
# The organizational and regional determinants of interregional collaborations – Academic inventors as bridging agents

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Friedrich Dornbusch, Sidonina von Proff and Thomas Brenner

Philipps Universität Marburg

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Prof. Dr. Dr. Thomas Brenner
Deutschhausstraße 10
35032 Marburg
E-Mail: thomas.brenner@staff.uni-marburg.de

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# The organizational and regional determinants of inter-regional collaborations – Academic inventors as bridging agents

**Friedrich Dornbusch**[1]

Fraunhofer Institute for Systems and Innovation Research ISI, Competence Center Policy and Regions

**Sidonia von Proff, Thomas Brenner**

both from Economic Geography and Location Research, Philipps-University, Marburg.

**Abstract:**

Collaboration over distance is difficult to maintain in innovation projects which require a great deal of regional collaboration. However, patent documents reveal that a number of inventor teams are able to overcome long distances. Earlier literature started to investigate factors, which increase the probability of long-distance innovation co-operation. The paper at hand is restricted to patents with academic participation, but takes a close look at two types of factors in the environment of the inventors: (1) the characteristics of the university that employs the academic inventor(s), and (2) the influence of the regional environment. Research on the impact of these factors is still underdeveloped in the literature. By considering only patents with at least one academic inventor we have a relatively homogeneous subset of patents and can concentrate on the external impacts. We find that a similar research area structure, a high absorptive capacity as well as a high start-up rate foster intra-regional collaboration. More TTO staff and a larger university lead to more long-distance collaboration while the industry orientation of the university does not exert an influence on the distance between inventors.

**Keywords:** patents, research collaboration, academic patents, collaboration over distance, Germany.

**JEL Classifications:** O31, R12, L14

1 Corresponding Author: Friedrich Dornbusch, Frauenhofer Institute for Systems and Innovation Research ISI, Competence Center Policy and Regions. E-Mail: friedrich.dornbusch@isi.fraunhofer.de.

# 1 Introduction

Many studies have proven that technology and knowledge spill over locally from universities to firms and entrepreneurs (e.g. Audretsch/Feldman 1996; Jaffe et al. 1993). However, the production of scientific knowledge is one of the most globalized human activities and local interaction is not a university's primary business. Bearing this ambiguity in mind, it remains unclear which circumstances support localized collaborative knowledge production, which circumstances foster rather non-local interactions, and in how far policy should focus on trying to incorporate universities as central agents into regional innovation systems, e.g. by recasting research funding as regional allocations (see also Power/Malmberg 2008). In order to contribute to this discussion this paper reverts to a unique dataset of academic patents that are either filed by small firms or by large corporations. The dataset is further enriched by secondary data to model the influences of regional environments and organizational characteristics of universities.

The literature on collaborative relationships can be distinguished into two different strands regarding space. The first one investigates the space in which collaborative relationships are embedded (outside dimension). That is, the characteristics of space have an impact on the relationships of the actors. The second strand (inside dimension) in contrast describes , the idea of actors and their relationships shaping space and not vice versa (e.g. Aydalot 1986; Granovetter 1983; Granovetter 1985). In these concepts, the roles of space have changed from an active role as a trigger of or a barrier to collaboration activities to the role of a supporter or substitute in case other features in a relationship fail or remain underdeveloped. Both strands of research can be viewed jointly: relationships between actors are influenced by space and have themselves an impact on it.

Innovation collaboration over distance is especially difficult to maintain in comparison with other forms of collaboration or economic relationships. Due to the complexity of the process, close interaction between team members is necessary which is hampered by distance. Nevertheless, we can see in patent documents, that inventor teams are often dispersed in space, thanks to other forms of proximity. Several factors have an influence on the ability of inventor teams to overcome spatial distance, e.g. social proximity resulting from temporary collocation (Torre 2008) or the institutional background of the inventors (Von Proff, Dettmann 2012). The paper by Von Proff and Dettmann (2012) has investigated the differences in collaboration over distance between patents with academic inventors and those with researchers from companies.

Hence, it is well studied in the literature that university research has an impact mainly within the region in which the university is located or on firms that are located nearby (e.g. Acs et al., 1992, 2002; Anselin et al., 1997; Autant-Bernard, 2001; Blind and Grupp, 1999, D'Este and Iammarino, 2010; Jaffe, 1989 among others). Furthermore, there is good evidence for the spatial proximity of research collaborations independent of whether universities are involved or not (see, e.g., Autant-Bernard 2001, Broekel and Boschma 2011, Cassi and Plunket 2012, Hoekman, Frenken, van Oort 2009, Maggioni and Uberti 2009, Scherngell and Barber 2011, Scherngell and Lata 2012). The literature also provides many theoretical arguments on why local interaction is more likely (see, e.g. Asheim et al. 2011, Breschi and Lissoni 2009 and Karlsson and Manduchi 2001). However, it has so far rarely been studied what characteristics of the involved actors influence spatial range of interaction. A comparison of actors from academia and from the private sector is all that has been done so far in this direction. We add to this by studying industry-university collaborations that lead to patents. The main questions that we intend to answer are: (1) How do the characteristics of universities influence the distance to the collaboration partners from industry, (2) how do the characteristics of universities influence the likelihood to collaborate within the region, and (3) how do regional characteristics influence the likelihood to collaborate within the region?

Hence, the study at hand is restricted to patents with academic and private business participation and takes a close look at two types of factors in the environment of the inventors: (1) the characteristics of the university that employs the academic inventor(s), and (2) the influence of the regional environment of this university. By including only patents with at least one academic inventor we have a relatively homogeneous subset of patents and are able concentrate on external impacts.

There is a strong tendency to collaborate locally (Ponds et al. 2007; Von Proff, Dettmann 2012). In a first step, we analyze which factors lead to intra-regional vs. inter-regional collaboration. In a second step, we investigate which factors influence the propensity to overcome shorter or longer distances. Special attention will be paid to sector-specific differences as underlying modes of interaction are likely to depend on the institutional backgrounds in industries and scientific disciplines (Perkmann/Walsh 2007). In order to account for this, the analyses will be conducted not only for the whole sample, but also separately for the different technological areas, namely mechanical engineering, ICT, measurement, life sciences, chemicals and electrical engineering.

In the next section we will theorize how the organizational and the regional environment may influence the collaboration behavior in the space of academic inventors. The third section then presents our data and method for testing our hypotheses. A discussion of the results can be found in section four. Section five concludes this paper.

# 2 Background: spatial collaboration behavior

Knowledge transmission in collaborative activities requires cognitive, geographical, cultural and social proximity among agents (Balconi et al. 2004). While technological and academic knowledge tends to circulate in global networks, traditional face-to-face contacts remain an important condition for the generation and exchange of non-standardized and complex knowledge (van Oort et al. 2008). Geographical proximity acts as a facilitating dimension in helping to establish and/or substitute for other dimensions of proximity (Boschma 2005). One can argue here that spatial proximity favors linkages between academia and firms particularly when interactions include highly advanced technical and scientific knowledge. The more complex, ambitious and innovative the research the more important the development of other features becomes to bridge cognitive distance. In this context, face-to-face contacts enable the exchange of non-verbal information and serve as social tools (Asheim et al. 2007; Torre 2008; Zeller 2002). Even more importantly, they increase the likelihood for intense and intact relationships between team members, which are strong drivers for successful collaborations (Agrawal et al. 2006; Von Proff, Dettmann 2012).

Summing up, the literature clearly argues for a higher proportion of local university-industry interactions. However, it is also reasonable to assume that the emergence of regional or inter-regional collaborations is driven by an interplay between the type of research conducted at the university and local characteristics like the availability of potential collaboration partners as well as local demand for the knowledge provided by the university (next to inventor-specific characteristics).

