The Dynamics of Inter-Regional Collaboration –

An Analysis of Co-Patenting

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Abstract

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1 Introduction

The role of geographical space for innovation activities has been stressed in a large amount of theoretical and empirical studies. Proximity facilitates interaction, especially in the case of complex activities like innovation (Frenken et al. 2009, Hoekman et al. 2010). Proximity consists not only of geographical proximity, but also of further dimensions like social, organizational, and institutional proximity (Boschma 2005). These are partly substitutable with each other (see e.g. Sternberg 2007). Ongoing interaction based on different kinds of proximity leads to a network of actors. The resulting networks shape economic success and technological change and they are a popular subject-matter for economists. Earlier work decomposed the observable clustering into links established through social networks and those established by mere geographical proximity (e.g. Breschi and Lissoni 2005, Ponds et al. 2007). Non-regional relationships are created on the basis of personal links, i.e. the collaborators know each other either from collocation at an earlier point in time (which ended for example because of job mobility), from belonging to the same organization, or from having met at conferences/fairs or business meetings (Dettmann and Brenner 2010). Next to networks based on the individual level or firm level, the regional level is of interest for policy makers. In the literature it is repeatedly stated that intra-regional as well as inter-regional linkages are needed for a healthy economic development of regions (see, e.g., Broekel and Meder 2009). Therefore, policy makers have begun to support collaborative activities between regions in order to improve the effectiveness of regional policies and instruments (EU INTERREG 2011). The question is how new innovation links between regions can be established and which regional characteristics make such links more likely. It is well known that regional development is path-dependent (for a recent review see Martin and Sunley 2006). Hence, collaboration that has been established in the past can be expected to be repeated with a high probability. Therefore, it improves the understanding of co-inventing between regions to examine the establishment of new links and the repetition of cooperation separately. To the authors' knowledge this has not been investigated so far.

The existing literature on innovation collaboration links is to the largest extent of static nature. Although Ter Wal and Boschma (2009) have recommended to take a dynamic view on clusters only a few papers in economic geography have tackled this task. Analyzing the evolution of business networks can be expected to provide interesting insights on how stable relations and networks are; how young and/or small firms find and hold a position in their environment; how knowledge spreads in time and space; how policy measures influence the interaction among firms; and more (cf. e.g. Ernst and Kim 2002, Walker et al. 1997). The paper at hand investigates the dynamics of interregional collaboration behavior, i.e. how the establishment of new collaborations and the repetition of old collaborations depends on a several regional characteristics.

Prior work closest to our approach is the paper by Hoekman et al. (2009) but with a static approach. They explain the amount of co-patenting of inventors from two regions by the amount of overall patenting in the two regions, their distance, the existence of a national border between the regions, and by controlling whether the regions comprise top scientific institutions or a capital city. In all model specifications, distance decreases the amount of collaboration, which is in line with earlier findings about the necessity of proximity for complex interaction.

Data on co-inventing activities is taken from the PATSTAT database. The analysis is restricted to German regions and to all patents with inventors from, at least, two regions in Germany. We use the German labor market regions as spatial unit. Two regions are said to have collaboration activity with each other if there exists, at least, one patent listing with, at least, one inventor from each of these region. The co-invented patents of a time period of three years represent the stock of collaboration activities between regions. This is necessary because a continued collaboration does not necessarily lead to a patent each year. We then calculate the probability of a continuation of the relationship and the generation of a new relationship respectively in the following year using a logit model.

The remainder of the paper is structured as follows. The second section presents the scarce existing literature in the field of the persistence of innovation collaboration and contains our theoretical considerations. The third section presents the database and the methods. The empirical results are presented and discussed in section four. Section five concludes.

2 Dynamics of collaboration

It is known from regional innovation literature that collaboration on innovative activities enhances innovation performance, especially if collaboration partners are close-by (Arndt and Sternberg 2000) and if there is some variety in the partners (Toedtling et al. 2010). In addition, having also links to actors outside the home region enhances innovativeness (Bathelt et al. 2004). However, too many and unbalanced collaboration links can do damage as well

(Broekel and Meder 2008). Hence, firms have to find collaborations partners from whom they benefit. The search is difficult and costly, because firms try to keep secret what they know and at the beginning of a research project it may be even unclear what abilities the partner must have. Therefore, firms want to find trustworthy collaborators and screen their business contacts for partners with whom the relationship could be intensified. Most often, innovation projects emerge from contacts to suppliers and customers (Cohen et al. 2002). When they are mutually dependent from each other, a reasonable level of trust exists already. Earlier studies found that innovation activities of firms are rather persistent and relationships often long-term oriented (Cefis and Orsenigo 2001, Orsenigo et al. 1997).

Interregional collaboration links can also emerge out of links between subsidiaries or joint ventures of large companies. In this case, links should be built strategically and especially stable. Of course, necessity-driven one-time cooperation projects do also exist which will not be pursued after the solution of the research problem. Overall, there is evidence that inter-firm links are rather stable in time and links on the interregional level are, therefore, stable too.

