually, inventor teams are characterized by these features. Therefore, the third hypothesis is:

H 3: The rise of ICT did not increase the distance between the members of inventor teams. This holds for academic, corporate and mixed teams.

The three hypotheses are studied on the bases of patent data, more precisely by the information about the inventors and owner. The concrete database and methods are explained in the next section.

3 Data

3.1 Dataset

The initial dataset contains ca. 5,000 patent applications with at least one German professor among the inventors and priority country Germany. These patent applications were collected by searching in a first step for professor titles among university-owned patents. After a check whether the professors are really affiliated to a German public university (and not honorary professors or professors of research institutes from the Max Planck / Fraunhofer Society etc.) the patent applications of each professor were searched manually. Here, using the professor title on the patent document is no longer a search criterion because the internet searches for background information about the professor facilitates to use the full names and affiliation information for the search. Of course, our search strategy does not result in the full dataset of German professors' patents, because those who have never used their title are lacking. We excluded patents from non-professorial staff, because professors are the group of inventors where biographical data due to university homepage is available. Non-professorial faculty (e.g. post-docs) often moves to industry and only in a few cases websites with biographical data are available. Thus, it is not possible to investigate ex-post whether an invention of a non-professorial researcher degree was devised while being employed at a university or at a company.
The assignee of the patent is classified into four groups: university/research institute, company, joint application of a university and a company, or individual person(s). The time period covers the years 1993 to 2006 (due to a new postal code system in 1993 older data was not included) and the priority country is Germany.

In order to compare academic and corporate patents (i.e. create the dataset for the paper at hand) each academic patent was matched with a company patent in the same patent class at the same time of application. The patent class was matched by using the first patent class on the document of the academic patent (finest level of classification). This patent class is not mandatorily the first patent class of the corporate patent but has to be among the classes the patent was assigned to. The search was done for a part (961 patent applications, chosen randomly) of the original database due to three reasons: the time effort that is necessary for matching the patents, the exclusion of patents with single inventors, and the fact that there are purely "academic" patent classes where it is impossible to find a matching corporate patent. The term "same time" refers to a priority date of the matched patent which is as close as possible to the priority date of the original patent. Because in some patent classes there are only very few patents the deviation is in a few cases up to a year. The matching process excludes differences in the fields of research and the numbers of patents per year and allows concentrating on the spatial distance between the inventors. The search was done manually and in order to secure that the patents are corporate ones, the requirement was not only company assignment but also the absence of professor titles among the inventors. This was necessary, because we know from the first dataset that academic patents are often assigned to companies. It could be that a university scientist among the inventors without a professor title is included. But that is an exception because the share of patents with academic background was only 5.9% overall in 1999, the year with the most academic patent applications until today (cf. Schmoch 2007, p. 5). The patents we already excluded are owned by a university, a research institute or an individual person or have a professor title.

The final dataset thus contains the same amount of “academic patents” (where at least one inventor is a scientist) and “corporate patents” (where all inventors are corporate researchers). However, the academic group is in fact a mix of purely academic collaborations as well as science-industry collaborations. Without detailed information about each inventor it is not possible to distinguish between these groups. At this point, the strength of having a large dataset implies the weakness of lacking detailed information about the individual inventors. However, we make an assumption: those patents assigned to a university or research institution are most probable to be the result of purely academic team work, while those belonging to a company (with or without a university as second assignee) are most probable to be the result of science-industry collaboration. We add dummy variables for those two types of ownership and another one for individual ownership (usually the inventing professor himself). The last group is somehow data-driven; we do not know whether the inventor did not find an organization filing the patent for her (because of low perceived invention quality) or whether she wanted to own the patent (because of high perceived invention quality), so we do not have expectations about the distance between inventors of those patents.