## 2.1 University characteristics and their influence on academic inventors

***Scientific excellence in basic research***

Regarding the influence of scientific excellence and basic research orientation, one can conjecture two opposing mechanisms. Firstly, a higher publication output as well as scientific regard of the research that is conducted within a university is likely to make research teams less sensitive to distance. Larger distances between the collaboration partners might be more frequent, due to the signaling effect of higher publication output and higher quality of research, which might be recognized by industrial researchers as being at least partially embedded in academic and epistemic communities (Fontana et al. 2006).

***H1a:*** *The larger the scientific output and the larger the scientific quality of research conducted at a university, the <u>larger</u> the likelihood that its researcher collaborate extra-regionally and over distances with corporate researchers.*

Secondly, more complex and higher quality basic research raises the need for face-to-face contacts in collaborations between academics and firm researchers and is likely to enhance the need for spatial proximity. A high scientific regard is an indicator for research on the research frontier, which implies that more intensive interaction is necessary to transfer the involved knowledge. Thus, collaborations with high quality universities in terms of higher publication output as well as scientific regard might be more likely to take place in geographical proximity to the university. This is most likely the case in sectors with a strong science-base.

***H1b:*** *The larger the scientific output and the larger the scientific quality of research conducted at a university, the <u>lower</u> the likelihood that its researchers collaborate extra-regionally and over distances with corporate researchers.*

***Orientation towards applied research***

The industry orientation of universities differs. Some are very active in contract research, consulting, and patenting (whether in collaboration with firms or not), while others focus more on purely academic research. A high industry orientation should be visible in a large number of patents. Drawing on the aforementioned arguments one might again argue that it is possible that two different patterns of spatial collaboration emerge. Firstly, regarding distance, a strong industry orientation could lead to a better overview of collaboration possibilities and thus lead to lower distance sensitivity. This is most likely the case in sectors in which research services dominate the collaboration patterns between universities and firms.

***H2a:*** *The larger the patented output from research conducted at a university, the larger the likelihood that their researchers collaborate extra-regionally and over distances with corporate researchers.*

Secondly, we know from previous research that long-lasting relationships with high relational involvement constitute the main basis for multi-modal ways of knowledge exchange (Perkmann/Walsh 2007; Perkmann/Walsh 2009). Mutual cognitive understanding and social proximity might become crucial and contribute to the formation of "communities of practice" in which learning processes among individuals are likely to take place. They are triggered and enabled by geographical proximity, which means that social networks and searching for knowledge tends to be spatially biased (Brökel/Binder 2007). Here, engineers and researchers in manufacturing firms often act as focal actors around whom these communities develop (Breschi/Lissoni 2009; Ostergaard 2009). In doing so, a higher number of patents with academic participation might be the result of highly innovative localized networks with high relational and collaborative involvement.

***H2b:*** *The larger the patented output from research conducted at a university, the lower the likelihood that their researchers collaborate extra-regionally with corporate researchers.*

***Support infrastructure***

Next to the peers, the transfer infrastructure has an impact on the engagement in transfer activities. The more supportive a technology transfer office (TTO) of a university is, the more patents are filed at this university (Malmberg/Power 2005; Owen-Smith/Powell 2001; Sellenthin 2009). We expect that not only the overall patent propensity increases with the available TTO personnel but also the propensity to collaborate over distances. TTOs help to formulate collaboration contracts in such a way that the possibility of problems arising from lower face-to-face meeting frequency is reduced. In addition, larger TTOs have more industry contacts and thus the probability of finding a distant collaboration partner among these contacts is increased. Thus, once collaborations between universities and firm researchers extend over regional boarders, better equipped TTOs help inventor teams in bridging distances.

***H3:*** *The better equipped the universities' TTO, the higher the support intensity and the* *higher* *the likelihood that their researchers collaborate extra-regionally and over distances with corporate researchers.*

Additionally, there are many policy measures which foster regional/local collaboration. This may overlay the effect discussed above.

### 2.2 The regional environment and how it shapes local collaboration possibilities

In simplified terms, clusters are economic concentrations in space with connections between the collocated firms. That means, two conditions have to be met in order to have a flourishing local/regional economy: firstly, there must be a critical mass of economic activity; and secondly, there must be interaction between the actors. If a university is located in an economically weak environment, it is a "cathedral in the desert" (Uyarra 2010) and has to search for distant collaboration partners. If there is some economic activity in the environment, but with a different specialization than the research focus of the university, again, local collaboration is almost impossible. These examples show that the regional environment influences collaboration possibilities of scientists working at universities. In the following paragraphs we will discuss the influence of the environmental economic conditions on the collaboration behavior of scientists at universities.

Firstly, we assume that a similar specialization between the universities' research and the local industries' innovation profile, namely the technological fit, is likely to significantly raise the likelihood that collaborations between academics and industrial researchers take place within the same region. Search processes of firms and individuals are often biased towards their local environment as well as well-known and familiar technologies in that search processes take place along established trajectories created by past experiences, routines, and heuristics (Dosi 1982; Malerba/Orsenigo 1993). Consequently, a proportionally higher share of information, experiences and knowledge are gathered from local sources and social networks and have a higher propensity to be built up locally. Institutional factors like habits, routines, practices and laws often shape territory and industry-specific structures in which individuals are embedded (Asheim/Coenen 2005), creating institutional proximity as a normative dimension that regulates interactions between actors in shared local environments (Boschma 2005; Mattes 2012). This might be particularly the case for collaborations between university and academia, because cultural differences between academia and industry require inter-organizational trust and long-term systems of informal reciprocity which are considered as important parts of university-industry networks (Bruneel et al. 2010).

Hence, local interaction has various advantages and should be more frequent. The basic assumption here is that the various kinds of proximity, as described above, are more likely to develop if both actors deal with similar issues. Enhanced opportunities for social interaction in close proximity, increases the probability of establishing social networks (Singh 2005; Sorenson et al. 2006).

***H4:*** *The higher the technological fit between the university and its surrounding region, the higher the likelihood that collaboration between academics and corporate researchers takes place within the region.*

Secondly, the innovative capability of a region enhances the probability for collaboration between academics and corporate researchers. In general, interaction patterns and innovation impacts of universities are not primarily directed towards their home region. It is rather likely that the opportunities for local interaction and collaboration increase in industrial agglomerations and with the nearby presence of potential collaboration partners. Especially the local firms' knowledge base and regional absorptive capacity are likely to determine if collaborations between academics and firms researchers take place within or outside the region (Cohen/Levinthal 1990; Hewitt-Dundas 2013). Similarly, the regional start-up rate enhances local collaboration. Entrepreneurs usually establish a firm in the region where they are already living (Helm/Mauroner 2007). There, they know the infrastructure and have a social network. Since they do not have large resources for overcoming distance, their collaboration behavior is rather regionally concentrated. As a consequence, patent active academics and start-ups can be expected to collaborate mainly locally.

Thus, if a university is located in a very dynamic and innovative research milieu, this is likely to increase the likelihood that it engages in intra-regional collaboration.

***H5:*** *The higher the absorptive capacity and the start-up rate of the university's region, the higher the likelihood that collaboration between academics and corporate researchers takes place within the region.*

### 2.3 Small and large firms as collaboration partners

The resources of large and small firms for collaboration differ and from former studies (Arndt and Sternberg 2000) we know that their collaboration behavior in space may differ as well. The institutional and organizational proximity created in subsidiaries and with contractually bound partners enables firms to access specific knowledge and personnel, making spatial proximity between partners less important. Thus, large firms are able to maintain inter-regional partnerships and look for horizontal co-operation with companies and research institutions outside their region, while they build vertical networks to smaller businesses within the region. Due to resource constraints, small businesses are more likely to interact within existing clusters (Torre 2008). They miss the resource-based backup of colleagues and are likely to be more oriented towards their local environment if this provides sufficient opportunities for local interactions.

