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

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Abstract:

The paper compares academic and corporate patents in Germany to shed light on the geographical distribution of the inventors. The residences of the inventors show different patterns in the two datasets. Furthermore, we analyze the spatial distance between inventors for patents invented in collaboration and give insights into the distance's change over a time period of 14 years. The distance between collaborating inventors of corporate patents exceeds that of inventors of academic patents. In spite of the rise of ICT and cheap passenger transportation the collaboration distances have not increased. This supports earlier literature on the importance of proximity in innovation.

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

JEL Classifications: R12, O34, L14

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1 Introduction

During the last two decades the concept of clusters, first of all by 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 studies about clusters revealed that very 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, Ter Wal 2009) 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? Are there differences between inventions made in a corporate or an academic environment? These questions will be tackled with the help of team-invented patents covering a time period from 1993 to 2006. In the first dataset, all patents include at least one German professor and thus it consists of purely academic and industrial-academic collaborations. In order to reveal differences between academic and corporate collaborations we created a second database consisting of corporate patens only which match the academic patents by time and field of research. The datasets cover all patent classes in order to give some general conclusions.

We find that in several cases the partners were not collocated during their collaboration and thus an innovation is not exclusively the result of a local knowledge base. The reason is that academic researchers as well a corporate ones are highly mobile and change their firms and affiliations occasionally. Hence, formerly collocated individuals are separated from each other more often, but this does not mean the end of their collaboration (Agrawal et. al 2006). Furthermore, the rise of ICT helps to decrease costs, organizational effort and enables real-time communication in collaborative projects. Hence, the spatial radius to choose favored partners for joint projects can increase and individuals are enabled to collaborate over a larger distance today.

There are differences between academics and non-academics concerning the distance between partners. Assuming that individuals have a preference for well known partners, with whom they expect a valuable outcome and share an enjoyable relationship, then academics will show a more local partner selection behavior, which is strengthened by their limitation in resources. The reason is that academics build up their own partner networks, what requires spatial proximity to get in touch unintended, in different contexts and to interact face to face. These aspects are prerequisites to build up trustful collaborative relationships and thus to minimize the risk of failing and opportunism. Concerning collaborative partnerships, non-academics are embedded and guided by strong organizational structures and economic decisions of their firm. Assuming that they are restricted to a certain extent in choosing their partners due to instructions by superiors and by being embedded in a market environment, non-academics can be supposed to collaborate over larger distances. Very often there is a linkage between the size of a firm and the distance within which collaborations take place, because the larger a firm is, the more likely this firm acts internationally. This finally leads to collaboration over larger distances between individuals inventing for these firms. In summary, academics build up their own partner networks, whereby spatial proximity guides the search. Non-academics collaborate over larger distances because they are highly directed and supported by a predefined organizational framework, namely their firm’s structures and networks.

The remainder of the paper is structured as follows. Firstly, our paper will give an overview about the theories in economic geography supporting our assumptions. In a second step we will analyze where inventors of academic and corporate patents live in Germany and how the number of joint patents developed between 1993 and 2006. The third step is to measure the physical distance between the collaborating individuals in our two databases and compare the results between academic and corporate patents. The location as well as calculating the distances is done with the help of the postal codes which can be found on the patent document. Finally, we check the robustness of our results.

2 Theory

2.1 Spatial distribution of invention in Germany

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 and agglomeration economies. Often, important R&D sites are close to the headquarters (Feldman and Florida 1994). Therefore, the inventors of academic patents will be accumulated around university locations and industrial cities (cf. Malecki 1981, p. 319). This is in line with the finding of Feldman and Florida (1994), that university and industrial R&D expenditures are spatially correlated and complementary (for the complementarity of public and private research cf. also David et al. 2000). However, being complementary does not mean that public and private R&D is performed at the same place. Even though there is some collaboration between academic and corporate researchers, the two spheres are to a certain extent independent from each other. When private firms are asked for the importance of academic sources of knowledge, university patenting is not perceived to be very important. Rather, they rely on other sources (customers, suppliers) and in the case of academic knowledge, they learn about new findings via informal channels of knowledge transfer as well as publications (cf. Colyvas et al. 2002; Cohen et al. 1998). Hence, the geographical distribution of academic and corporate inventors can be expected to differ.

Of course, the distributional pattern of German inventors cannot completely be explained with the location of universities and companies. A further factor is the spatial distribution of research fields, because the patent propensity varies between research areas and over time. For example, biotechnology is a relatively new field of research, where many patents are filed (cf. von Ledebur 2008). As soon as strengths in certain research areas of universities and companies are not identically distributed (spatially) we will find that the inventors of academic and corporate patents respectively live in different regions. In the empirical part of the paper this will be of minor relevance because the datasets are matched by research field (patent class).