Postal codes of the inventors are used to display the geographical distribution and to calculate distances between the inventors. Three measures of distance are used in the analysis: (i) the log of the greatest distance between any of the inventors of one patent in kilometers[1]; (ii) the log of the average distance between all inventors of one patent in km; (iii) an ordinal variable taking the value one for same or neighbored two-digit postal code (regional collaboration), two for non-neighbored two-digit postal codes (national collaboration), and the value three for collaborations where one or more inventors are located outside Germany (international collaboration). In other words, the ordinal variable measures regional, national, or international collaboration. Neighbored two-digit postal code areas are not the finest possible level of detail to define regions. However, this region size is used elsewhere, too. Hoekman et al. (2010) use NUTS2 regions (which are larger than two-digit postal code areas) for investigating the share of regional collaboration. The logarithms of the metric distances are taken in order to have measures which are robust to outliers, i.e. transcontinental collaboration. The three measures are useful for taking into account particularities like international

1 We used a route planner for calculating the distances in order to take account of the real reachability. This approach is similar to the one used by Frenken et al. (2009). For distances exceeding the scope of the route planner (i.e. extra-Europe) an air-line distance was estimated.

cooperation near country borders, i.e. over short distance, and long-distance cooperation inside one country.

3.2 Descriptive statistics

The descriptive statistics in Table 1 give a first hint on the differences in collaborative behavior of academic and corporate inventors.

	Inventors				
	Academic				Corporate
distance measure	purely ac.	mixed	indivi.	*all*	all
log of larg. dist.	1.45	1.89	1.64	*1.69*	1.66
log of av. dist.	1.39	1.80	1.59	*1.61*	1.57
frequency of regional collab.	306	156	189	*651*	620
frequency of national collab.	73	128	70	*271*	256
frequency of international coll.	6	19	14	*39*	85
sum	*385*	*303*	*273*	*961*	*961*

Table 1: Descriptive statistics

Overall, the share of international collaborative inventions is low. Even though academic scientists are able to speak English and travel around the world, they invent rather locally. And similarly, the existence of MNEs is not reflected in an absolute number of international teams – but relatively to academic patents, international collaboration takes place twice as often.

The high number of patents filed by an individual refers to the former German "professors' privilege", which guaranteed up to 2002 every professor the intellectual property rights on inventions stemming from his or her research. Only a few universities supported patenting activities and therefore professors who did not have adequate industry contacts (or wanted to commercialize a patent on their own) had to file patents in their own name.

For the regressions in the next section further data details were collected. The main patent class (*A* to *H*) indicated the technology, because the collaboration behavior may differ among fields of research. The *number of inventors* was included because the largest distance between inventors is non-decreasing with the number of inventors. A dummy variable *metropolis* for the assignee being located in a large city (here defined as cities with more than 500,000 inhabitants) was added. The reason behind is that on the one hand large cities are more often known to foreigners, which could facilitate international contacting, and they can be more attractive for the best researchers. On the other hand, they provide ample possibilities of companies, universities, and research institutes, which facilitate local collaboration (Toedtling et al. 2010). Thus, the spatial collaboration behavior of researchers in large cities may differ from those working in smaller cities, but whether the collaboration distances are larger or smaller is unclear at first. Lastly, the size of the patent family (*famsize*), i.e. the number of countries where IP protection is sought for, was added as a proxy for the quality of the patent. D'Este and Iammarino (2010) showed that research quality influences the collaboration behavior. They used the prior quality of the researcher and not the quality of the resulting invention, where the relationship with the distance is maybe reversed (distance influences quality). However, we use *famsize* as a control variable. Table 2 gives an overview of the variables of the model. There is no significant correlation between them.

Variable	Explanation
Year	Year of the patent application (priority), covering 1993 to 2006
No of inv	Number of Inventors appearing on the patent document, at minimum 2, since collaborative inventions are investigated. Maximum: 10, average: 2.8
A-H	Patent class according to the first letter of the International Patent Classification. Reference category in the model: *H*
Metropolis	Dummy indicating that the assignee of the patent is located in a city of >500,000 inhabitants. In case of multiple assignees, the dummy takes the value 1 only if all assignees are located in large cities. The variable takes the value one for 306 of the academic and 376 of the corporate patents.
Pure univ, mixed, individual, corporate	These four variables indicate the type of collaboration. The reference category in the model is corporate collaboration (found by non-professorial inventors and company assignment). A collaboration is regarded as purely academic (*pure univ*), when the assignee is a university; and as jointly from science and industry (*mixed*), if the assignee is a company or a company together with a university. If the assignee is one of the inventors himself (*individual*), the institutional background is unclear and these patents form an own group.
Famsize	Number of patent documents with country codes other than Germany which refer to the same patent application

Table 2: Explanation of variables.