***H6:*** *Large firms are more likely to cross regional borders than small firms.*

# 3 Data and Method

### 3.1 Dataset

In order to identify the patents co-invented by university employees, but filed by SMEs or MNEs as part of contractual agreements, this paper draws on a recently developed approach to identify academic patenting activities. The basic principle is an algorithm that matches author names from scientific publications with inventor names derived from patent filings. The patent data were extracted from the "EPO Worldwide Patent Statistical Database" (PATSTAT), which provides information about published patents collected from 81 patent authorities worldwide. All patent filings at the DPMA (Deutsches Patent- und Markenamt) were included. For the publications Scopus, provided by Elsevier, was chosen. The dataset was on both sides restricted to authors from German organizations and to inventors residing in Germany, in order to account for the inventor principle (Hinze/Schmoch 2004). Two steps are employed during the matching. The first includes the construction of appropriate databases including the cleaning, harmonizing and complementing of missing data. The second involves the matching of names of inventors and authors complemented by further filtering criteria[1] to increase the matching accuracy. When dealing with a trade-off between high recall and precision priority is put on precision. Thus, the rate of incorrect assignments was kept as low as possible. Estimates show that the assigned patents are correctly identified in more than 93 percent of cases. As a consequence the dataset contains only approximately 60 percent of all academic patents – meaning patents that the algorithm should identify. Hence, we miss quite a number of academic patents, but those identified are characterized by high precision allowing representative analyses of structures in academic patenting (for details see Dornbusch et al. 2013).

The analyses refer to academic patents filed at the DPMA with priority years between 2005 and 2009 including only those patents with a firm as the applicant. The differentiation of the type of filing entity was made by the name and legal status of an applicant (e.g. Inc., AG, GmbH, S.R.L, etc.) as well as the difference between the name of the applicant and the name of the inventor. Applicants with more than three patent filings in a three- year time window and more than 500 employees were classified as MNEs, others as SMEs, corresponding to the German SME definition (Günterberg/Kayser 2004). Data on employees were taken from the Hoppenstedt database and complemented with information from internet searches where necessary.

Since one aim of this study is to consider different knowledge dynamics in different sectors it was important to coherently assign scientific articles to patent technology codes. The WIPO34 technology fields (Schmoch 2008) were aggregated into seven technology groups for which all existing Web of Science journal codes could be assigned without any overlap. Scientists and patent attorneys active in research on both patent analysis as well as bibliometric indicators at the Fraunhofer ISI validated the classification.[2] In the end, seven technological sectors and associated scientific disciplines were obtained: electrical engineering, IT and ICT, measurement and controls, life sciences, chemicals, mechanical

1 These criteria were: 1. Location of the authors' employer and the inventors' residence by postal codes. 2. 2-years-publication period to each priority year of patent filings, considering a time-lag of one year that is needed for the review of scientific publications. 3. Assignment of the scientific subject (of the publishing journal) to the technological area of the patent.

2 We are particularly grateful to Professor Ulrich Schmoch. Without his expert knowledge and helpful advice these analyses would not have been possible.

engineering, environmental sciences. Due to low numbers we had to exclude environmental sciences in the regressions.[3]

Additional data regarding regional and university characteristics are gathered from Eurostat and from the EUMIDA dataset, which was established within the European Union project "*Feasibility Study for Creating a European University Data Collection*".[4]

## 3.2 Variables

### Dependent variables (dV)

In order to test our hypotheses we employ two different dependent variables:

- CrossReg: In a first step, we aim to explain why university-industry collaborations are conducted within or outside of the region in which the university is located. Thus, our dV in the first set of regressions is a binary variable, coded “0” for intra-regional and coded “1” for inter-regional collaborations.
- TwoRegDist: In a second step, we aim to analyze which university characteristics influence the distance that is bridged between two regions, once regional boarders have been crossed. Thus, the distance in kilometres between the centres of two regions builds the explained part in our second set of regressions. The data are derived from a matrix, which entails all distances between European NUTS Regions. The matrix is part of the REGPAT-database (provided by the OECD) which is in turn based on PATSTAT.

### Independent variables

<u>Research team background:</u>

- MNE: Following the definition  above, we differentiate between SMEs and MNEs as collaboration partners of universities. This dummy indicates MNEs.

[3] Note: For consumer goods no publications were assigned. Further note: the fields are not exclusive. One patent can be assigned to more than one technology class.

[4] http://datahub.io/dataset/eumida

University characteristics

- Scientific Regard (SR): On the basis of the journal-specific expected citation, the 5-year Scientific Regard was calculated. It indicates whether a publication of an entity is cited above or below average compared to the other documents in the same journal.[5] A positive SR shows above-average citation rates, negative values indicate below-average citation rates and 0 means equivalent to the average.
- Publications per scientists (PUB): This variable represents the average number of publications to which a university contributed from 2005 till 2009 in relation to the number of scientists employed at the university.
- Patents per scientists (PAT): This variable represents the average number of patents to which a university contributed from 2005 till 2009 in relation to the number of scientists employed in patent relevant disciplines.
- Technology transfer staff per patent relevant scientist (TTO): To proxy universities' resources in technology transfer we consulted the homepages of the universities' TTOs, based on a list provided by Kratzer et al. (2013). In doing so, we counted all persons that are listed as being responsible for entrepreneurship, patents and/or technology transfer related tasks at the focal university. This was done in October 2010.

Regional characteristics (NUTS 2-level):

- Similarity (SIM): The technological fit between a university's scientific and its local environment's profile is calculated as the cosine similarity between the specialization of a university's scientific and a region's technological specialization.

  As a measure of specialization we employ the Revealed Symmetric Comparative Advantage (RSCA) as defined by (Laursen 1998). Where the Revealed Comparative Advantage (RCA)

$$RCA_{ij} = \frac{Xij / \sum_{i} Xij}{\sum_{j} Xij / \sum_{i} \sum_{j} Xij} \qquad \text{(I)}$$

  is standardized and made symmetric

[5] The calculation of the SR is represented in the following formula: $SR_k = 100 \tanh \ln (OBS_k/EXP_k)$; $OBS_k$ refers to the actual observed citation frequency of publications of an entity k. $EXP_k$ is the expected citation rate resulting from the average citation frequency of the journals where the authors of this entity published their papers.

$$RSCA = (RCA - 1)/(RCA + 1) \qquad \text{(II)}$$

The RSCA is calculated for both, the scientific output (publications[6]) and economic innovation activity (patents) and is used to calculate the cosine similarity which measures the cosine of the angle between two vectors of an inner product space:

$$similarity = \cos(\theta) = \frac{A \bullet B}{\| A \| \| B \|} = \frac{\sum_{i=1}^{n} A_i \times B_i}{\sqrt{\sum_{i=1}^{n} (A_i)^2} \times \sqrt{\sum_{i=1}^{n} (B_i)^2}} \qquad \text{(III)}$$

The vectors A and B are defined by the specialization of A = each university in a scientific field and B the adhering NUTS2 region's specialization in the belonging technology[7]. Thus, a value between 0 and 1 indicates the similarity between a university's scientific and local environment's technological activities, where 1 means high and 0 no similarity.

- Innovative capability (InnoCap): As a proxy for innovative capability we use patent activity per capita in a region. Of course, patents are neither a necessary nor a sufficient condition for innovation. But patents can be seen as the major output indicator for R&D processes and thus are often taken as an indicator for innovation (Griliches 1990).
- Absorptive capacity (AbsCap): The regional absorptive capacity is proxied by the number of persons employed in R&D in relation to the number of manufacturing firms in a region.[8]
- Start-up (STUP): Start-up activity per capita.