2.2 Collaboration on inventions

Boschma (2005) distinguishes between cognitive, organizational, social and geographical proximity. For corporate and academic inventors different types of proximity are influential. 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). That type of proximity is important for academic and corporate partnerships, because it enables people to work together effectively and with a valuable outcome, a necessary precondition for innovation.

However, organizational and social proximity have a differing influence on the collaboration behavior of academic and corporate researchers. For the discussion of these differences the definition of these two types of proximity are relevant (Boschma 2005, pp. 64-66): "[O]rganizational proximity is needed to control uncertainty and opportunism in knowledge creation. […] Organizational arrangements (such as networks) are not only mechanisms that coordinate transactions, but also they are vehicles that enable the transfer and exchange of information and knowledge in a world full of uncertainty. [...] Social proximity is defined […] in terms of socially embedded relations between agents at the micro-level. Relations between actors are socially embedded when they involve trust based on friendship, kinship and experience."

Academics are embedded in a scientific community, but most of their contacts or partners belong to other organizations or universities. Normally, strong professional and personal bounds connect scientists. The former refers to cognitive proximity and the latter to social proximity. These types of proximity help to build up trust, to work effectively and to minimize the risk of failing in joint projects. Organizational proximity is rather underdeveloped. The situation of corporate researchers is different. Keeping innovative projects secret is important and collaborators have to be chosen carefully. Hence, individuals cannot choose external collaborators independently, but they are embedded in the firm's own network with pre-defined partners they can collaborate with. Today, multinational enterprises (MNE) have an increasing number of R&D entities distributed over many countries (cf. Gassmann and von Zedtwitz 1999; Malecki 1979). These entities conduct their research independently from the headquarter, but there is internal job mobility (see Criscuolo 2005), i.e. for knowledge exchange and joint research projects the collaborating individuals easily overcome large distances. Thus, individuals have to overcome a higher distance to get in touch with other partners in the firm network, but they are supported by a strong internal infrastructure, common norms, hierarchies, and rules. Further sources of collaboration are partly outsourced R&D, the acquisition of small innovative companies fitting into the product portfolio, and joint projects with customers and suppliers. According to Arundel and Geuna (2004, p. 565), customers and suppliers are next to affiliated firms and joint ventures the most important sources of innovative ideas for companies. Usually, a company has built up organizational proximity with these partners by signing long-term contracts. They organize their production and joint meetings coordinately. If they do not sign contracts, then because there is some informal institutional proximity in the industry (or the region), e.g. like always keeping one's oral promise. In summary, corporate researchers have a certain level of organizational and/or institutional proximity towards the most probable collaboration partners. This organizational proximity may substitute (to some extent) social proximity.

The social proximity approach is strongly linked to the idea of spatial proximity. The reason is that building up social relationships, especially their indispensable social features, requires a very high communication frequency at the beginning and the chance to talk to each other unplanned and in different contexts (Kraut et al. 1988). Howells (1995) showed that ICT only partly facilitates collaboration over great distances, because non-verbal information, which enables individuals to build up trust and which is important to share tacit knowledge, can hardly be exchanged via ICT. Similar arguments can be found in Fritsch et al. (2007), who explain the regional boundaries found for collaborations between academic scientists and companies with necessary face-to-face contacts; and in Storper and Venables (2004), who list four properties of face-to-face contact which explain why personal meetings are too important to be replaced completely by a phone call or e-mail. Therefore, we expect that the rise of ICT and the reduction of passenger transportation costs have not increased over time the distance between inventors.

Because of organizational proximity corporate inventors do not necessarily need to be socially proximal to work together successfully. But academics often cross organizational boundaries in collaborations. They are risk-averse and need social proximity to minimize the risk of opportunistic behavior in projects or the risk of failing. Additionally, scientists have fewer resources to overcome distance than individuals working for large or international firms. Hence, scientists need geographical proximity to their partners to build up social proximity, which in turn enables them to collaborate with less risk. They have a preference for well-known partners and because spatial proximity is an indispensable feature to get in touch with other individuals, academic scientists rather collaborate regionally (Dettmann and Brenner 2010). Furthermore, spatial proximity helps them to perform the project with less organizational, financial and time effort. Corporate inventors are restricted to the partners available within the firm network to reduce risk in collaborative projects, and these firm networks are often large in spatial terms. Our hypothesis is therefore that inventors of corporate patents collaborate over larger distances.