4 *Comparison of academic and matched corporate patents*

4.1 Regional, national, and international knowledge sourcing

For the empirical part of the study at hand it is important to recollect that patents display only persons formally involved in the invention process. Knowledge pieces gained by talking to colleagues or business contacts will not be displayed. That means, we cannot analyze the exact spatial origin of the knowledge but find only the place, where the main persons responsible for the invention are living, i.e. those who contributed most to the project. Since smaller knowledge pieces probably spill over unintentionally only over short distances, the local part of an invention will be rather underestimated. In addition, patents display only successful innovation projects. It is known that many cross-organizational projects fail. We will keep that in mind during the discussion.

Analyzing the ordinal distance variable, we find a clearly higher share of international collaboration among corporate inventors than among academic inventors (overall 9% versus 4%). It is important to note, that there are only few corporate patents which have more than one owner on the patent document, while multiple ownership is found more often for academic patents. The low level of co-assigned corporate patents is in line with Fontana and Geuna (2010). Different reasons can be given: Firstly, collaboration takes place within one company. Secondly, there is one company with greater bargaining power which becomes assignee of a joint invention. Thirdly, the collaboration partners can sign an ex-ante contract for sharing the revenues. Because co-ownership is quite difficult to handle, a private contract can be a superior solution (Fontana and Geuna 2010). However, due to a lack of information about the individual inventors we cannot investigate all organizations involved in the patent with the data at hand.

Regional collaboration is the normal case when a patent is invented by a team of inventors (cf. Figure 1). Of course, our ordinal distance measure depends strongly on the definition of "regional". By using neighbored two-digit postal code areas we use a very broad definition. However, the findings are in line with those of Hennemann et al. (2010, p. 10) for team publications between authors from different organizations (excluding papers from PhD students and their supervisors or two professors of one institute which are included in the dataset here): they find that up to a radius of 100km the likelihood of collaboration is much higher than for far distant researchers. In addition, their data show a similarly low level of international collaboration. A second study with similar results regarding the share of regional collaboration is the one by Hoekman et al. (2010) where according to the research area 56% to 93% of co-authored papers (at least two organizations involved) are regional and 3% to 23% are international collaborations.

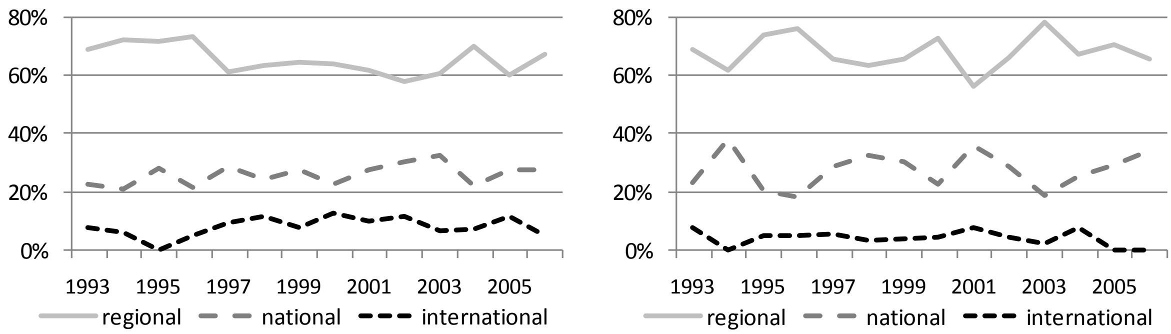

Figure 1: Shares of regional, national, and international collaboration on corporate (left) and academic (right) patents. Datasets of 961 patents each.

There is a slightly negative trend of regional collaboration for corporate inventors (significant at 10% level). This finding points to the trend of decentralizing R&D activities within MNEs and globalization of knowledge sourcing. The initially large number of local patents could display the centralization of R&D at headquarter sites at that time. The other curves do not exhibit a significant trend.

Our considerations about the prevalence of regional knowledge sourcing are supported by the empirical data which show that independently from the institutional background of the inventors (academia/ industry) partners in the region (from the same or a different organization) play an essential role for team inventions. This is in line with the finding of other authors (see section two). Only for corporate inventions, the regional knowledge sourcing has become slightly less important during the last decades, and international collaboration takes place only sporadically.