<u>Controls:</u>

The control variables include: University size as measured by all scientists employed by the university (STAFF). Furthermore, for each patent a citation count to non-patent literature (NPL) is included as a proxy for a patent's closeness to science (Deng et al. 1999). Patent backward citations (BW) are included to control for the technological breadth and originality of a patent. Furthermore, we add the family size of a patent application (FAM), i.e. the number of distinct patent offices a patent has been filed at. It indicates the breadth of

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6 We used a classification of all publishing German institutions in WoS which was implemented by the "Institut für Wissenschafts- und Technikforschung (IWT) - University of Bielefeld". We acknowledge and are thankful for the valuable work which has been supported and funded by the German Ministry for Education and Research under the research project "Kompetenzzentrum Bibliometrie" (Förderkennzeichen 01PQ08004D).

7 Scientific fields and technologies are assigned to each other as described in section 3.1.

8 Disaggregated numbers by region are not available for R&D employees. But, following EUROSTAT in 2005 and 2007 ca. 87% corporate R&D expenditures in Germany come from manufacturing firms.

international market coverage, which is also associated with rather high patenting costs (Harhoff et al. 2003). By including the size of a region, proxied by its population (POP), as well as GDP per capita (GDP) we control for wealth and agglomeration effects in a region.

An overview of the used variables is provided in the summary statistics (Table 1).

Table 1: Summary statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| CrossReg | 2863 | 0.492 | 0.500 | 0 | 1 |
| TwoRegDist | 2863 | 96.876 | 140.406 | 0 | 720 |
| MNE | 2863 | 0.802 | 0.399 | 0 | 1 |
| TTO | 2863 | 0.006 | 0.006 | 0.000 | 0.163 |
| PAT | 2863 | 0.02792 | 0.01397 | 0.00114 | 0.04714 |
| SR | 2863 | 10.978 | 8.882 | -24.701 | 68.081 |
| PUB | 2863 | 0.836 | 0.298 | 0.159 | 5.249 |
| STAFF[1] | 2863 | 3.038 | 1.289 | 0.194 | 5.349 |
| AbsCap | 2863 | 14.709 | 9.088 | 1.837 | 27.375 |
| SIM | 2863 | 0.955 | 0.052 | 0.613 | 0.995 |
| STUP | 2863 | 0.00088 | 0.0004 | 0.00003 | 0.00191 |
| InnoCap | 2863 | 0.00093 | 0.0004 | 0.00013 | 0.00171 |
| GDP[2] | 2863 | 332.311 | 65.378 | 202.600 | 471.400 |
| POP[3] | 2863 | 305.018 | 130.534 | 66.312 | 521.619 |
| FAM | 2863 | 3.234 | 2.742 | 1 | 25 |
| INV | 2863 | 3.542 | 1.643 | 2 | 17 |
| BW | 2863 | 3.849 | 5.781 | 0 | 92 |
| NPL | 2863 | 1.392 | 4.855 | 0 | 99 |
| Year | 2863 | 2006.981 | 1.397 | 2005 | 2009 |
| El. Engineering | 2863 | 0.177 | 0.382 | 0 | 1 |
| ICT | 2863 | 0.200 | 0.400 | 0 | 1 |
| Measurement | 2863 | 0.216 | 0.411 | 0 | 1 |
| Life Sciences | 2863 | 0.291 | 0.454 | 0 | 1 |
| Chemicals | 2863 | 0.183 | 0.387 | 0 | 1 |
| Mech. Engineering | 2863 | 0.238 | 0.426 | 0 | 1 |
| Env. Sciences | 2863 | 0.020 | 0.141 | 0 | 1 |
| Cons. Goods | 2863 | 0.056 | 0.230 | 0 | 1 |

[1] per 100; [2] per 1.000; [3] per 10.000

### 3.3 Econometric modeling

In order to test our hypotheses we set up two formal models to estimate the cross-regional activities of an inventor team. Firstly, we regress whether the patent emerged from an intra- or an inter-regional collaboration between academic and firm inventors. The model can (in a simplified form) be described as follows:

$$P(\mathrm{CrossReg_i} = 1) = f(\alpha_{1i}\mathrm{MNE_i} + \alpha_{2i}\mathrm{TTO_i} + \alpha_{3i}\mathrm{PAT_i} + \alpha_{4i}\mathrm{SR_i} + \alpha_{5i}\mathrm{PUB_i} + \alpha_{6i}\mathrm{STAFF_i} + \alpha_{7i}\mathrm{SIM_i} + \alpha_{8i}\mathrm{InnoCap_i} + \alpha_{9i}\mathrm{AbsCap_i} + \alpha_{10i}\mathrm{STUP_i} + x_i^{'}\beta_i) \quad (1)$$

with $i = 1, \ldots n$ patents

where $CrossReg_i$ is a dummy that denotes whether the collaboration of patent i takes place within the region or not (0/1), and $x_i^{'}$ represents a set of control variables that might affect the spatial patterns of a collaboration, namely the GDP per capita in the region, the population of a region, the number of inventors listed on a patent application, the family size of a patent application, i.e. the number of different patent offices a patent has been filed at, the number of non-patent literature citations, the number of backward citations and a vector of field- as well as period-specific effects. The model isolates the effect of the firm's background ($\alpha_{1i}$), the university's characteristics ($\alpha_{2i}$-$\alpha_{6i}$) and the characteristics of the university's home region ($\alpha_{7i}$-$\alpha_{10i}$). Since the dependent variable is binary we use a logit model to analyze whether research interaction takes place within or across regional borders.

Our second model can (in a simplified form) be described as follows:

$$\mathrm{TwoRegDist_i} = \alpha_{1i}\mathrm{MNE_i} + \alpha_{2i}\mathrm{TT_i} + \alpha_{3i}\mathrm{PAT_i} + \alpha_{4i}\mathrm{SR_i} + \alpha_{5i}\mathrm{PUB_i} + \alpha_{6i}\mathrm{STAFF_i} + x_i^{'}\beta_i + \varepsilon_i \quad (2)$$

with $i = 1, \ldots n$ patents

where $TwoRegDist_i$ denotes the distance between the center of the regions that are connected by the collaboration in patent i. The model includes as independent variables all university characteristics as above. Our second analysis includes only those observations in which regional borders have been crossed. Thus, we exclude the home region characteristics. As for the firm partner's characteristics we are not able to reasonably differentiate effects of the geographical structures and effects of the economic and innovative activities characterizing the firm partner's region. Thus, we prefer to include the regional characteristics as controls in $x_i^{'}$, but are careful in interpreting them as explanatory effects. Zero-truncated negative binomial regression models are employed, since our dV firstly has no zeros and secondly constitutes count data for which simple OLS regressions might provide inefficient, inconsistent and biased estimates. A likelihood ratio test shows that we face overdispersion, which can be accounted for by a negative binomial regression model, which adds an overdispersion parameter alpha reflecting the unobserved heterogeneity between observations (Long/Freese 2001). Therefore, the negative binomial regression model is most suitable for our analysis. Controlling for non-constancy in the residual variance of the variables, we employ robust (heteroscedasticity-consistent) standard errors in all our models (White 1980).

The following section will present and discuss the results of both models in light of the current literature. In doing so, we firstly introduce the model on the intra- vs. inter-regional collaboration and secondly the model on the distance between two regions. For both, we firstly discuss the main model and afterwards separate models for each technological area. Going into detail for six technology fields allows us to get closer to the individual inventor's institutional environment and to obtain additional information on how collaboration patterns differ between heterogeneous technological areas.