3 Data

The first dataset contains more than 5,000 patent applications with at least one German professor among the inventors. For simplicity, the term “patent” will be used sometimes instead of the full term “patent application”. The time period covers the years 1991 to 2006 (postal codes for locating the inventors are available from 1993 on) and the priority country is Germany or Europe, i.e. direct application at the European Patent Office. The assignee of the patent is classified as university, research institute, company, or individual person(s). In order to compare academic and corporate patents a second dataset was developed as follows. For a part of the dataset (1305 patents), each patent was matched with a company patent in the same patent class at the same time of application, i.e. with a priority date 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. This matching process excludes differences in the fields of research and the numbers of patents per year and allows the research to be concentrated 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 the first dataset shows that academic patents are often assigned to companies. The first dataset contains patent classes, which are purely academic. As it would have been impossible to find matching corporate patents, these classes were excluded. From the remaining mixed patent classes 1305 patents were chosen randomly because of the time effort necessary for the manual matching.

In short, two datasets were used: one with patents where at least one inventor is a scientist (“academic patents”) and one with patents where all inventors are corporate researchers (“corporate patents”). It is impossible to divide purely academic patents from those related to science-industry collaboration, because the necessary information is not surveyed in patent data. So it was assumed that as soon as one university scientist is involved, the proprietary industry sphere is left and the patents differ from purely corporate ones. This assumption will be relaxed in section five.

The inventors were localized using their postal code. Three measures of distance are used in the analysis: (i) the log of the longest distance between any two 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 the same or a neighboring two-digit postal code (regional collaboration), two for non-neighboring 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. The logarithms 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 cooperation near country borders, i.e. over short distance, and long-distance cooperation inside one country.

Patent data has limitations when used for analyzing innovation. Most importantly, it is difficult to say whether patents are an input for or an output of innovation. Mansfield (1984) describes the limitations in detail. For this paper, these questions are of minor relevance, since patents are used just for illustrating inventor collaboration.

4 Descriptive statistics, trend over time

4.1 Origin of inventors

Former studies on the patenting behavior of German professors showed the strength of the eastern part of Germany in this respect during the 1990s (cf. Huelsbeck and Menno 2007). Similarly, the state of Baden-Wuerttemberg focused on academic patenting from the early 1990s on (cf. Technologie-Lizenz-Buero 2010). The analysis of postal codes of the inventors in our dataset of academic patents (patents with one to four inventors, international postal codes are excluded) supports these findings. The number of inventors located in each two-digit postal code area is divided by the number of all inventors in the dataset (excluding foreigners) for each year. There is only one region with an average yearly share of more than 3% of all inventors which does *not* belong to Saxony, Thuringia, or Baden-Wuerttemberg (cf. Figure 1).

[1] A route planner was used 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.

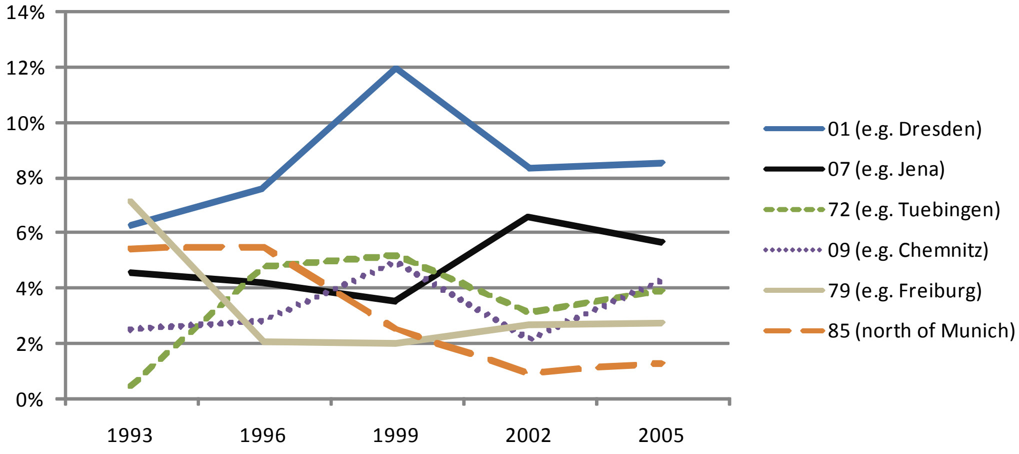

Figure 1: Location (2-digit postal code) of inventors of academic patents – top six regions

One level higher aggregated (1-digit postal codes, see Figure 7 in the appendix for a map) we can see that Region 0 (covering the Universities of Dresden, Jena, Halle, Leipzig) as the most "inventive" region has 4 times as many inventors as the regions with the lowest values. The University of Dresden and the University of Jena with their dedicated focus on patenting activities are responsible for most of the patents with inventors living in the postal code area 0. This shows the success of the strategy to increase patent awareness among professors and to support those who are willing to file patents. Note that the analysis at hand does not give any information about the financial success, because the focus is on the collaboration behavior.

