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Innovators and the Diversity of Innovation Systems*

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Abstract

This work deals with the determinants of cooperative invention and innovation within innovation systems. Several proximity dimensions are used to identify the levels on which systemic innovation activities can be observed. To disentangle the effects of different proximity dimensions a procedure is suggested to identify the relative regional impact (RRI) on cooperative invention and innovation. Applying this method to German patent data shows that there are significant differences in the RRI of German regions. These differences are related to measures of the technological relatedness of the regions knowledge bases, and over time they show a considerable path dependency.

JEL classification: O31, P25, Q55

Keywords: proximity concepts, cooperative innovation, innovation systems

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1. Introduction

The notion of cooperative or systemic inventive and innovative activities draws back on several sources. Extending the classification of Schumpeter I (the driving actors innovative activities are entrepreneurs or small firms; Schumpeter 1912) and Schumpeter II (the driving forces of innovative activities are large firms; Schumpeter 1942) Imai/Yamazaki (1994) coined the concept of Schumpeter-J. The "J" refers to the Japanese economy within which inventive and innovative activities are pursued in cooperation between firms and other actors such as research institutes and political institutions (mainly the MITI). The notion of collective invention was introduced about 10 years before Imai/Yamazaki by Allen (1983) who described the cooperative activities in the development of furnaces. Von Hippel (1987) extended this concept by focussing on the informal trading of know-how. Another important source is Kline/Rosenberg (1986) who extended the simple linear model of the innovation process to the so-called feedback model. There the various phases of the innovation process are coupled by several feedback loops implying that inventive, innovative and adopting actors influence each other in pursuing innovative change.

Backed by these sources the systemic concept of invention and innovation has been developed by several authors at the end of the 80ies and early 90ies of the last century. This concept unites cooperative invention and innovation with often informal exchange of know-how, the involvement of other actors than firms such as research institutes and political institutions and organisations, the covering of the whole innovation process as well as the feedback relationships herein: the Systemic Innovation Approach was born. First there were analyses on the national level leading to the concept of national innovation systems as suggested by Freeman (1988), Lundvall (1992), and Nelson (1992). Here the national borders and the national membership of the actors serve as demarcation. So-called technological systems have been suggested by Carlsson/Stankiewicz (1991) where actors belonging to a specific technological field such as biotech or automobiles are connected to each other. Hence the demarcation of the system is of a technological or knowledge related nature. To a certain extend the concept of sectoral innovation systems as suggested by Malerba/Orsenigo (1997) can be considered on the one hand an application of the technological approach and on the other an extension of this concept to sectors and industries. In 1992 Cooke coined the notion of the regional innovation system and just brought in the regional dimension of inventive and innovative activities. Concepts by Breschi/Lissoni (2001) referring to local innovation systems, by Fischer at al. (2001) referring to urban innovation systems, as well as the literature on industrial districts (referring to Marshall 1920) and the innovative milieu (Camagni 1991) are considered refinements of this spatial dimension of inventive and innovative activities.

Looking from this perspective on actors engaged in cooperative invention and innovation it is obvious that they at the same time belong to several of the innovation systems mentioned. A biotech firm takes part in the national innovation systems, as it belongs to a technological innovation systems comprising several biotech firms, to a sectoral system related to pharmaceuticals, to a regional systems related to the location of the firm including some surroundings, and finally also to the urban system of the city of location. In this context two interesting question arise: First, one may ask how the several types of innovation systems are conceptually related. And, secondly, in view of the inventive and innovative performance of actors and the multiple memberships in innovation systems, one may ask whether and how the effects arising from the various innovation systems can be disentangled.

The answer to the second question relies heavily on the answer to the first one. There several concepts of proximity between cooperatively inventive and innovative actors can be used to distinguish several levels of innovation systems and to show how they are related to each other. This then helps to suggest a method to disentangle the several layers of cooperative invention and innovation.

The paper is structured as follows: section 2 contains a discussion of the dimensions influencing cooperative innovation finally leading to a classification of innovation systems. Section 3 introduces a method to disentangle the effects of several layers of systemic invention and innovation and applies it to data from Germany. Here regional differences in the level of cooperative invention and innovation are explained by a pure technological or sectoral effect on the one hand and a regional or spatial effect on the other. Section 4 then attempts to find the determinants of the regional effect. Section 5 concludes and lays out further research avenues.