# 4 Results and Discussion

### 4.1 Intra-regional vs. inter-regional collaboration

In this subsection we study the factors that determine whether a university-industry (U-I) collaboration crosses regional borders. In doing so, we aim at understanding which factors enable the function of universities as providers of locally anchored knowledge and which rather foster inter-regional linkages.

#### 4.1.1 Main model

Turning briefly to the controls in Table 2 we find significant effects for the GDP per capita in a region as well as for the overall size. Universities located in more wealthy regions are more likely to collaborate inter-regionally. At the same time the pure size, measured by the number of inhabitants, reduces this probability. The patent family size also reduces the likelihood for interregional collaboration. Patents with broader international market coverage are more likely to emerge from intra-regional collaborations. Unsurprisingly, more inventors on a patent lead to a higher propensity that a patented project has bridged the regional border.

Regarding the organizational characteristics and the working environment of academics the full model without sector-specific differentiations indicates that the university characteristics on average provide only a weak influence on the spatial collaboration behavior of academics. The opportunities and demand provided by the local environment seem to dominate the question of whether collaboration occurs intra- or inter-regionally. The only significant effect is a negative influence of scientific regard on the likelihood for research teams to cross the regional border. In line with H2b this provides at least weak evidence that collaborations between firms and scientifically more excellent and research-oriented universities are more likely to take place within a region. This further supports findings by Hewitt-Dundas (2013) that businesses will cooperate with a local university where the university displays research excellence. Furthermore, Laursen et al. (2011) find that closeness to a top-tier university increases the likelihood of collaboration in general. We do not find support for other hypotheses regarding the influence of university characteristics from the full model.

Turning to the regional characteristics, the full model provides strong evidence for their impact. Three of four variables are highly significant. From a general point of view, this shows that when one discusses the role of universities as sources of regional innovation, the spatial environment has to be considered as a determining factor. In doing so, our results add to the current discussion by confirming that the direct academic contribution to the local knowledge base depends on innovation and economic dynamics taking place within the region. Two basic mechanisms seem relevant here. Firstly, the results clearly show that a higher technological fit between the activity profiles of the local industry and the university significantly raises the propensity of collaborations within the focal region (H4). Secondly, higher innovation capability and start-up activity in a region significantly reduce the share of collaborations with firm partners outside the region (both H5). We might conclude that regions which combine high quality academic research, technological fit as well as a dynamic and innovative regional milieu are most likely to constitute an "excellent region" in terms of a science-based co-evolutionary process of technological innovation. The findings indicate that research which is conducted in areas underpinning the region's economic knowledge base is more likely to find its way into the local knowledge base via localized collaborations. Furthermore, it is particularly in innovative and dynamic contexts where trickling down effects of academics' technological knowledge are taking place in the universities' home region.

Additionally, the results show, as expected in H6, that MNEs seem to be less dependent on the availability of appropriate local universities as partners. The propensity to conduct inter-regional collaborations rises when the collaborating firm is an MNE. Their higher absorptive capacity and research capabilities obviously help large firms to tap into distant regions and to maintain inter-regional knowledge pipelines to distant universities. SMEs are more likely to collaborate with the local university and are to a larger degree dependent on the local availability of academic collaboration partners.

The field dummies give a first impression on how heterogeneous spatial collaboration behavior between universities and firms is in different technologies. While patents from the more applied sectors of electrical engineering and ICT are more likely to emerge within a region, the science-based sectors of life sciences and chemicals have a higher likelihood to cross the regional border. The latter are dominated by an analytical knowledge base. Here research collaborations focus on scientific partners and epistemic communities are the dominant frameworks for interaction, searching and researching. On the contrary, in synthetic or industrial knowledge bases hands-on activities are dominant. Innovation processes take place in applied R&D and learning emerges from, doing, using and interacting, making local communities of practice important as frameworks for knowledge exchange and learning (Manniche 2012; Mattes 2012).

#### 4.1.2 Technological areas

Turning to the field-specific models, (Table 2) provides us with additional information on factors influencing the role that universities play as local knowledge hubs in different technological areas.

Regarding university characteristics, the technology-specific models now offer additional insights and show field-specific influences that have been blurred in the full model. Interestingly, the TTO resources have a significant and negative effect on the likelihood that collaborative patents between academia and firms pass the regional border in electrical engineering and in chemicals. This indicates that a higher degree of support offered to the scientific staff at the university might help academics to induce local collaborations at least within these disciplines. This might be due to the fact that one objective of university TTOs usually is to support the development of the surrounding region (Wright et al. 2008; Youtie/Shapira 2008). In doing so, well- equipped and supportive TTOs have a good overview of the regional industrial landscape and the local demand for often very specific skills and competences at faculties within their institution. Furthermore, they often have a regional scope in supporting spin-off formation and running regional incubators.

The field-specific models provide also additional information on the role of application orientation and excellence. Interestingly, we find an opposing effect for different technological areas. Electrical engineering and ICT notably have been shown (see above) to be more oriented towards their own region, but a higher application orientation raises the probability to cross the regional border (in line with H2a). This seems to indicate that more experience and a critical mass of applied projects make it easier to collaborate over distance. At the same time, for life sciences and chemicals which have been shown to collaborate over larger distances, a higher patent intensity reduces the likelihood to go outside of the own region (in line with H2b). This might indicate a signaling effect or a grown network of long-term partnerships with firms outside of the region. Abramovsky (2007) e.g. finds strong evidence for co-location of pharmaceutical R&D labs and related university research leading to a cooperation between the two.

Notably, the scientific regard becomes significant only for mechanical engineering, indicating that only here a stronger orientation towards scientific excellence raises the share of intra-regional collaboration (H1b). At the same time, the publication intensity is positive, indicating a signaling effect to extra-regional firms (H1a). A higher publication intensity is negatively associated with regional border-crossing in ICT, but only weakly significant. Nevertheless, the evidence for an influence of universities' (scientific) excellence-orientation remains weak even in the field-specific analyzes.

The regional characteristics resemble a picture pretty much consistent with the full model described above. Therefore, we will basically refer to the observed differences. While all other fields remain significantly negative, we do not observe an influence for the start-up rate in ICT. This might be due to the fact that ICT is dominated by large firms and thus start-ups play a minor role.[9] For life sciences and chemicals the local innovative capability has no significant influence. The outward or application orientation of universities (see above) seems to be more important in these fields than the local environment. Notably, the absorptive capacity of the firms in the region, which is not significant in the overall model, only becomes partially significant in the technology-specific models (positive effect in electrical engineering and chemicals). This indicates, in line with findings by Hewitt-Dundas (2013), that a higher absorptive capacity of the firms in a region raises their ability to connect to distant

[9] SME's account for only ~10 percent of the patent applications in ICT.

universities in other regions. In line with this we also find that the effect described for MNEs in the full model stays consistent for each technological field (H6).

An interesting side-result is obtained from the time controls. In life sciences we find evidence that the likelihood for crossing regional borders strongly increases over time. This deserves further attention in future research.