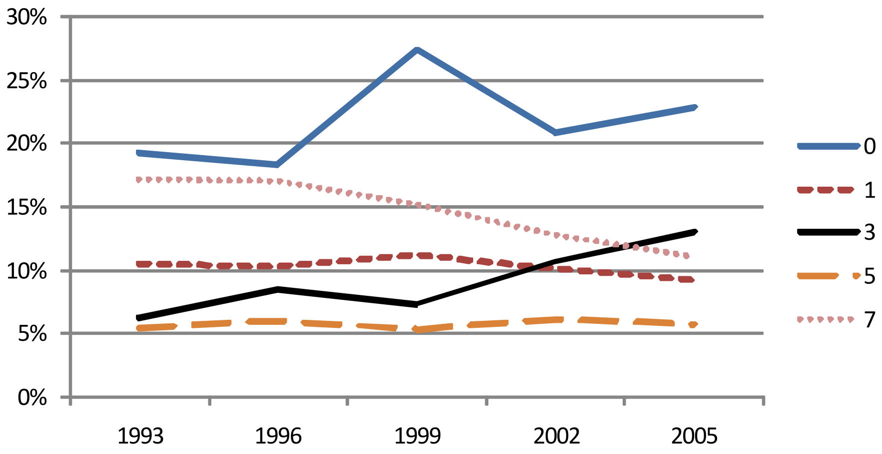

Figure 2: Location (1-digit postal code) of inventors of academic patents

For better illustration only half of the regions are displayed in Figure 2, the remaining regions, which are similar to each other in their share of inventors, are shown in Figure 8 in the appendix. Most regions do not exhibit a special trend over time. Exemptions are on the one hand region 8 (Universities of Munich, Ulm, Ingolstadt, Augsburg) and region 7 (Universities of

Stuttgart, Freiburg, Tuebingen, Karlsruhe) with a decreasing trend, maybe due to initial success which was relativized as soon as other regions became active in patenting. On the other hand, regions 0 and 3 (Universities of Braunschweig, Hannover, Magdeburg) exhibit a positive trend.

The dataset of academic patents contains 1305 entries. The geographical distribution of the inventors differs considerably from that of the academic patents, as expected from the theoretic argumentation in section 2.1. Some of the regions with the highest shares of inventors of academic patents are unimportant for corporate patents and vice versa. On the 1-digit level, region 0 is second least often the origin of corporate inventors and region 6 most often (see Figure 3). Only Baden-Wuerttemberg is often the home of academic and corporate inventors at the same time. The distribution is quite stable in the long run. On the 2-digit level, the regions 67 and 91[2] are most important and none of these stood out in the analysis of the academic patents above.

The differing origins of academic and corporate inventors show that the complementarity of both types of research does not imply a collocation of them. The knowledge can be transferred in a codified form or by meetings at fairs and conferences, so it is no necessary condition for the inventors to be collocated (cf. Cohen 2002 et al. for a discussion of the important channels of knowledge transfer from science to industry).

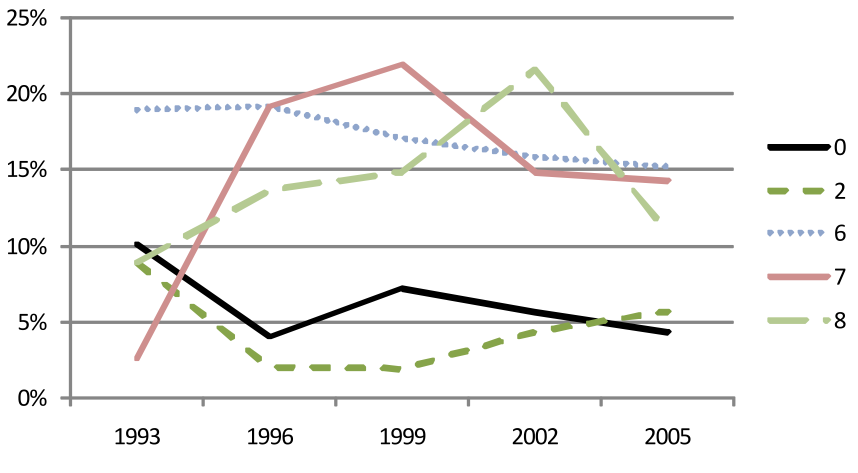

Figure 3: Location (1-digit postal code) of inventors of corporate patents – best and worst areas