However, there are of course environmental factors on the level of the region influencing the continuation of links between regions. The main difference between the regional level and the firm level is that an interregional link does not have to be maintained by the same co-inventors. Of course, several ongoing links are based on the same pairs of inventors, but others are newly established between different actors, where the first contact may be related to the individuals of the first link, but can also emerge randomly. The environmental factors influencing inter-regional collaboration will be discussed in the following.

Distance

Social interaction decreases with distance. The human nature favors short-distance connections for regularly and intensive communication and empirical findings state a decrease of collaboration with distance between firms (Hoekman et al. 2010, Christ 2010), between academia and industry (von Proff and Dettmann 2010), and between academics (Frenken et al. 2009). Not even the rise of information and communication technologies was able to increase long-distance collaboration strongly, especially not when the work is complex as it is the case for innovation projects (Olson and Olson 2000). If long-distance links exist, one can assume that they have arisen out of personal acquaintances, mediated by former collocation, by meetings on conferences and so on (Dettmann and Brenner 2010). Due to a probable lack of regular meetings and profound exchange of problems and wishes, there is a high risk of either project failure or termination of cooperation over time. Since a person from one region knows more potential partners in near regions than in regions far away, there is also a higher chance to start a new collaboration with someone from a near region.

Hence, we expect:

Hypothesis 1: New collaboration is less likely to be established over large distance and link continuation is less likely for larger distances.

Universities and research institutes

Research on university-industry linkages found that academics use a variety of linkages to industry (D'Este and Patel 2007), i.e. informal relations like meeting on conferences as well as formal contacts like contract or joint research. Since universities are usually short of government funding, it is essential to receive funding from industry in addition. It is not always easy to find adequate partners and a successful relationship (for both sides) will certainly be repeated (Lee 2000). If the link cannot be maintained over time, it is likely that the academics will search for new partners – they either need funding or are interested in the commercialization of research findings. It is known that the amount of academic patenting has increased over time (von Ledebur et al. 2009) and even under the constraint that patents display only a part of science-industry links, the rise in patenting indicates an orientation towards industrial application and commercialization of academic research. An increasing use of academic knowledge in industry has been found by Kim et al. (2005) empirically. According to the findings about the importance of proximity (see above), establishing new links will likely be happen at places familiar to researchers, i.e. predominantly places where they have lived before or where other universities are (in case of inter-university collaboration). The creation of new links involving such places is more likely, because researchers at universities are a specifically mobile group of employees and have often more than one region, where they have lived before where they could establish links to. Furthermore, researchers at universities often have many far-distance collaboration activities with other researchers whom they meet on conferences. These contact are usually quite stable, so that universities should also contribute to the stability of links from regions that contain a university.

Hypothesis 2: New collaboration is more likely to be established in regions containing a university and existing links are more likely to be continued in such regions.

Since there are more than 300 universities in Germany and 270 labor market areas, most of the studied regions contain a university. As a proxy for size and research strength of the universities in a region, the number of graduates in subjects related to the studied industry is used here.

Employment

The employment in the relevant industries in a region is, of course, a measure of the overall potential of collaboration that might take place with an involvement of this region. Most inventors behind patents are employees in firms. Hence, regions with higher employment can be expected to be more likely involved in new collaboration as well as to have higher chances to continue existing collaboration links.

However, not all kinds of employees have the same relevance for innovation activities. R&D is disproportionally often carried out by persons with tertiary education. Therefore, regions with a high level of employees with tertiary education will certainly have more R&D activities and at the same time more collaboration links. Highly-educated persons are spatially more flexible when changing jobs (van Ham et al. 2001). Existing contacts, however, are not lost when moving to another region. Furthermore, they can stay in contact with the professors that were their teachers and with fellow students who probably work elsewhere. If they have spent considerable time together the relationship may be strong enough to overcome distance even in the longer term.

Similar arguments hold for R&D employees. They are even more likely to be involved in innovation activities and, hence, in patenting. Usually they hold a university degree and sometimes they even have stayed in public research before moving to a R&D department in a firm. Thus, they have many scientific links that might bridge large distances.

Hypotheses 3: Regions with a higher number of tertiary-educated employees and R&D employees have a higher probability of link continuation and link creation.

According to the above arguments we expect in addition:

Hypothesis 3a: R&D employees have the highest importance among the employees for innovation processes and, therefore, they have the highest impact on the establishment and continuation of links.

Start-ups and spin-offs

Start-ups and spin-offs are usually established where the entrepreneurs are already living and have their social network (Dahl and Sorenson 2009). In the case of spin-offs, close ties to the incubator remain, but since they are mainly intra-regional they are not relevant for an analysis of interregional links.

Industry life cycle

The collaboration behavior of innovating firms differs between the different stages of the industry life cycle. In the early stage, it is not yet clear which actors will be the core of the industry. This uncertainty will lead to a change of partners and the trial to hire successful engineers from competitors in order to gain as much knowledge as possible (Ter Wal and Boschma 2009). This search is predominantly limited in space (Ter Wal 2010). In the following growth phase new and low-performing firms will try to form links with central firms, i.e. the linking process takes place by preferential attachment. They are not necessarily located in the same region, i.e. proximity becomes less important over time. Instead, according to Ter Wal (2010), a friends-of-friends search becomes more prevalent in order to minimize spill-overs to non-trustful actors. These links should be rather stable. In later stages of the industry life cycle, the number of innovations will decrease and thus the number of collaboration activities as well. The remaining links should be stable. In short, we expect the stability of collaboration links to increase over the industry life cycle. However, when analyzing only a time period of a few years, there is no clear industry life cycle pattern. Other developments like the overall economic growth will superimpose the life cycle. Therefore, no industry life cycle variable will be included in the analysis.