Table 2: Regression results for intra- vs. inter-regional collaborations between universities and firms

| | | Full | | El. Eng. | | ICT | | Measurement | | Life Sciences | | Chemicals | | Mech. Eng. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *i-dep(V)s* | ***Cross Reg*** | | ***Cross Reg*** | | ***Cross Reg*** | | ***Cross Reg*** | | ***Cross Reg*** | | ***Cross Reg*** | | ***Cross Reg*** | |
| | | β | se | β | se | β | se | β | se | β | se | β | se | β | se |
| | SME/MNE (MNE=1) | 0.809 *** | 0.121 | 1.395 *** | 0.372 | 1.699 *** | 0.535 | 0.509 ** | 0.255 | 0.846 *** | 0.204 | 1.548 *** | 0.261 | 1.205 *** | 0.321 |
| University characteristics | TT-EMP/SCIENTIST | -4.849 | 10.826 | -134.550 ** | 52.703 | 15.608 | 58.922 | -34.459 | 26.337 | -38.115 | 35.215 | -109.727 *** | 39.967 | -8.178 | 9.770 |
| | PAT/ACAD | -1.940 | 4.066 | 314.229 *** | 86.768 | 194.881 ** | 77.871 | 21.229 | 38.983 | -51.170 * | 29.869 | -102.671 *** | 39.265 | -47.483 | 30.188 |
| | SR | -0.011 * | 0.006 | -0.007 | 0.008 | -0.005 | 0.017 | -0.005 | 0.010 | 0.018 | 0.027 | 0.005 | 0.011 | -0.013 ** | 0.005 |
| | Pubint | -0.231 | 0.193 | 2.975 | 4.736 | -11.134 * | 5.774 | 0.303 | 3.127 | 0.035 | 0.232 | 0.401 | 1.877 | 2.918 * | 1.705 |
| | Acad_staff | -0.083 | 0.055 | 0.077 | 0.162 | -0.007 | 0.278 | -0.143 | 0.134 | -0.090 | 0.160 | -0.621 *** | 0.197 | 0.228 * | 0.135 |
| University region | COS_SIM | -3.578 *** | 0.961 | -4.945 ** | 2.362 | -5.782 ** | 2.615 | 0.026 | 2.595 | -5.512 ** | 2.423 | 1.621 | 1.797 | -12.799 *** | 3.158 |
| | REGPAT_rate | -954.614 *** | 161.469 | -19580.019 *** | 4537.535 | -19688.485 *** | 5687.138 | -8481.456 *** | 2493.482 | -1289.272 | 3665.954 | 7022.134 | 4498.166 | -1010.919 ** | 450.761 |
| | R&Demp/firm | 0.019 | 0.013 | 0.092 * | 0.047 | 0.020 | 0.050 | 0.006 | 0.032 | 0.040 | 0.032 | 0.072 * | 0.038 | -0.018 | 0.024 |
| | Startup_rate | -1217.787 *** | 147.060 | -1402.314 *** | 540.387 | -434.677 | 285.616 | -1396.528 *** | 335.214 | -1714.657 *** | 276.311 | -2196.186 *** | 428.190 | -1212.938 *** | 294.224 |
| Controls | GDP/CAP | 0.005 *** | 0.002 | 0.001 | 0.004 | 0.000 | 0.005 | 0.007 ** | 0.003 | 0.003 | 0.004 | -0.002 | 0.004 | 0.008 *** | 0.003 |
| | POP | -0.001 ** | 0.001 | -0.001 | 0.002 | -0.006 *** | 0.002 | -0.002 | 0.001 | -0.0004 | 0.001 | -0.001 | 0.001 | -0.0020 ** | 0.001 |
| | famsize_o | -0.060 *** | 0.017 | 0.059 | 0.046 | -0.161 ** | 0.066 | -0.118 ** | 0.050 | -0.022 | 0.025 | -0.061 ** | 0.030 | -0.019 | 0.043 |
| | invt_cnt | 0.235 *** | 0.029 | 0.201 *** | 0.072 | 0.354 *** | 0.106 | 0.276 *** | 0.065 | 0.146 *** | 0.049 | 0.139 ** | 0.063 | 0.282 *** | 0.053 |
| | Bwcit_CNT | -0.011 | 0.007 | -0.044 ** | 0.018 | -0.047 * | 0.027 | 0.011 | 0.023 | -0.030 * | 0.017 | -0.012 | 0.009 | 0.029 | 0.021 |
| | NPLcit_CNT | -0.001 | 0.009 | -0.050 | 0.057 | -0.045 | 0.042 | -0.012 | 0.033 | 0.005 | 0.011 | -0.016 | 0.020 | 0.008 | 0.040 |
| | _Iprior~2006 | 0.360 *** | 0.131 | 0.959 *** | 0.317 | 0.155 | 0.319 | -0.356 | 0.304 | 0.559 ** | 0.239 | 0.586 * | 0.319 | -0.008 | 0.284 |
| | _Iprior~2007 | 0.410 *** | 0.129 | 0.877 *** | 0.319 | 0.526 * | 0.303 | 0.063 | 0.294 | 0.820 *** | 0.231 | 0.709 ** | 0.331 | -0.041 | 0.290 |
| | _Iprior~2008 | 0.201 | 0.132 | 0.331 | 0.336 | 0.231 | 0.332 | -0.290 | 0.286 | 1.089 *** | 0.251 | 0.278 | 0.346 | -0.239 | 0.269 |
| | _Iprior~2009 | 0.254 * | 0.139 | 0.604 * | 0.336 | 0.843 ** | 0.406 | -0.220 | 0.303 | 1.110 *** | 0.245 | -0.372 | 0.354 | -0.347 | 0.293 |
| | patdum_eeng | -0.322 ** | 0.126 | | | | | | | | | | | | |
| | patdum_ict | -0.470 *** | 0.124 | | | | | | | | | | | | |
| | patdum_mea | 0.104 | 0.105 | | | | | | | | | | | | |
| | patdum_life | 0.574 *** | 0.121 | | | | | | | | | | | | |
| | patdum_chem | 0.223 * | 0.120 | | | | | | | | | | | | |
| | patdum_meng | -0.066 | 0.115 | | | | | | | | | | | | |
| | patdum_env | 0.092 | 0.275 | | | | | | | | | | | | |
| | patdum_con_goods | -0.447 ** | 0.202 | | | | | | | | | | | | |
| | _cons | 2.845 *** | 0.944 | 3.500 | 2.608 | 7.094 *** | 2.437 | 0.349 | 2.479 | 5.047 ** | 2.448 | 1.151 | 1.863 | 9.731 *** | 2.994 |
| | | | | | | | | | | | | | | | |
| | N | 2863.000 | | 508 | | 573 | | 619 | | 847 | | 533 | | 682 | |
| | p | 0.000 *** | | 0.000 *** | | 0.000 *** | | 0.000 *** | | 0.000 *** | | 0.000 *** | | 0.000 *** | |
| | r2_p | 0.110 *** | | 0.109 *** | | 0.191 *** | | 0.114 *** | | 0.132 *** | | 0.218 *** | | 0.126 *** | |
| | aic | 3590.613 *** | | 660.600 *** | | 651.512 *** | | 801.425 *** | | 1047.760 *** | | 603.903 *** | | 868.173 *** | |
| | bic | 3763.442 *** | | 749.440 *** | | 742.881 *** | | 894.415 *** | | 1147.336 *** | | 693.752 *** | | 963.199 *** | |

Significance Level: ***p<0.01, **p<0.05, *p<0.1, robust standard errors.

### 4.2 Distances

After having explored which factors foster inter-regional collaboration compared with collaborations within one region, we will now focus on the concrete distances between the inventors. We will explain, which factors help to overcome long distances – firstly in general and secondly technology-specific.

#### 4.2.1 Main model

The zero-truncated negative binomial model in Table 3 shows, which factors influence the distance between collaboration partners. From the university variables the TTO personnel is highly positively significant and scientific regard is significant, but has a negative effect. The first result was expected in hypothesis 3, the second one shows, that the mechanism of hypothesis 1b prevails over those in hypothesis 1a: short-distant collaboration is easier to manage in the case of high-quality research at the scientific frontier, so that academics' choose more often proximate partners. In a further specification of the model, scientific regard has been added in a quadratic term (Table 3). The coefficient is positive and significant. In combination with the negative coefficient for the linear term this means, that universities with a very high scientific regard are able to overcome large distances when collaborating. Universities with a medium scientific regard are those that mainly collaborate with nearby firms. Only highly reputable universities have the radiance which is necessary to be noticed by far-distant firms. The amount of international publications - another measure of quality - is not significant. This shows that it is not the amount which is important but the perception and the amount of citations from other scientists.