2 Which are broadly spoken the Pfalz/Ludwigshafen region (67) and Erlangen and surroundings (91).

4.2 Descriptive statistics of the matched patents

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

	inventors:	
distance measure	academic	corporate
largest distance (km)	210.72	281.59
average distance (km)	175.77	193.46
log of larg. dist.	1.46	1.28
log of av. dist.	1.42	1.21
frequency of regional collab.	631	578
frequency of national collab.	229	237
frequ. of international coll.	35	80
no. of patent pairs with single inventors among academic OR corporate inventors	410	

Table 1: Descriptive statistics

Overall, the share of international collaborative inventions is low. Even though academic scientists speak English and can travel around the world, they invent rather locally. Similarly, the existence of MNEs is not reflected in an adequately high absolute number of international collaborations – though relative to academic patents, it takes place twice as often.

4.3 Trend of collaboration distances over time

Some patents are filed by single inventors, and this holds for both academic and corporate patents. Hence, for all analyses with distance measurement, we use only those pairs of matched patents, where both patents have two or more inventors listed on the document. This is the case for 895 patent applications. A linear regression on the average of the first distance measure (largest distance between any inventors) does not reveal a trend over time for both academic and corporate patent applications (cf. Table 2). Figure 5 shows the graphs. This supports the notion from section two that ICT was not able to increase inventive collaboration over large distances.

Coefficients	**Estimate**	**Std. error**	**p-value**		**Coefficients**	**Estimate**	**Std. error**	**p-value**
Time	-0.0067	0.0074	0.385		Time	0.0059	0.0041	0.182
Constant	1.6479	0.0630	0.000		Constant	1.6752	0.0352	0.000
Multiple R^2: 0.0633		Adj. R^2: -0.0147			Multiple R^2: 0.143		Adj. R^2: 0.072	

Table 2: Linear regression of distance over time (left: academic patents, right: corporate patents).

Correlation between the two metric distance measures is high and because the largest distance is relevant when investigating collaboration behavior over distance, the average distance between inventors is taken into account only in the following comparison of the matched patents.

5 Comparison of academic and matched corporate patents

5.1 Analysis of distance measures

Analyzing the ordinal distance variable, we clearly find a higher share of international collaboration among corporate inventors than among academic inventors (overall 8% versus 4%). It is important to note that only few corporate patents have more than one owner on the patent document, while multiple ownership is found more often for academic patents. This suggests that the collaborations normally take place within one company or in order of one company. Hence, it supports the argument of organizational proximity mentioned above. However, due to the lack of information about the individual inventors we cannot investigate this with the data at hand and the result cannot be proved. Regional collaboration occurs more often on academic patents, as the theoretical considerations had suggested. Even though academic patents have more often multiple owners (suggesting boundary-crossing research collaboration), the share of international collaboration is lower for academic inventors and the share of regional collaboration is higher.

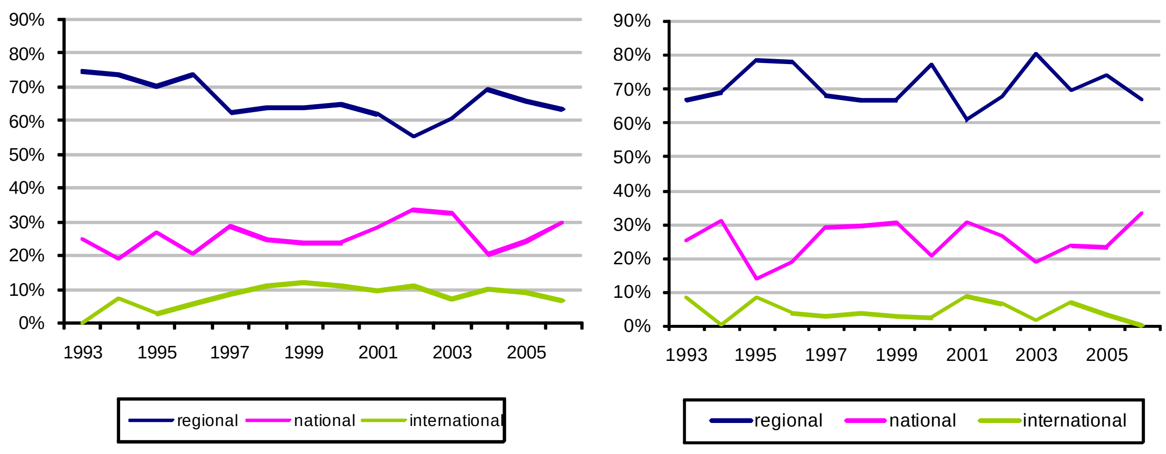

Figure 4: Shares of regional, national, and international collaboration on corporate (left) and academic (right) patents. Dataset of 895 matched patents.