4.2 Distances between inventors

The two metric distance measures ("log of largest distance between any of the inventors of a patent" and "log of average distance between all inventors") show similar patterns. Figure 2 shows the average largest distances between two inventors in a comparison of "purely academic" patents and their corporate counterparts (matched as described in section 3.1; n=385). We do not observe a trend over time. It seems that improved ICT as well as reduced passenger transportation costs have not been able to alter the collaboration behavior of researchers.

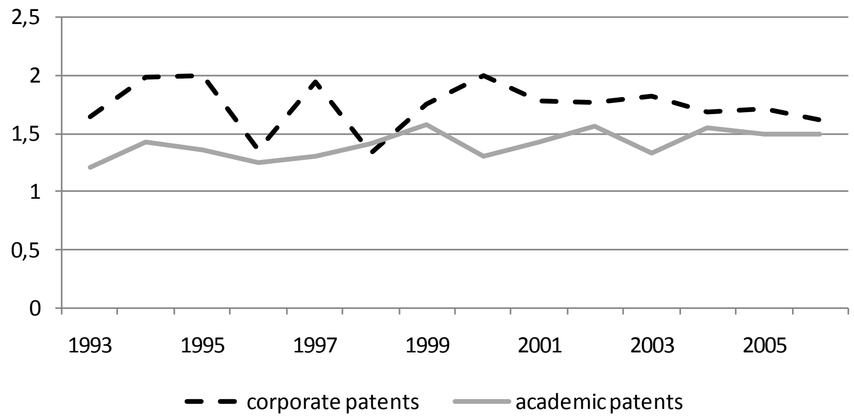

Figure 2: Average of the log of the largest distance between any of the inventors for 385 purely academic and corporate patents each.

In order to investigate the real differences between inventors of corporate and academic patents linear model is estimated, where the influence of the institutional background, the number of inventors, and further information on the metric distance measures is estimated. The matching information is not necessary for a regression, however, the matching leads to a balanced distribution of patent classes/technologies among corporate and academic inventors.

Due to the very high correlation between the two distance measures the results are very similar in the two regressions (Table 3). There is no trend over time as the visual inspection of Figure 2 suggested. Hence, Hypotheses 3 can be rejected. The number of inventors clearly influences the distance between the inventors, because a larger team increases the probability of including a person from abroad. Furthermore, bigger research teams should have more resources available, especially if a firm assembles the team. Like mentioned in section two, we assume corporate teams to have more resources, because doing research is expensive and usually only bigger firms engage here. The described effect is stronger for the largest distance than for the average distance. The most interesting finding is that the type of collaboration, i.e. the institutional background of the inventors has a significant influence on the distance. Inventors of purely academic patents collaborate over shorter distance than corporate researchers, while the longest distance is measured in the case of science-industry cross-institutional collaboration. The group of patents where one inventor is at the same time assignee does not differ from the reference group of corporate inventors. Thus, Hypotheses 1 is supported, while Hypothesis 2 has to be rejected surprisingly. Even though institutional and organizational borders have to be bridged during science-industry invention projects, the distance is larger than for purely corporate patents. A possible explanation is the mismatch of university specialization and the local industry forcing firms to engage in co-operations with institutes that are far away, but fit in terms of content. Here, cognitive proximity substitutes spatial proximity (Boschma 2005). Another possible explanation is the data: Ponds et al. (2007) control for other types of proximity which we do not do here. It is possible that the patents in the dataset are not representative for science-industry collaboration. A last possible explanation is that many of such projects fail. Only a few are successful due to trust built up with the help from other forms of proximity, e.g. social proximity based on earlier personal relationships. In order to investigate this, one would have to look, whether such research collaborations last especially long and where the inventors have met first. In addition the failure rate of science-industry research collaborations would be necessary to compare to intra-institutional (i.e. within academia or within industry) collaborations. This research exceeds the scope of the paper at hand but is certainly worth investigating.