Technology / industry

Innovation patterns of technologies and industries differ. There are industries where patents are essential for developing and exploiting inventions (e.g. pharmaceuticals, chemicals) and others, where patents are of low relevance (e.g. rubber, office equipment, cf. Mansfield 1986). Similarly, there will be industry effects in the collaboration behavior. We take care of this by analyzing three industries separately.

3 Data and method

Patents are widely-used data in innovation studies, e.g. for the analyses of the location of knowledge production and the network where the knowledge diffuses. For the latter means, two approaches are common: citations display how new knowledge spreads in space over time, and co-inventions show the network structure of collaboration in space. According to the focus of our study on collaboration links we will use co-invention data taken from the PATSTAT database. Full data is available for 1999 to 2007. Since the existence of a link between two regions is measured over three years and is lagged one year, the regression will be done for 2002 to 2007. The regional units are the 270 labor market regions in Germany. We focus exclusively on German inventors because use a number of the independent variables that are available for us only for German regions.

Next to the independent variables explained above some control variables are included. First of all, the sheer size of a region plays a role for innovation links. Therefore, the sum of population of each pair of regions is included. Similarly, the overall employment of a region plays a role. This variable is probably correlated with the population and the two other employment variables (employees with tertiary degree/R&D employment), so we will take a close look which variables are significant. The overall number of patents filed in a region is, of course, related to the number of links to other regions. We control for the amount of patenting by including the overall number of patents which have been filed in any pair of regions (fractional counting for multiple inventors and multiple patent classes on one patent). All non-patent data are either from official databases from the Federal Statistical Office of Germany (graduates, employment and population) or from the German Institute for Labor (R&D employees and employees with a tertiary degree). Table 1 gives an overview of the variables.

Variable	**Explanation**
$Link_{ijt}$	Dummy variable taking the value one if there is at least one co-invention between regions i and j in year t
$Distance_{ij}$	Distance in km between the centers of regions i and j
$Graduates_{i,j,t-1}$	Sum of graduates in industry-related subjects in regions i and j in year t-1.
$R\&DEmpl_{i,j,t-1}$	Sum of employment in R&D in the industry in regions i and j in year t-1
$TertDegree_{i,j,t-1}$	Sum of employees with tertiary degree in the industry in regions i and j in year t-1
$Employment_{i,j,t-1}$	Sum of employment of regions i and j in year t-1
$Population_{i,j,t-1}$	Sum of populations of regions i and j in year t-1
$Patents_{ijt}$	Number of patents (fractional counting for multiple inventors and multiple patent classes on one patent) in regions i and j (sum) in year t
$stockoflinks_{ijt}$	Dummy variable taking the value one if there has been at least one collaboration between regions i and j during the years t-3 and t-1

Table 1: Variables.

We chose three industries for our analyses for which there is a good fit between the industry classification (WZ03) and the patent classification (IPC) according to an examination by the Fraunhofer institute ISI in Karlsruhe. We analyze the industries of medical equipment (33.1), telecommunications (32.2), and pharmaceuticals (24.4). Patenting is quite important in these three industries, so that we can rely on a large dataset. The following industry-relevant graduates are selected and included in the analysis:

- Pharmaceuticals: graduates in medical/veterinary sciences, chemistry, and pharmaceutical sciences
- Medical equipment: graduates in medical/veterinary sciences, electrical engineering, and biology
- Telecommunications: electrical engineering, mathematics, and physics.

For each industry two regressions are conducted: one for the probability that an existing link is continued and one for the probability that a link is built in case there has been none during the last three years. The dataset is divided into the respective parts by the variable *stockoflinks*. Expectedly, the number of region pairs with collaboration links is much smaller than those without. Since the dependent variable is dichotomous, a logistic regression is used:

$$P\left(Link_{ijt} \middle| stockoflinks_{ijt} = 1\right) = f(Patents_{ijt}, Population_{i,j,t-1},\ Employment_{i,j,t-1}, R\&DEmpl_{i,j,t-1}\ , TertDegree_{i,i,t-1}, Graduates_{i,j,t-1}, Distance_{ij}) \qquad (1)$$

$$P\left(Link_{ijt} \middle| stockoflinks_{ijt} = 0\right) = f(Patents_{ijt}, Population_{i,j,t-1},\ Employment_{i,j,t-1}, R\&DEmpl_{i,j,t-1}\ , TertDegree_{i,i,t-1}, Graduates_{i,j,t-1}, Distance_{ij}) \qquad (2)$$