The industry orientation, measured by patents per scientist, is insignificant in the model. As a control, the size of the university was added (amount of scientific staff) and is positively significant, as was expected. Interestingly, the dummy variable for MNEs is insignificant as well. As soon as the border of the own region has been crossed, it seems to be irrelevant whether the co-operation partner is a small or a large firm. Only the amount of intra-regional collaboration is larger for small firms (see section 4.1).

We are not able to extract information about the influence of the two involved regions' characteristics on the distance of collaboration. The reason is that the location of the university influences the potential distances. An inventor from a region located in the center of Germany cannot collaborate over distances as long as it is possible from a region located at the border of the country. Thus, it is impossible to distinguish between effects stemming from the regions' characteristics and structural effects stemming from the location of the university region within Germany. Furthermore, we would have to correct the overall distribution of economic activity in Germany. Therefore, we include the features of the firm's region only as control variables, not claiming that the results for these variables are clearly interpretable. They are all significant, even though the size (population) is only weakly significant at the 10% level.

From the further control variables regarding patent characteristics some are significant. The distances are shorter than 2005 (reference category) in all years. The coefficients hint at a decreasing distance over the years (except 2009), but five years are too short a time period to investigate whether there is a significant trend (e.g. due to the financial crisis and economic downturn during the period of observation) or only a statistical artifact. The size of the patent family as well as the number of inventors is insignificant. The same holds for the amount of backward and non-patent literature citation.

Some of the technology dummies are significant. The following subsection will present details of the technology-specific models.

### 4.2.2 Technological areas

Let us start again with the university-specific variables. Hypothesis 3 is supported: for all technologies more TTO staff helps to overcome larger distances. In the life sciences and chemicals, a high scientific regard leads to rather limited distances between the co-operation partners. As discussed above, high scientific regard seems to signify very fundamental and thus especially complex scientific knowledge, so that spatial proximity is essential for its transfer to firms. For the other technologies the variable is insignificant except for a positive quadratic term in measurement. Probably, both mechanisms underlying hypotheses 1a and 1b take effect in parallel. A high industry orientation, measured by patents per scientist at the university leads to shorter distances in life sciences and longer distances in mechanical engineering and is insignificant for the other technologies. Thus, mechanical engineering is the only technology supporting our considerations in hypothesis 2a: high industry orientation of universities provides them with the necessary experience to collaborate over large distances. International publication activity enhances far-distant collaboration in the life sciences and electrical engineering and for three of the six technologies the size of the university plays a positive role for collaboration over distance.

The control variables of the firms' regions are not so clearly significant as it was in the main model (section 4.2.1). The dummy for MNEs is insignificant for all technologies except mechanical engineering, where in contrast to our arguments the collaboration with large firms takes place over shorter distances than that with small firms. We have no explanation for this result.

The last interesting finding is a rather strong time trend in electrical engineering, where the collaboration behavior becomes more and more proximate during the period of observation. Further investigation would be necessary to find reasons for this finding (see above).

Table 3: Regression results for intra- vs. inter-regional collaborations between universities and firms

| | | Full | | El. Eng. | | ICT | | Measurement | | Life Sciences | | Chemicals | | Mech. Eng. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *i-dep(V)s* | | *Two Reg Dist* | | *Two Reg Dist* | | *Two Reg Dist* | | *Two Reg Dist* | | *Two Reg Dist* | | *Two Reg Dist* | | *Two Reg Dist* | |
| | | β | se | β | se | β | se | β | se | β | se | β | se | β | se |
| | SME/MNE (MNE=1) | 0.001 | 0.054 | 0.275 | 0.187 | 0.253 | 0.164 | 0.094 | 0.112 | -0.085 | 0.094 | 0.041 | 0.100 | **-0.134 *** | **0.079** |
| University characteristics | TT-EMP/SCIENTIST | **29.003 ***** | **7.359** | **34.717 ***** | **10.610** | **42.507 ***** | **8.444** | **24.387 ***** | **8.693** | **24.485 **** | **10.537** | **24.271 **** | **11.502** | **14.939 **** | **6.663** |
| | PAT/ACAD | 1.418 | 1.535 | -8.101 | 19.410 | -10.037 | 9.540 | -20.349 | 13.762 | **-12.671 **** | **5.217** | -9.758 | 11.868 | **20.609 ***** | **7.984** |
| | *SR* | ***-0.015 ****** | ***0.003*** | *-0.002* | *0.005* | *0.001* | *0.005* | *-0.002* | *0.003* | ***-0.041 ****** | ***0.012*** | ***-0.008 ****** | ***0.003*** | *-0.001* | *0.003* |
| | ***SR²*** | ***0.0003 ****** | ***0.000*** | *0.0000* | *0.000* | *0.0002* | *0.000* | ***0.0002 ****** | ***0.000*** | *0.0005* | *0.001* | *0.0001* | *0.000* | *0.0001* | *0.000* |
| | Pubint | -0.007 | 0.088 | **3.910 **** | **1.962** | -1.246 | 1.456 | -0.585 | 1.091 | **0.164 *** | **0.096** | -0.651 | 0.456 | -0.425 | 0.358 |
| | Acad_staff | **0.107 ***** | **0.021** | 0.008 | 0.067 | -0.014 | 0.054 | **0.126 ***** | **0.045** | **0.127 ***** | **0.047** | -0.040 | 0.048 | **0.138 ***** | **0.035** |
| Region controls | REG2: COS_SIM | -0.758 *** | 0.274 | -0.377 | 1.077 | -0.180 | 0.626 | 0.077 | 1.172 | 0.803 | 0.505 | 2.590 *** | 0.430 | -0.751 | 0.832 |
| | REG2: REGPAT_rate | -345.95 *** | 56.451 | -627.55 | 656.171 | -112.01 | 720.541 | -1503.80 *** | 562.714 | -578.18 | 465.779 | -736.62 | 1024.589 | -756.34 *** | 119.319 |
| | REG2: R&Demp/firm | 0.050 *** | 0.005 | 0.069 *** | 0.013 | 0.049 *** | 0.011 | 0.031 *** | 0.009 | 0.040 *** | 0.009 | 0.034 *** | 0.008 | 0.043 *** | 0.007 |
| | REG2: Startup_rate | -143.351 *** | 47.252 | -35.838 | 131.020 | 9.830 | 138.195 | -103.684 | 108.247 | -95.412 | 81.389 | -35.578 | 80.059 | -255.512 *** | 52.101 |
| | REG2: GDP/CAP | -0.003 *** | 0.001 | -0.006 *** | 0.001 | -0.005 *** | 0.002 | -0.004 *** | 0.001 | -0.003 ** | 0.001 | -0.001 | 0.001 | -0.002 ** | 0.001 |
| | REG2: POP | 0.0004 ** | 0.000 | -0.0010 | 0.001 | 0.0012 * | 0.001 | 0.0007 | 0.001 | 0.0001 | 0.000 | 0.0009 ** | 0.000 | -0.0001 | 0.000 |
| Controls | famsize_o | -0.006 | 0.008 | 0.011 | 0.020 | 0.008 | 0.022 | -0.042 ** | 0.018 | -0.011 | 0.012 | -0.016 * | 0.009 | 0.011 | 0.015 |
| | invt_cnt | 0.002 | 0.012 | 0.028 | 0.025 | -0.080 *** | 0.025 | 0.027 | 0.019 | -0.001 | 0.020 | -0.020 | 0.020 | -0.012 | 0.017 |
| | Bwcit_CNT | 0.001 | 0.004 | -0.022 ** | 0.011 | -0.026 ** | 0.013 | 0.010 | 0.011 | 0.007 | 0.008 | -0.005 | 0.004 | 0.002 | 0.006 |
| | NPLcit_CNT | -0.002 | 0.004 | 0.006 | 0.020 | -0.001 | 0.017 | 0.000 | 0.017 | -0.002 | 0.005 | 0.007 | 0.006 | -0.002 | 0.014 |
| | _Iprior~2006 | -0.091 * | 0.050 | -0.230 ** | 0.107 | -0.034 | 0.106 | -0.115 | 0.118 | -0.195 * | 0.108 | -0.159 | 0.099 | 0.062 | 0.099 |
| | _Iprior~2007 | -0.118 ** | 0.055 | -0.236 ** | 0.121 | 0.102 | 0.104 | -0.229 ** | 0.107 | -0.080 | 0.101 | -0.073 | 0.112 | -0.205 * | 0.107 |
| | _Iprior~2008 | -0.201 *** | 0.053 | -0.329 ** | 0.144 | -0.057 | 0.089 | -0.155 | 0.095 | -0.129 | 0.099 | -0.314 *** | 0.110 | -0.221 ** | 0.094 |
| | _Iprior~2009 | -0.165 *** | 0.060 | -0.492 *** | 0.134 | 0.074 | 0.108 | -0.143 | 0.118 | -0.164 | 0.100 | -0.076 | 0.137 | 0.014 | 0.119 |
| | patdum_eeng | -0.139 *** | 0.050 | | | | | | | | | | | | |
| | patdum_ict | -0.136 *** | 0.045 | | | | | | | | | | | | |
| | patdum_mea | -0.107 ** | 0.045 | | | | | | | | | | | | |
| | patdum_life | -0.005 | 0.050 | | | | | | | | | | | | |
| | patdum_chem | -0.033 | 0.052 | | | | | | | | | | | | |
| | patdum_meng | -0.238 *** | 0.046 | | | | | | | | | | | | |
| | patdum_env | -0.109 | 0.092 | | | | | | | | | | | | |
| | patdum_con_goods | -0.475 *** | 0.087 | | | | | | | | | | | | |
| | _cons | 6.390 *** | 0.298 | 6.393 *** | 1.142 | 5.884 *** | 0.701 | 5.744 *** | 1.051 | 5.137 *** | 0.478 | 3.166 *** | 0.515 | 6.190 *** | 0.817 |
| | lnalpha/cons | -1.161 *** | 0.035 | -1.538 *** | 0.101 | -1.768 *** | 0.106 | -1.306 *** | 0.081 | -1.107 *** | 0.058 | -1.179 *** | 0.057 | -1.473 *** | 0.078 |
| | N | 1410 | | 218 | | 210 | | 319 | | 481 | | 318 | | 336 | |
| | p | 0.000 *** | | 0.000 *** | | 0.000 *** | | 0.000 *** | | 0.000 *** | | 0.000 *** | | 0.000 *** | |
| | r2_p | 0.025 *** | | 0.053 *** | | 0.068 *** | | 0.028 *** | | 0.024 *** | | 0.035 *** | | 0.039 *** | |
| | aic | 16866.490 *** | | 2571.561 *** | | 2433.573 *** | | 3762.089 *** | | 5742.736 *** | | 3843.976 *** | | 3894.835 *** | |
| | bic | 17029.282 *** | | 2649.404 *** | | 2510.557 *** | | 3848.689 *** | | 5838.781 *** | | 3930.503 *** | | 3982.628 *** | |