Linear model	**Log of largest distance**			**Log of average distance**		
	coeff.		std.err.	coeff.		std.err
const.	-14.279		(9.683)	-14.213		(9.464)
year	0.008		(0.005)	0.008		(0.005)
no of inv	0.166	***	(0.014)	0.084	***	(0.013)
pure univ.	-0.204	***	(0.044)	-0.196	***	(0.043)
science-ind	0.186	***	(0.046)	0.187	***	(0.045)
individual	0.033		(0.050)	0.042		(0.049)
famsize	0.011	**	(0.005)	0.010		(0.005)
A	0.065		(0.071)	0.071		(0.070)
B	0.026		(0.073)	0.031		(0.071)
C	0.144	**	(0.066)	0.142	**	(0.064)
D	0.044		(0.184)	0.026		(0.180)
E	-0.014		(0.174)	-0.021		(0.170)
F	0.099		(0.096)	0.108		(0.093)
G	0.125	*	(0.070)	0.128	*	(0.069)
metropolis	0.069	**	(0.034)	0.069	**	(0.033)
	Adj. R^2=0.1161			Adj. R^2=0.0608		
	Significance: ***/**/*: alpha<1/5/10%, n=1922					

Table 3: Regression. Reference institutional background: collaboration between corporate researchers. Reference patent class: IPC class "H".

The collaborations in most patent classes are over similar distance, only the classes C and G show larger distances between inventors. Those two classes comprise the most of biotechnology. Whether biotechnology is actually a technology with long-distance collaboration behavior needs further investigation not provided at this place. The dummy for a metropolitan environment is significant as well: patents with an assignee located in a large city show longer distances between the inventors. A larger patent family is associated with longer distances. Interestingly, this variable correlates weakly with the number of inventors, i.e. for team inventions a larger spatial protection is sought, which hints at a better exploitation of the invention.

In summary, there is some evidence that the collaboration networks of corporate inventors are larger in space. With the analysis at hand we cannot exclude that the social networks (i.e. acquaintances) of the academic inventors are the same large or even larger than those of corporate inventors, but whenever the networks are used for commercialization oriented research projects the scientists rely on smaller (in spatial terms) networks. Our theory is therefore supported by the empirical data.

5 Discussion

Overall, the empirical findings are in line with the theoretical considerations. The institutional background of inventors affects their collaboration behavior. The organizational proximity of corporate inventors and their greater resources help to overcome longer distances for collaboration in comparison with academic inventors. Only the finding, that cross-institutional collaborations between academia and industry display the largest distances between the inventors, is surprising. The data at hand does not provide an explanation. We offered some thoughts about reasons for this finding, but further research is necessary to prove or disprove these ideas. In the following subsections we integrate our findings into a larger context and discuss the limitations.

5. 1 Local and global knowledge sourcing

In how far do our results contradict earlier findings about the globalization of production, markets, and innovations? Power and Malmberg (2008) state that scientific research is "one of the most globalized of human activities" (p. 239). Publications are cited all over the world, conferences are attended in foreign countries, and most relevant articles are written in English independently of the origin of the author. Regarding the industry sphere the emergence of MNE has led to a globalization of production processes and innovative activities. However, these findings do not contradict a rather regional production of inventions. Firstly, an innovation can be global in the sense that it is sold globally. Secondly, a patent is not necessarily a complete product but can protect a part of a technology that is composed of a lot of preliminary products developed at different places (cf. Rosenkopf and Schilling 2007). Thirdly, the information disclosed in the patent can be absorbed and further developed from people all over the world. As we have noticed earlier, the inventors on the patent documents only display formal involvement into the invention process. The inventors may have had contact with further persons located anywhere during the invention process and in so doing they have collected and distributed knowledge. Hence, the long-term influence of regional invention activity not only benefits the same region, but also becomes noticeable at a larger space.

5.2 Commercialization of patented inventions

In the regressions, we have added the size of the patent family as a control variable. However, this variable displays the commercialization efforts of the assignee which is only a rough proxy for quality. How do the variables above influence the commercialization process? A Poisson regression of the patent family size as dependent variable gives interesting results which will be discussed shortly here.

	Coeff.		**Std. Error**
constant	51.229	***	(8.607)
year	-0.025	***	(0.004)
no. of inv.	0.089	***	(0.011)
purely acad.	-1.059	***	(0.055)
individual	-0.815	***	(0.055)
mixed	-0.240	***	(0.040)
average dist.	0.079	***	(0.021)
metropolis	-0.023		(0.031)
a	0.440	***	(0.070)
b	-0.184	**	(0.078)
c	0.480	***	(0.066)
d	-0.049		(0.196)
e	-1.078	***	(0.308)
f	-0.341	***	(0.109)

g	-0.049		(0.074)
Significance: ***/**/*: alpha<1/5/10%, n=1922			

Table 4: Determinants of the size of the patent family. Reference patent class: IPC class "H".