The descriptive statistics (see

Medical equipment	**stockoflinks = 1** # of cases:	6279	**stockoflinks = 0** # of cases:	211611	(mean|1)/
Variable	*mean*	*sd*	*mean*	*sd*	(mean|0)
Link	0.1688	0.3746	0.0061	0.0777	27.8
Patents	131.78	118.11	31.00	51.87	4.3
Employmt	2706.89	2115.29	967.30	1160.92	2.8
R&DEmpl	221.13	270.53	77.30	184.64	2.9
TertDegree	130.19	147.29	28.59	64.57	4.6
Population	1546522	1125295	583053	509581	2.7
Distance	280.59	189.84	385.52	184.74	0.7

Telecomm-unications	**stockoflinks = 1** # of cases:	6076	**stockoflinks = 0** # of cases:	211814	(mean|1)/

Variable	mean	sd	mean	sd	(mean|0)
Link	0.1575	0.3643	0.0048	0.0689	33.0
Patents	248.93	353.75	32.92	92.54	7.6
Employmt	2149.92	2164.54	482.47	1028.26	4.5
R&DEmpl	364.63	364.63	94.41	94.41	3.9
TertDegree	273.22	347.24	49.90	151.97	5.5
Population	1611335	1133307	582561	504919	2.8
Distance	294.63	195.37	385.01	184.82	0.8

Pharma-ceuticals	**stockoflinks = 1** # of cases:	13348	**stockoflinks = 0** # of cases:	204542	(mean|1)/
Variable	*mean*	*sd*	*mean*	*sd*	(mean|0)
Link	0.2858	0.4518	0.0090	0.0942	31.9
Patents	179.97	148.06	34.93	68.20	5.2
Employmt	2973.08	2945.29	690.23	1399.67	4.3
R&DEmpl	219.15	249.72	47.55	119.34	4.6
TertDegree	503.77	578.54	103.68	255.76	4.9
Population	1413799	1028433	558417	470477	2.5
Distance	304.44	186.12	387.59	184.55	0.8

Table 2) show, how much larger (in terms of all variables) the region pairs with links during the last three years are in comparison with link-less region pairs. The probability of having a collaboration link in *t* is around 30 times as high for region pairs with a prior link. This holds for all industries. In Pharmaceuticals, there are twice as many regions linked with each other than in Telecommunications and Medical equipment.

Medical equipment	**stockoflinks = 1** # of cases:	6279	**stockoflinks = 0** # of cases:	211611	(mean|1)/
Variable	*mean*	*sd*	*mean*	*sd*	(mean|0)
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Table 2: Descriptive statistics. Mean values over all years of observation for any pair of region. Note: the variable Graduates is still missing in these first regressions).

The descriptive statistics support the earlier static findings that proximity is related to a higher probability of a link as well as larger values for overall patenting, employment, R&D employment, employment with tertiary degree, and a larger population.

4 Results and Discussion

Control variables: population and patenting

Let us first discuss the control variables before we check our hypotheses. We find a significant positive relationship between the establishment as well as the continuation of links and the total patent output of a region independent of the industry studied (Tables 3 and 4). Hence, regions that are more active in patenting are also more likely to establish new collaboration and continue existing collaboration.

Similar results are obtained for total population. However, in the case of the population there is one exception: For the continuation of existing links in the pharmaceutical industry a slightly significant positive relationship is only found in one of the three models (see Table 3). For the other two models no significant relationship is found between the continuation of collaboration and population. Hence, in the pharmaceutical industry the continuation of collaboration seems not or, at least, not so strongly to depend on the total population in the involved regions. Once a link is established, it is not a (great) advantage for the continuation of the collaboration to be located in a (big) city. The establishment of collaboration, instead, seems to be easier from within a (big) city. In the other two industries (big) cities are more active in both establishing and continuing collaboration.

Distance (Hypothesis 1)

A significant negative coefficient is found for distance in all conducted regressions. Hence, Hypothesis 1 is clearly confirmed. In line with the studied in the literature, we find that the probability to establish new links as well as the probability to continue an existing link decreases with the distance between the two involved regions. Spatial distance matters for collaboration.