There is a slightly negative trend of regional collaboration for corporate inventors (significant at the 5% level, ca. 0.8 percentage points per year). This finding points to the trend of decentralizing R&D activities within MNEs. 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.

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 of a patent") show similar patterns. Figure 5 shows the average largest distances between two inventors; Figure 6 shows the average of the average distances between all inventors (all in logs).

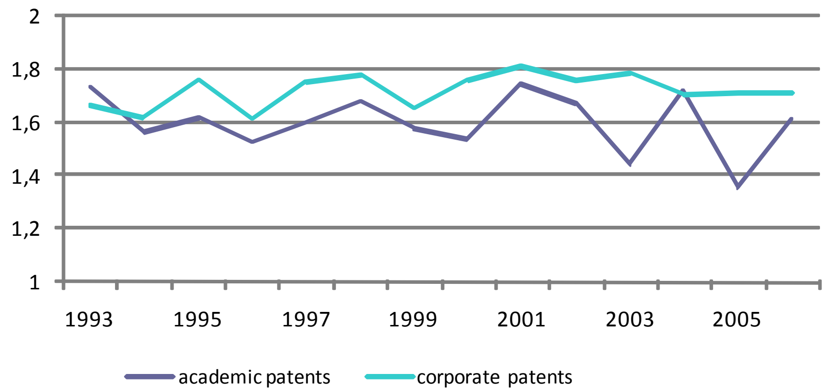

Figure 5: Average of the log of the largest distance between any of the inventors.

Table 3 shows the results of the comparison of means for the three distance measures. In all cases, the distance between the inventors of corporate patents exceeds that between the inventors of academic patents. The dataset should be large enough to use a t-test. However, a Wilcoxon signed rank test is necessary for the ordinal variable.

	Mean comparison, t-test of paired sample			Wilcoxon
	mean of diff.	std. err.	p-value for mean(diff)=0	p-value
log of largest distance	0.140	0.034	**0.000**	**0.000**
log of average distance	0.084	0.032	**0.004**	**0.004**
ordinal distance measure				**0.000**
n = 895				

Table 3: Comparison of means of the matched patents and Wilcoxon signed rank test.

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 of the same extent 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.

5.2 Robustness of results

As mentioned above, in the database, that there are more patents with two owners among academic patents than among corporate patents. The reason for this is that collaborations crossing the boundary between public and private research were included among the academic patents and excluded in the construction of the corporate dataset. Since we know the assignee of the academic patents, we can restrict this dataset to pure university ownership. Of course it is legally possible to have university ownership of a patent after collaboration with a company. But there is a high probability that a patent which results from science-industry collaboration is either filed by both organizations or is sold or given to the company. Prior to the abolition of the inventor ownership model in 2002 it was even more common, that companies received intellectual property ownership of inventions resulting from collaborative research projects. If we now compare only university-owned patents with their matched corporate counterparts, the cases of cross-border collaboration should be strongly reduced. The resulting analysis then compares patents coming from the science sector with those coming from industry. Of course, some noise in the data is unavoidable.

Mean comparison, t-test of paired sample			
	mean of diff.	std. err.	p-value for mean(diff)=0
log of largest distance	0.277	0.051	**0.000**
log of average distance	0.223	0.048	**0.000**
ordinal distance measure	0.197	0.042	**0.000**
n = 365			

Table 4: Comparison of means of the matched patents

As can be seen in Table 4 the difference between the two types of patents increases.

The differences between academic and corporate patents are less pronounced for the average distance variable (see Figure 6). This is caused by an overrepresentation of two-inventor collaborations in the dataset of academic patents. The average distance measure decreases with the number of inventors. For two inventors the average distance is the same as the largest distance, but the more inventors participate, the higher the probability that some of them are located near each other and then the average distance decreases. In our case the average distance is most probably larger than in reality because the inclusion of more patents with more than two inventors would reduce the average distance. By this, the difference to the corporate patents would increase. Hence, the bias does not challenge the results.

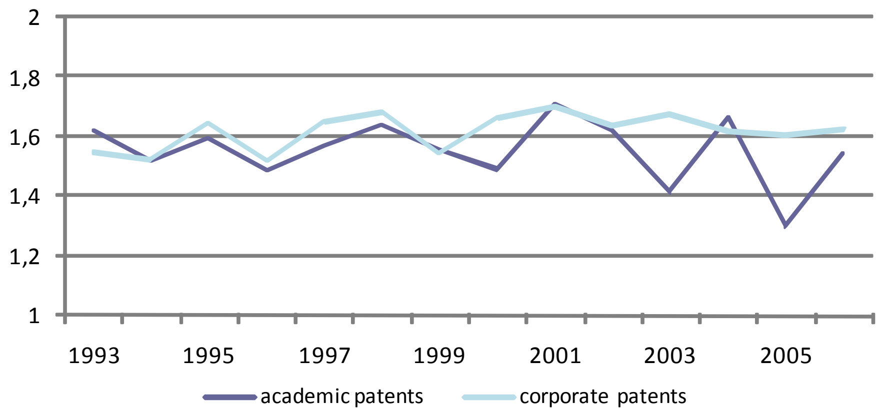

Figure 6: Average of the log of the average distance between all inventors.