2. Dimensions of Proximity Influencing Cooperative Innovation

The conceptual basis for cooperative invention and innovation are actors’ heterogeneity, the necessity to access knowledge external to an actor, and the internalisation of spillovers, the exchange of knowledge and interactive learning. We detail those concepts in turn.

The resource based view of the firm as introduced by Penrose (1959) and then completed by Wernerfelt (1984) and Barney (1991) offers an explanation for rather persistent differences in the characteristics and performances among firms. Each firm is considered a specific assemble of resources whereas the latter are described as productive resources that are rare, valuable, non-imitable and, thus, sticky to the possessing actor. Prominent among those resources are knowledge, human capital, patents, etc. They, in turn, are important inputs into innovative activities and by the firm specificity they provide for firm specific or localised innovative activities.

A major consequence of such a perception is an idiosyncratic path of inventive and innovative activities of firms and thus a resulting path-dependency of progress. Whereas such path-dependency may be a source of competitive success of a firm it may be also constraining especially when the inventive and innovative potential of a firm gets exhausted step by step. A resulting lock-in may be severe threat for the long-run viability of the firm. Access to knowledge external to the firm and combining it with firm internal knowledge may be a source of new generic inventive potentials and thus it may be a way out.

For accessing external knowledge a firm has several options to do so. First, missing technological knowledge can be bought on appropriate markets. External R&D expenditures are used to pay someone else to do research and to deliver the results. Also licensing fees or buying patents belong to this category. Secondly, a firm can integrate other actors with appropriate technological knowledge into the own firm. Mergers and acquisitions as well as the market for human capital allows for this. Finally and for this paper the relevant mode of accessing external knowledge is research cooperation. Here, different actors agree formally as well as informally to cooperate in inventive and innovative activities.

A closer look at research cooperation delivers three important motives for firms to get engaged. First, on purely economical grounds research cooperation provide for participating actors a reduction in the risk involved and a sharing of the R&D costs (Deeds/Hill 1996, Baum et al. 2000). The second motive refers to the fact that combining complementary assets in order to enhance the propensity of a successful development project (Teece 1986, Nooteboom 1999). And third, it is the internalization of knowledge spillovers (Griliches 1992), the possibility to knowledge exchange and the resulting interactive learning which may lead to higher inventive and innovative success of the participating actors. Obviously, these three motives cannot be seen in isolation but any cooperative arrangement with the aim to further technological development and to invent and innovate will to be governed by all of the three motives at the same time – although from case to case by a variant degree. For this paper it is the third motive we want to look at more closely.

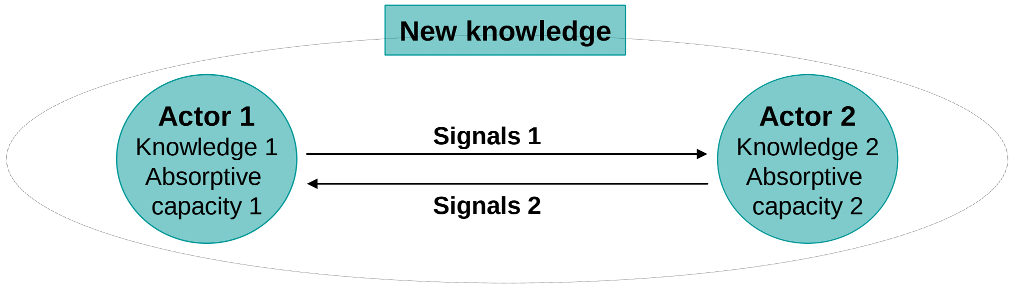

Figure 1: Model of Exchanging Technological Knowledge

For this we refer to a model of communication between two actors, 1 and 2, in figure 1. Both actors possess specific technological knowledge and some absorptive capacities. They exchange information by sending signals to each other. Their common objective is to generate new knowledge by combining their respective knowledge and competences. This model based on two actors can easily be extended to more than two actors.

For knowledge exchange to take place some conditions have to be fulfilled. First the actors involved have to be different in their knowledge because otherwise, if they have the same knowledge base, there is no basis for an exchange of knowledge. Secondly, in addition to the heterogeneity of actors with respect to their specific knowledge they need to have certain absorptive capacities (Cohen/Levinthal 1990). Those capacities are required in order to understand, evaluate and apply knowledge transferred from outside. They are partly being built up as a kind of by-product of a firm's R&D and innovative activities. Besides this, the effectiveness of absorptive capacities is dependent on the technological distance expressed in terms of proximity between actors. If the proximity is too large the absorptive capacities might not be sufficient to understand the knowledge of others.