stock of links = 1	Model (1)			Model (2)			Model (3)		
	Medical Equipment								
constant	**-1.897**	**(7.65E-02)**	*******	-1.877	(7.62E-02)	***	-1.779	(7.31E-02)	***
Patents	**5.639E-03**	**(5.77E-04)**	*******	5.632E-03	(5.77E-04)	***	3.589E-03	(4.46E-04)	***
Employmt				1.159E-05	(3.77E-05)		a)		
R&Dempl	**2.846E-04**	**(1.88E-04)**					-3.006E-04	(1.71E-04)	*
TertDegree	**-3.066E-03**	**(5.58E-04)**	*******	-2.716E-03	(5.57E-04)	***			
Population	**4.689E-07**	**(4.38E-08)**	*******	4.475E-07	(5.13E-08)	***	3.874E-07	(4.10E-08)	***
Distance	**-3.876E-03**	**(2.29E-04)**	*******	-3.870E-03	(2.29E-04)	***	-3.793E-03	(2.28E-04)	***
AIC	5089.1			5091.2			5117.6		
	Pharmaceuticals								
constant	**-1.1**	**(4.38E-02)**	*******	-1.063	(4.32E-02)	***	-1.054	(4.23E-02)	***
Patents	**4.240E-03**	**(2.43E-04)**	*******	4.296E-03	(2.46E-04)	***	4.106E-03	(2.49E-04)	***
Employmt				9.279E-05	(1.92E-05)	***	1.976E-06	(1.40E-05)	
R&Dempl	**1.246E-03**	**(1.69E-04)**	*******				6.522E-04	(1.45E-04)	***
TertDegree	**-3.313E-04**	**(7.96E-05)**	*******	-2.430E-04	(9.32E-05)	***			
Population	**5.719E-08**	**(3.11E-08)**	*****	-1.246E-08	(2.98E-08)		2.300E-08	(3.08E-08)	
Distance	**-2.169E-03**	**(1.16E-04)**	*******	-2.150E-03	(1.16E-04)	***	-2.218E-03	(1.16E-04)	***
AIC	15262.0			15293.0			15279.0		
	Telecommunications								
constant	-2.413	(8.58E-02)	***	**-2.389**	**(8.60E-02)**	*******	-2.379	(8.51E-02)	***
Patents	1.370E-03	(1.12E-04)	***	**1.439E-03**	**(1.15E-04)**	*******	1.151E-03	(1.03E-04)	***
Employmt				**3.535E-04**	**(4.31E-05)**	*******	-3.580E-05	(3.74E-05)	
R&Dempl	1.127E-03	(1.42E-04)	***				7.612E-04	(1.83E-04)	***
TertDegree	-8.824E-04	(1.78E-04)	***	**-1.762E-03**	**(2.60E-04)**	*******			
Population	4.432E-07	(4.25E-08)	***	**3.234E-07**	**(4.89E-08)**	*******	4.500E-07	(4.57E-08)	***
Distance	-2.683E-03	(2.19E-04)	***	**-2.537E-03**	**(2.21E-04)**	*******	-2.725E-03	(2.19E-04)	***
AIC	4587.6			4580.7			4613.0		
Standard errors in parentheses. Significance levels ***/**/*: 1/5/10%. a) When TertDegree is excluded, but Employmt still included, the VIF for Employmt is larger than 10.									

Table 3: Regression for those region pairs where a link has existed in the previous three years.

University graduates (Hypothesis 2)

Due to data problems Hypothesis 2 will be tested in the revised version of the paper.

stock of links = 0	Model (4)			Model (5)			Model (6)		
	Medical Equipment								
constant	-4.982	(6.56E-02)	***	**-4.98**	**(6.54E-02)**	*******	-4.869	(6.45E-02)	***
Patents	9.596E-03	(5.49E-04)	***	**9.428E-03**	**(5.49E-04)**	*******	5.816E-03	(4.22E-04)	***
Employmt				**1.758E-04**	**(2.60E-05)**	*******	a)		
R&Dempl	8.029E-04	(1.43E-04)	***				2.993E-05	(1.52E-04)	
TertDegree	-5.516E-03	(5.68E-04)	***	**-5.615E-03**	**(5.62E-04)**	*******			
Population	8.206E-07	(4.03E-08)	***	**6.536E-07**	**(4.26E-08)**	*******	6.919E-07	(3.74E-08)	***
Distance	-3.466E-03	(1.76E-04)	***	**-3.483E-03**	**(1.76E-04)**	*******	-3.426E-03	(1.77E-04)	***
AIC	13755.0			13745.0			13849.0		
	Pharmaceuticals								
constant	**-4.58**	**(5.61E-02)**	*******	-4.467	(5.41E-02)	***	-4.439	(5.31E-02)	***
Patents	**5.534E-03**	**(3.75E-04)**	*******	6.703E-03	(3.65E-04)	***	5.901E-03	(3.99E-04)	***
Employmt				a)			-2.070E-05	(2.45E-05)	
R&Dempl	**2.864E-03**	**(2.66E-04)**	*******				5.455E-04	(2.47E-04)	*
TertDegree	**-1.305E-03**	**(1.27E-04)**	*******	-2.218E-04	(7.02E-05)	**			
Population	**5.918E-07**	**(5.55E-08)**	*******	3.898E-07	(5.21E-08)	***	3.607E-07	(5.37E-08)	***
Distance	**-2.525E-03**	**(1.37E-04)**	*******	-2.503E-03	(1.37E-04)	***	-2.540E-03	(1.37E-04)	***
AIC	19954.0			20050.0			20056.0		
	Telecommunication								
constant	-5.24	(7.35E-02)	***	**-5.237**	**(7.43E-02)**	*******	-5.237	(7.38E-02)	***
Patents	1.074E-03	(1.43E-04)	***	**1.167E-03**	**(1.46E-04)**	*******	1.035E-03	(1.34E-04)	***
Employmt				**2.721E-04**	**(4.55E-05)**	*******	9.475E-05	(3.75E-05)	*
R&Dempl	7.835E-04	(1.41E-04)	***				4.437E-04	(1.82E-04)	*
TertDegree	4.274E-05	(1.87E-04)		**-7.357E-04**	**(2.88E-04)**	*****			
Population	8.670E-07	(3.87E-08)	***	**7.766E-07**	**(4.59E-08)**	*******	8.233E-07	(4.28E-08)	***
Distance	-3.105E-03	(1.94E-04)	***	**-3.028E-03**	**(1.94E-04)**	*******	-3.077E-03	(1.94E-04)	***
AIC	11425.0			11417.0			11418.0		
Standard errors in parentheses. Significance levels ***/**/*: 1/5/10%. a) When one variable is excluded, but Employmt still included, the VIF for Employmt is larger than 10.									