Using only those matched patent which both have exactly two inventors, reduces the dataset to 261 patents, i.e. around 19 per year. The variance of the average distances is large and the difference in distances between academic and corporate patents is not significant. However, the share of international collaborations is still twice as high for corporate patents (12 vs. 6 patents) compared to academic ones. A constraint on university-owned academic patents would reduce the dataset to only 109 patents and an econometric analysis would not be possible.

5.3 Single inventors

A further question which must not be neglected here is the frequency of single inventors. In the analysis of distances between inventors patents with single inventors were excluded. However, the share of such patents differs between our two datasets. Regarding the full academic dataset of 5624 patents (in the slightly longer time period 1991 to 2006), there are 622 or 11% single inventors. In contrast, the dataset of matched corporate patents contains 335 out of 1305 (26%) single inventors. Both figures appear to be rather low compared with the figures of Wuchty et al. 2007. In their study about increasing team size in science, the share of single inventors on US patents is around 40% in 1995 with a decreasing trend. Similar data for Europe or Germany was not found. The dataset of corporate patents is most likely not representative for German patents, but the academic patents dataset is largely representative for academic patents (cf. von Ledebur et al. 2009). In any case, the difference in the share of single inventors is striking. Therefore a more detailed analysis of the single inventors follows, in particular for the patenting professors, for whom more detailed data is available.

In the dataset of academic patents, there are 250 professors who appear on a patent document as single inventors, but 214 of them have in addition filed patents with co-inventors. Hence, only 36 of the 986 patent active professors (3.7%) have not filed a patent with a co-inventor during the period between 1991 and 2006. The annual number of single-inventor patents decreases significantly over the period of observation (Figure 7, linear regression). In the smaller dataset of corporate patents (those which were matched with a part of the academic patents) there is no significant downward trend in single-inventor patents observable. The rising awareness towards IP issues at universities could be responsible for the higher share of team inventions, because filing a patent is no longer a private affair. We find some evidence for that when evaluating additional information available on the patent-level. On average, single-inventors are affiliated to universities with 4 years less experience in patenting activities (significant at 1% level). Individual persons own 42% of the single-inventor patents, which is only for 15% of patents with two or more inventors the case. In contrast, patents with many inventors are often owned by companies (37% of corporate versus 18% of academic patents), while the share of university ownership is similar for both types. The geographical coverage of protection is lower for single-inventor patents as well. The average number of countries for which the patent application seeks protection is 2.55, this is significantly (at 5% level) less than the 2.82 countries of the team-invented patents

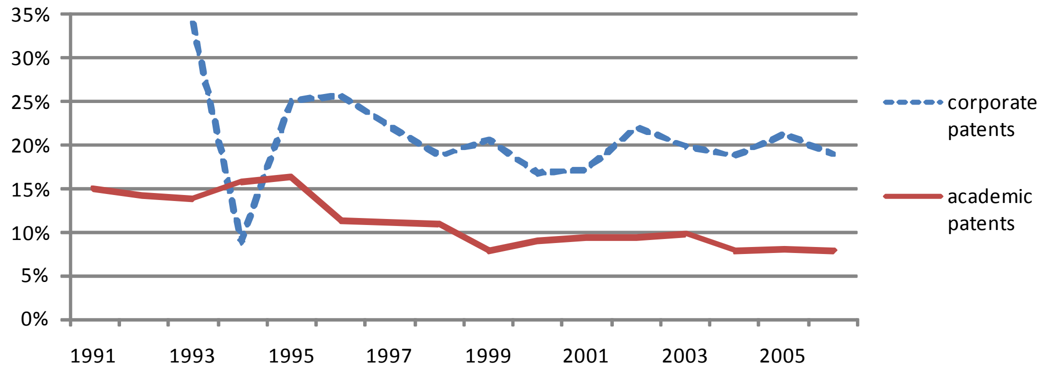

Figure 7: Yearly share of patents with single inventors.