As can be seen in Table 4, academic patents (all three sub-types) have less spatial coverage of patent protection. Most likely, the high costs of patent protection constrain the universities. A larger number of inventors in contrast increase *famsize*. The possible explanation that larger teams lead to inventions of higher quality which are then more valuable needs further investigation in future research. Interestingly, the patent family size has decreased during the period of observation. This is related to the findings of Thursby and Thursby (2002) who show that the growth of patent applications is stronger than the growth of license revenues. They argue "that the marginal university innovation offered to the market has declined in commercial appeal; universities are apparently delving more deeply into the available pool of innovations in their efforts to increase their commercial activities" (p.102). We can support this statement, because a regression with interaction variables of the application year and academic and corporate patents respectively shows that the decrease can be found only for academic patents (cf. Table 5 in the Appendix).

As expected from the results in Table 3 a longer average distance between the inventors (it holds for the largest distance as well) comes along with a larger spatial coverage. The different significant estimators for the patent classes point at differing levels of global commercialization of inventions: While patents from the classes "C" and "A" have larger spatial coverage than the reference category "H", those from class "E" are valid in the lowest number of countries.

5.3 Limitations

Measuring the distance between co-inventors does not give information on how they have met. We do not know whether the inventors are employed by the assignee of the patent and if they are, whether they work in the same team. Therefore, we cannot track the circumstances of their decision to invent jointly. However, other studies with patent or publication data share this problem. Breschi and Lissoni (2009) just take an inventor as the employee or contractor of the assignee and build a co-inventor network. They assume that professional knowledge flows along the links in the co-invention network. Most localized knowledge spill-overs (patent citations) can be explained by these indirect connections. Hennemann et al. (2010) as well as Hoekman et al. (2010) analyze co-publications where authors have different affiliations in order to exclude internal collaboration. However, the employment history of the individuals cannot be tracked and thus we do not know how the individuals met and why they decided to collaborate. The question with whom inventors actually share the knowledge, i.e. the social or professional relationship of two people, stays open in all large-scale analyses and can only be investigated in case studies.

6 Conclusion

The paper at hand has analyzed the spatial collaboration behavior of academic and corporate inventors of German patents. Due to the different institutional background the two types of inventors find their collaboration partner by different search mechanisms and the collaboration is based on different types of proximity. The empirical results of our analysis strengthen the theoretical considerations that corporate inventors collaborate over larger distances than academic ones. This holds not only when measuring the distance in kilometers, but also regarding the share of international collaboration which is higher. Contrary to our expectations cross-institutional collaborations come out to take place over the largest distances of all cases analyzed. Since we do not control for other types of proximity, the geographical distance could be overestimated. Further research on this finding is necessary.

Overall, the level of international collaboration is rather low and has not increased during the period of observation (14 years). Our data do not show an increasing distance between inventors, which is in line with prior literature. Regional collaboration prevails, probably because spatial proximity favors most other types of proximity, which in turn facilitate to build up trust and to collaborate successfully.

Since the dataset consists of successful research collaborations resulting in a patent application, it is not possible to determine whether national/international teams are few in the dataset because those projects fail more often than regional ones. Further open research questions remain whether the more limited spatial collaboration has economic consequences and whether policy could have influence on the spatial dimension of academic research collaborations.

7 References

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Appendix

	Estimate		Std. Error
constant	6.746275		(10.319)
year*corporate patent	-0.003095		(0.005)
year*academic patent	-0.076837	***	(0.008)
noinv	0.092187	***	(0.011)
pureuni	146.507908	***	(18.691)
indiv	146.582979	***	(18.670)
collscind	147.189875	***	(18.674)
avdist	0.079988	***	(0.021)
metropolis	-0.027053		(0.031)
a	0.432256	***	(0.070)
b	-0.189653	**	(0.078)
c	0.468723	***	(0.066)
d	-0.058641		(0.196)
e	-1.092285	***	(0.308)
f	-0.340313	***	(0.109)
g	-0.050389		(0.074)
Significance: ***/**/*: alpha<1/5/10%, n=1922			

Table 5: Poisson regression of famsize with interaction variables of the year and the type of institutional background.