Table 4: Regression for those region pairs where no links have existed in the previous three years.

<u>Industry-specific qualified employees (Hypotheses 3 and 3a)</u>

In Hypothesis 3 we have claimed that employees with tertiary degree and R&D employees are often involved in innovation activities. Hence, they should positively influence the collaboration probability between regions. The regression with a full model, considering all variables, is problematic due to the highly correlated three employment variables (*population* is less correlated with the employment variables). A variance inflation factors analysis shows that *employmt* is the critical variable. Therefore, we conducted three regressions for each industry and the establishment and continuation of collaboration (see

stock of links = 1	Model (1)			Model (2)			Model (3)		
	Medical Equipment								
constant	**-1.897**	**(7.65E-02)**	***	-1.877	(7.62E-02)	***	-1.779	(7.31E-02)	***
Patents	**5.639E-03**	**(5.77E-04)**	***	5.632E-03	(5.77E-04)	***	3.589E-03	(4.46E-04)	***
Employmt				1.159E-05	(3.77E-05)		a)		
R&Dempl	**2.846E-04**	**(1.88E-04)**					-3.006E-04	(1.71E-04)	*
TertDegree	**-3.066E-03**	**(5.58E-04)**	***	-2.716E-03	(5.57E-04)	***			
Population	**4.689E-07**	**(4.38E-08)**	***	4.475E-07	(5.13E-08)	***	3.874E-07	(4.10E-08)	***
Distance	**-3.876E-03**	**(2.29E-04)**	***	-3.870E-03	(2.29E-04)	***	-3.793E-03	(2.28E-04)	***
AIC	5089.1			5091.2			5117.6		
	Pharmaceuticals								
constant	**-1.1**	**(4.38E-02)**	***	-1.063	(4.32E-02)	***	-1.054	(4.23E-02)	***
Patents	**4.240E-03**	**(2.43E-04)**	***	4.296E-03	(2.46E-04)	***	4.106E-03	(2.49E-04)	***
Employmt				9.279E-05	(1.92E-05)	***	1.976E-06	(1.40E-05)	
R&Dempl	**1.246E-03**	**(1.69E-04)**	***				6.522E-04	(1.45E-04)	***
TertDegree	**-3.313E-04**	**(7.96E-05)**	***	-2.430E-04	(9.32E-05)	***			
Population	**5.719E-08**	**(3.11E-08)**	*	-1.246E-08	(2.98E-08)		2.300E-08	(3.08E-08)	
Distance	**-2.169E-03**	**(1.16E-04)**	***	-2.150E-03	(1.16E-04)	***	-2.218E-03	(1.16E-04)	***
AIC	15262.0			15293.0			15279.0		
	Telecommunications								
constant	-2.413	(8.58E-02)	***	**-2.389**	**(8.60E-02)**	***	-2.379	(8.51E-02)	***
Patents	1.370E-03	(1.12E-04)	***	**1.439E-03**	**(1.15E-04)**	***	1.151E-03	(1.03E-04)	***
Employmt				**3.535E-04**	**(4.31E-05)**	***	-3.580E-05	(3.74E-05)	
R&Dempl	1.127E-03	(1.42E-04)	***				7.612E-04	(1.83E-04)	***
TertDegree	-8.824E-04	(1.78E-04)	***	**-1.762E-03**	**(2.60E-04)**	***			
Population	4.432E-07	(4.25E-08)	***	**3.234E-07**	**(4.89E-08)**	***	4.500E-07	(4.57E-08)	***
Distance	-2.683E-03	(2.19E-04)	***	**-2.537E-03**	**(2.21E-04)**	***	-2.725E-03	(2.19E-04)	***
AIC	4587.6			4580.7			4613.0		
Standard errors in parentheses. Significance levels ***/**/*: 1/5/10%. a) When TertDegree is excluded, but Employmt still included, the VIF for Employmt is larger than 10.									

Table 3 and 4).

Hence, a detailed discussion is necessary in the case of the employment variables. Let us begin with total employment (*employmt*) in the considered regions. If this variable is included, we either obtain a significant positive relationship for the establishment and continuation of collaboration or no significant result. If we only consider in each case the model that leads to the smallest AIC-value (denoted by bold values in Tables 3 and 4), the total employment is always significantly positively related to the collaboration activity. This holds for the telecommunication industry (establishment and continuation of collaboration) and the establishment of new links in the medical instruments industry. Hence, we find some evidence for the fact that total employment matters. However, this seems not to be a general feature. No evidence for such a relationship is found for the establishment of new links in the pharmaceuticals industry and for the continuation of links in the medical instruments industry.