These findings still do not explain why academic scientists rely more heavily on team invention than industrial researchers. Two possible explanations will be discussed here. Firstly, patents do not play an important role for the career of academics. The interest in patenting activities can be based on the curiosity whether an invention is applicable or on the hope to earn some money with the patent. The probability of commercialization certainly increases with the number of inventors, as the higher share of company ownership for team inventions shows. Especially in cooperation with industrial researchers the commercialization is feasible. Sometimes, an invention is only patented because the university demands so. In this case the share of single inventors can still be expected to be low, since most academic research takes place in teams. For corporate inventors, patentable inventions are more likely related to a higher salary or career advancement. Sharing this success would not be an advantage, because the individual success is probably not related to the value of the patent (which is unknown or can be estimated only with a long delay) but to the fact of having invented something patentable. Secondly, the paradigm of open science helps to be informed about what other scientists are working on. Secrecy is much less important than for industrial research. Therefore it is easier to find contacts with complementary knowledge if needed. Due to difficulties which arise when organizational boundaries are crossed (e.g. trust, see above), collaboration may take place rather locally, but the willingness for cooperation is high. Of course, these considerations are only a discussion of possible reasons for the lower frequency of single inventors in academia and need to be verified by further research. In addition, the dataset of corporate patents is not representative and the true share of single inventors may be higher or lower.

In summary, industrial researchers collaborate over larger distances than academic inventors. But corporate patents display at the same time more often single inventors. If we include single inventions in the analysis of matched patents as an artificial "collaboration over a distance of 1km" (inducing a zero value when taking logarithms) and repeat the analysis of section 5.1, the patents with academic inventors display cooperation over larger distances. The more frequent collaboration somehow counterbalances the smaller distance in case of collaboration.

6 Conclusion

The analysis of a dataset of academic patents and a second dataset of corporate patents matched with the academic ones by time and patent class gives some insights in the geographical distribution of German inventors and the collaboration behavior. While the inventors of academic patents are mainly located in the regions where universities have a dedicated focus on patenting activities, the corporate inventors are clustered according to the industrial structure of Germany, e.g. around Stuttgart and Munich.

In case of collaboration, the distances between inventors are larger for corporate than for academic patents and twice as often the collaboration is international. Organizational and institutional proximity seem to facilitate long-distance collaboration, what is important for corporate inventors, who are often restricted to their (sometimes expanding) firm networks. However, the share of single inventors is lower in the dataset of academic patents. Thus, academics like to cooperate, but usually with people they are able to meet face-to-face regularly. A possible explanation is social proximity that enables academics to build up trustful personal and professional boundaries with their partners. To do so, academics need to interact face to face at certain points of time and for this spatial proximity is an indispensable prerequisite.

The study is not industry-specific but voluntarily analyzes a mix of patent classes in both datasets. This helps to give a general grasp of differing collaboration behavior in the academic and industrial worlds. Case studies on individual industries could now be added for deeper insights.

Still open remain research questions about the economic consequences of limited spatial collaboration and whether policy could have influence on the spatial dimension of academic research collaborations. A case study, could try to verify the assumption of trust as the factor behind the spatial pattern of collaboration, which we only derived indirectly as the source of the differences in the collaboration networks. In addition, an in-depth investigation of the reasons for single-inventor patents is missing up to now.

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Appendix

Figure 8: One-digit postal codes in Germany (source: www.deutschepost.de)

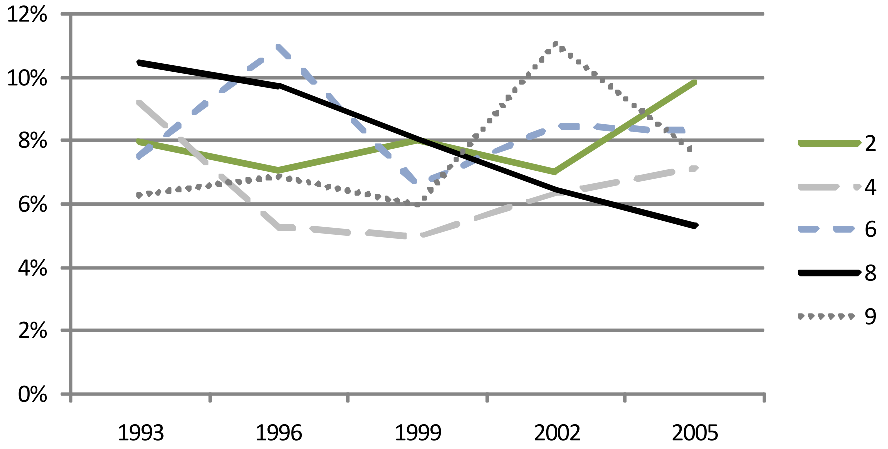

Figure 9: Location (1-digit postal code) of inventors of academic patents – regions not displayed in Figure 2.