Another important aspect of knowledge exchange is, thirdly, the way whether and how this is codified. The degree by which knowledge is codifiable determines the easiness of transfer. In the case of so-called tacit knowledge – which is of the not codifiable type – transfer and exchange becomes more difficult and face-to-face contacts are required. Finally, the parties involved in transferring and exchanging knowledge necessarily want to have some control over these processes. Trust is just an institution providing some control. Ttrust may be given ex ante, before a cooperation starts; but mainly trust (and, of course, distrust) is built up by the very exchange of ideas, concepts and knowledge (ex post trust). The mechanism involved is reciprocity of knowledge exchange, not in the sense of *uno actu* but over time.

Having introduced the bare bones of the promoting features of exchanging knowledge the question arises as to what are the principle conditions to be fulfilled for this interactive process to run effectively. Obviously, actors have to get to know each other, they have to show a common understanding combined with enough differences in the knowledge space for being creative (creative potential), and they should be able to have a certain degree of control over the interactive relationship. Boschma (2005) suggested five concepts of proximity between actors involved in the transfer and exchange of knowledge. These proximity concepts can be used to better understand the very conditions under which cooperative invention and innovation works.

In the following the five proximity concepts, first, are briefly introduced and, second, the influence of their degree on exchanging ideas and knowledge will investigated. As will be shown the combination of several proximity dimensions leads to various constellations just able to deal with a crucial trade-off in managing cooperative invention and innovation: whereas the cooperation arrangements have to be flexible for exchanging knowledge, learning interactively and generating new knowledge, they have to be appropriately structured allowing for an easy controlling of the respective exchanges and usages of knowledge.

Of crucial importance for successful interaction is the cognitive or technological proximity between the interacting agents. As mentioned above for the generic potential in cooperative invention and innovation actors have to be different in their knowledge and competences. However, some overlap in these knowledge bases and thus some degree of proximity in the cognitive or technological dimension is required for a common understanding. Appropriate absorptive capacities of the actors obviously sustain a fruitful exchange of different but complementary knowledge. Discussing technological proximity as a source of new ideas and innovations necessarily leads to discussing the economic relationships among the interacting partners which internalize economic spillovers or positive technological externalities. From the point of view of economic competition vertical relations along the value chain are rather unproblematic as firms here do not compete on the same markets. On equal terms the exchange of knowledge between firms from different sectors as discussed in Jacobs structures (Jacobs 1969) are not likely to harm the partners respective market positions. More problematic in this sense are horizontal relationships between the cooperating partners. As far as they compete on the same markets incentive problems may arise and their cooperative venture requires a more formalised and thus controllable design.

The issue of controllability of knowledge exchange in relation to the degree of market competition of the exchanging partners leads quite naturally to the question about the appropriate organizational design for the exchanging knowledge. The answer to this question first has to discuss the very nature of knowledge. It is immaterial and tends to have features of a public good satisfying the conditions of non-rivalry and non-appropriability (non-excludability). However, with respect to appropriability (or excludability) knowledge often tends to be not usable instantaneously by others but only when a patent has expired, some lead time has passed by, or learning advantages has been offset. In such cases knowledge is considered a latent public good. In other cases the condition of non-rivalry is violated when knowledge cannot be codified but is tacit so that it satisfies the conditions of a private good.

Turning now to the appropriate organisational design to transfer and exchange knowledge, the concept of organisational proximity is useful here. This kind of proximity mainly refers to the mode of knowledge transfer and here one usually distinguishes between (i) market transaction, (ii) hierarchical relationships, and (iii) network interaction. In the first case proximity between actors is rather low, flexibility is high and the exchange can take place even anonymously. This mode of exchange or transfer of knowledge might work when knowledge is protected by intellectual property rights and licensing or buying a patent works fine. It might even work in the case of tacit knowledge as one can acquire it by hiring human capital. However, when appropriate intellectual property rights are absent and the value of a specific peace of knowledge is not known market transactions usually fail. In those cases a hierarchical relationships (case (ii)) among actors may be a solution; here proximity becomes rather close. Paying scientists and researcher just as employees and pledging them to deliver the knowledge created reflects a high degree of control. Such arrangements for knowledge exchange and transfer are found in large firms running their own R&D laboratory. Of course, flexibility required for creative thinking and exploring and exploiting opportunities is much reduced herein. This missing flexibility is a major defect in exchanging knowledge in hierarchies leading us to a somewhat more flexible concept, network interaction (case (iii)). Here proximity is at a medium level; it allows being flexible and switching rather easily from one cooperation partner to another. The reciprocity of exchanging knowledge is essential but not necessarily *uno actu* (as in markets). Control is exerted by trust and reputation. Such network structures are suggested being the most appropriate mode of exchanging knowledge and they regularly are considered the core of innovation systems.