As claimed in Hypothesis 3a, the amount of qualified labor seems to be more important. Especially employees with tertiary degree are included always in the model with the lowest AIC-value and in each of these cases a significant relationship is found. However, this significant relationship between employees with tertiary degree and the establishment or continuation of collaboration is always negative. This means that a higher amount of employees with tertiary degree in a region comes with a lower probability of link generation and a higher probability of link dissolving. Hence, regions with many employees with tertiary degree loose innovation collaboration with time.

This result contradicts our expectation formulated in Hypothesis 3. Table 2 helps to qualify this result. Table 2 compares regions with links and those without links. It shows that regions with links contain a much larger number of employees with tertiary degree than those without links. Hence, a high number of employees with tertiary degree is, indeed, related to a high number of collaborations. However, we study the dynamics of collaborations here and we find that this difference is clearly decreasing. This means that regions with a lower number of employees with tertiary degree catch up. The importance of tertiary degrees in patent collaboration seems to be decreasing.

The results for R&D employees are similar to those for total employment: Sometimes a significant positive relationship is found; sometimes no significant results are obtained; and only in one case a significant negative relationship is found. Often R&D employees are not included in the model that leads to the lowest AIC-value. Strong differences are found between the three studied industries:

- In the case of the pharmaceutical industry, the R&D employees are included both times (establishment and continuation of collaboration) in the best model (lowest AIC) and have both times a significant positive coefficient. Hence, R&D employees are very important for collaborations in the pharmaceutical industry. The coefficient is larger than that for employees with tertiary degree, so that we can state that Hypothesis 3a is confirmed for the pharmaceutical industry.
- In the case of the telecommunication industry, the R&D employees show always a significant positive relationship with collaboration if they are included in the regression. However, they are never included in the best fitting model (lowest AIC).

Hence, Hypothesis 3 is confirmed in this case: higher R&D employment is connected to a higher probability of link generation and link continuation. Hypothesis 3a is not confirmed for the telecommunication: Other employment variables are more important.

- In the case of the medical instruments industry we obtain a very mixed picture. For the continuation of collaboration we find a significantly positive relationship for one model, but also an insignificant result for another model; and in the best model (lowest AIC) the R&D employment is not included. We might conclude that there is a slightly positive relation between link continuation and R&D employment. For the establishment of collaboration we find the opposite: there is a significant negative relationship for one model and in the best model (lowest AIC) no significant result is found. This rather means that R&D employment is negatively related to link generation, if it is related at all. Hence, neither Hypothesis 3 nor Hypothesis 3a is confirmed for the medical instruments industry.

To sum up, total employment plays some positive role for the dynamics of collaboration, while employees with tertiary degree are related to a decrease in the number of collaborations, meaning that there role in collaborations seems to decrease. R&D employment plays a strong role in pharmaceuticals, a limited role in telecommunication and no really confirmable role in medical instruments.

Comparison of link creation and link continuation

While the coefficients for distance are largely the same for link creation as for link continuation, the coefficients for the overall number of patents, the population, and R&D employment are larger for link creation than for link continuation. This holds for all industries except the population in the case of telecommunication. Hence, these variables play a stronger role for link creation than for link continuation. We can conclude that people matter more for the generation of links; while distance is as important for the establishment of a collaboration as for the continuation of an existing collaboration.

5 Conclusion

In this paper we studied the relationship of a number of regional characteristics and the probability of collaboration between regions. The main findings concern the dynamics of collaboration links and the relevance of different kinds of employees.

While for most variables, such as distance, population, total patent activity and total employment, we find the same relationship with the existing links as with the link dynamics; there is one variable, employees with tertiary degree, for which the results point in different directions. Hence, for most regional characteristics the link dynamics support the already existing difference between regions, so that this difference in collaboration activity is sustained. However, in the case of employees with tertiary degree and, to some extent, also in the case of R&D employees the regional differences that are related to these characteristics are disappearing. Thus, be taking a dynamic perspective we gain insights about the change in the relevance of different regional characteristics.

In addition, we found that especially in the case of R&D employees industries differ strongly in the relevance of this variable for inter-regional collaboration. We find a strong role in the pharmaceutical industry, a weak role in the telecommunication industry and no significant role in the medical instruments industry.

In order to investigate the mechanisms of the collaboration dynamics in more detail, it is necessary to analyze the firm and the inventor level of cooperation, too. However, the analysis in the paper at hand is an interesting starting point to see that largely the same variables account for the existence of inter-regional links and for the continuation of them. It is a classical Matthew effect.

6 References

Arndt, Olaf and Sternberg, Rolf, 2000. Do Manufacturing Firms Profit from Intraregional Innovation Linkages? An Empirical Based Answer. European Planning Studies, 8(4), 465 - 485.

Bathelt, Harald, Malmberg, Anders and Maskell, Peter, 2004. Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. Progress in Human Geography, 28(1), 31-56.

Boschma, Ron, 2005. Proximity and Innovation: A Critical Assessment. Regional Studies: The Journal of the Regional Studies Association, 39(1), 61-74.

Breschi, Stefano and Lissoni, Francesco, 2005, Knowledge Networks from Patent Data, Handbook of Quantitative Science and Technology Research, pp. 613-643.