Significance Level: ***p<0.01, **p<0.05, *p<0.1, robust standard errors.

## 5 Summary and Conclusion

The aim of the paper at hand was to provide some answers to the question under which circumstances universities contribute directly to the local knowledge base by means of collaboration with firms and in which cases they serve as a bridging institution for cross-regional knowledge exchange. In doing so, the first step of our analysis shows that the regional characteristics in terms of local demand for academics' contributions to technological innovation seem to be more important than university characteristics. Firstly, by applying a new indicator we are able to show that overlapping knowledge bases between university and local industry enhances the intra-regional collaboration propensity. Secondly, a dynamic and innovative milieu significantly fosters localized collaborations. Of the university characteristics only the scientific regard as a proxy for excellence orientation is significant on the general level, providing some evidence that higher excellence also strengthens localized knowledge production involving academic and firm researchers. If the collaborating firm is an MNE, the likelihood that the university collaborates beyond the regional border is increased. Putting it simply, high research quality, technological fit and innovative milieux in the surrounding region as well as SMEs as partners enhance the function of universities as local knowledge factories.

Once the regional borders are crossed the universities' excellence reveals a decreasing effect on the distance between collaboration partners. Nevertheless, from a certain threshold onwards a reputation effect becomes increasingly important. Thus, a higher reputation signaling research quality seems to attract corporate collaboration partners from very distant regions. Thus, we observe two complementary effects. Firstly, prestigious universities foster localized collaborations. Secondly, once regional borders have been crossed a certain gravitation of neighboring regions is observable for medium prestigious universities. However, with increasing scientific regard universities advance into the focus of distant firm researchers. Regarding the role of TTOs we find that they seem to act as local intermediaries in electrical engineering and chemicals. The second part of the regressions reveals that once the regional border has been crossed better equipped TTOs help to find distant business partners. This indicates that, at least in parts, well equipped TTOs are able to reconcile local responsibility with the support for academics in inter-regional collaboration.

The picture described above seems to hold for most technology regimes (keeping the described exceptions in non-engineering sectors in mind). Nonetheless, by expanding the analyses on different technology regimes, we get closer to faculties' direct working environments. This shows that the intensity in applied projects has a significantly different influence on the spatial collaboration behavior. In electrical engineering and ICT, which are regarded as more hands-on and problem-solving oriented, higher application intensity raises the outward orientation of universities. In life sciences and chemicals we find the opposite. This might help to explain some of the observed contradictions in previous research regarding the role of space in U-I interaction. Overall there seems to be a tendency that sectors dominated by more hands-on synthetic knowledge tend to collaborate locally, while sectors dominated by analytical scientific knowledge tend to collaborate non-locally. Now, intensifying collaboration activities and the appropriability of research seems to have counter-rotating effects on both knowledge bases.

Of course, our empirical study is not without limitations. We were not able to include inventor-specific data, even though personal characteristics have certainly the strongest impact on collaboration behavior. Since we did not want to determine the absolute effects of environmental factors in relation to personal ones, this does not lessen the value of our main finding: the academic inventor's environment affects his or her spatial collaboration behavior.

From a policy perspective, our findings have important implications. It seems that the interplay between type and content of research conducted at the university and by local firms as well as the local dynamics are important factors in shaping local spillovers. It seems questionable if policy measures in prioritizing regional collaborations are able to account for usually idiosyncratic and region-specific contexts. Trying to turn a university’s orientation away from global scientific competition might rather hamper the quality of its research and if the local environment is lacking adequate partners this is unlikely to exert local impact. Thus, appropriate supporting schemes should be able to take into account the bottom-up driven characteristics of U-I collaboration and in doing so the idiosyncratic situation of firms and academic researchers. One example which leads into this direction seems to be to provide TTOs with sufficient resources that allow them to act as service providers for the academic staff. In doing so, they should be enabled to act as supporters for scientific endeavors and should not be restricted to local commercialization. Another suggestion is to design supporting schemes from a network perspective in which firms and academia have to provide substantial own contributions. Nevertheless, this seems to account particularly for small firms and for firms with lower absorptive capacity. Large firms and (at least partially) local firms with more R&D relevant staff have been shown to be more outward oriented and able to search for the most appropriate academic partner independent from their geographical location.

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