Broekel, Tom and Meder, Andreas, 2008, The bright and dark side of cooperation for regional innovation, Papers in Evolutionary Economic Geography 08.11.
Broekel, Tom and Meder, Andreas, 2009, The bright and dark side of cooperation for regional innovation, Papers in Evolutionary Economic Geography 08.11.
Cefis, Elena and Orsenigo, Luigi, 2001. The persistence of innovative activities: A cross-countries and cross-sectors comparative analysis. Research Policy, 30(7), 1139-1158.
Christ, Julian P., 2010, The geography and co-location of European technology-specific co-inventorship networks, FZID Discussion Paper 14-2010.
Cohen, Wesley M., Nelson, Richard R. and Walsh, John, 2002. Links and Impacts: The Influence of Public Research on Industry R&D. Management Science, 48(1), 1-23.
D'Este, P. and Patel, P., 2007. University-industry linkages in the UK: What are the factors underlying the variety of interactions with industry? Research Policy, 36(9), 1295-1313.
Dahl, Michael S. and Sorenson, Olav, 2009. The embedded entrepreneur. European Management Review, 6(3), 172-181.
Dettmann, Anja and Brenner, Thomas, 2010, Proximity is a Social Process: A conceptual Modification, DRUID Winter Conference 2010, Aalborg.
Ernst, Dieter and Kim, Linsu, 2002. Global production networks, knowledge diffusion, and local capability formation. Research Policy, 31(8-9), 1417-1429.
EU INTERREG, 2011, INTERREG IVC Programme.
Frenken, Koen, Hoekman, Jarno, Kok, Suzanne, Ponds, Roderik, van Oort, Frank et al., 2009, Death of Distance in Science? A Gravity Approach to Research Collaboration. In: Andreas Pyka and Andrea Scharnhorst (Eds.), Innovation Networks - New Approaches in Modelling and Analyzing. Springer, pp. 43-57.
Hoekman, Jarno, Frenken, Koen and Tijssen, Robert J. W., 2010. Research collaboration at a distance: Changing spatial patterns of scientific collaboration within Europe. Research Policy, 39(5), 662-673.
Hoekman, Jarno, Frenken, Koen and van Oort, Frank, 2009. The geography of collaborative knowledge production in Europe. The Annals of Regional Science, 43(3), 721-738.
Kim, Jinyoung, Lee, Sangjoon John and Marschke, Gerald, 2005, The Influence of University Research on Industrial Innovation, NBER Working Paper.
Lee, Yong S., 2000. The Sustainability of University-Industry Research Collaboration: An Empirical Assessment. The Journal of Technology Transfer, 25(2), 111-133.
Mansfield, Edwin, 1986. Patents and Innovation: An Empirical Study. Management Science, 32(2), 173-181.
Martin, Ron and Sunley, Peter, 2006. Path dependence and regional economic evolution. Journal of Economic Geography, 6(4), 395-437.
Olson, Gary M. and Olson, Judith S., 2000. Distance Matters. Human-Computer Interaction, 15(2), 139-178.
Orsenigo, Luigi, Pammolli, Fabio, Riccaboni, Massimo, Bonaccorsi, Andrea and Turchetti, Giuseppe, 1997. The Evolution of Knowledge and the Dynamics of an Industry Network. Journal of Management and Governance, 1(2), 147-175.
Ponds, Roderik, Oort, Frank van and Frenken, Koen, 2007. The geographical and institutional proximity of research collaboration. Papers in Regional Science, 86(3), 423-443.
Sternberg, Rolf, 2007. Entrepreneurship, Proximity, and Regional Innovation Systems. Tijdschrift voor Economische en Sociale Geografie, 98, 652-666.
Ter Wal, Anne L. J., 2010, The Spatial Dynamics of the Inventor Network in German Biotechnology: Geographical Proximity Versus Triadic Closure, Best Paper Proceedings of the 2010 Academy of Management Meeting.
Ter Wal, Anne L. J. and Boschma, Ron A., 2009. Co-evolution of Firms, Industries and Networks in Space. Regional Studies, forthcoming.

Toedtling, Franz, Grillitsch, Markus and Hoeglinger, Christoph, 2010, Knowledge Sourcing and Innovation in Austrian ICT companies - Does Geography matter?, mimeo.

van Ham, M., Mulder, C. H. and Hooimeijer, P., 2001. Spatial flexibility in job mobility: macrolevel opportunities and microlevel restrictions. Environment and Planning A, 33(5), 921-940.

von Ledebur, Sidonia, Buenstorf, Guido and Hummel, Martin, 2009, University patenting in Germany before and after 2002: what role did the professors' privilege play?, Jena Economic Research Paper 2009-068.

von Proff, Sidonia and Dettmann, Anja, 2010, Inventor collaboration over distance – a comparison of academic and corporate patents, Marburg Working Papers in Innovation and Space #01.10.

Walker, Gordon, Kogut, Bruce and Shan, Weijian, 1997. Social Capital, Structural Holes and the Formation of an Industry Network. Organization Science, 8(2), 109-125.