Network interaction as just described can show quite different variants. With respect to the control exerted by trust it is often the institutional proximity which constrains such networks. The more actors share general habits and attitudes (at the macro level) the closer their institutional proximity and the stronger trust related to those institutions. An additional source of trust is based on social proximity and here on the repeated interactions along social relationships. This kind of trust is observed on the micro level and is built up by a frequently exchanging knowledge. In this sense it can be labelled as ex-post trust since it develops after the cooperation has started; contrary to this trust related to institutional proximity is more of an ex-ante type because it serves as a precondition for starting a cooperation.

Last not least, geographical or spatial proximity affects the cooperative activities. However, this type shows a rather facilitating function for the proximity concepts to work. Especially concerning social proximity the spatial dimension is often considered substituting the social dimension. Also organisational proximity in terms of networking seems to be facilitated by spatial closeness – and the exchange of tacit knowledge by face-to-face even requires spatial proximity.

To finish this discussion of proximity concepts a common feature has to be addressed. Looking at the dependence of the level of cooperative invention and innovation on the degree of the respective proximity one can argue that it is of an inverted-U type. This means that there is an intermediate level of proximity at which cooperation is highest whereas any deviation from that level (either to lower or an increased proximity) leads to a decreased level of cooperative invention and innovation.

With those proximity concepts in mind, knowledge exchange between actors is determined by each of these proximities at the same time although by varying degree. In this sense one can apply these concepts to characterize the various forms of innovation systems. Figure 2 contains this characterization.

First, the core of innovation systems is considered a network of actors exchanging ideas. Hence, in terms of organisational proximity stated at the top of figure 2 the network mode is relevant. Second, cooperative invention and innovation is based on the combination of different knowledge bases where, however, the cognitive or technological proximity – stated at the bottom of figure 2 – should not be too large. Third, with respect to trust, emphasizing institutional proximity leads to national systems of innovation. Referring, fourth, more to social proximity allows discussing technological or sectoral systems.

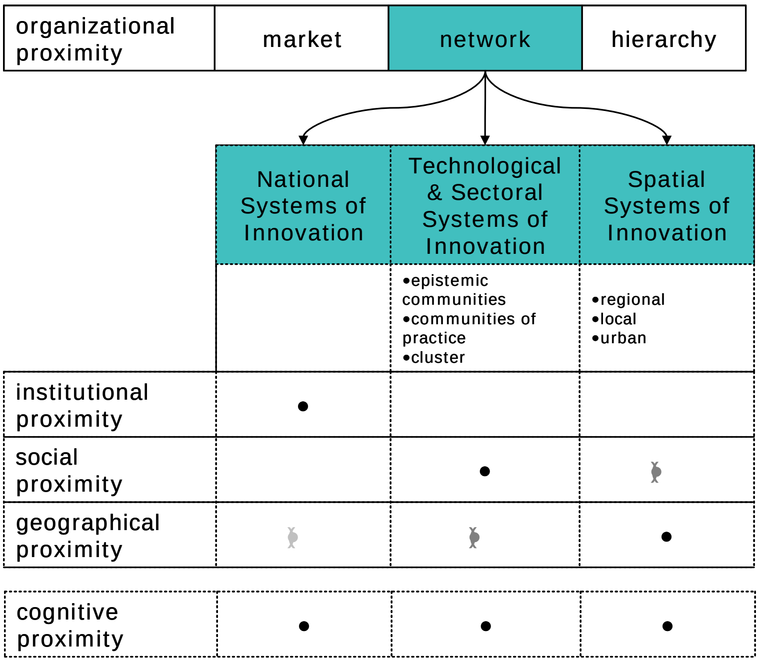

Figure 2: Proximity Concepts and Types of Innovation Systems

And finally addressing geographical proximity, spatial innovation systems get highlighted. The suggestion to interpret geographical proximity as facilitating and by this substituting other proximity concepts is taken into account by the grey dots in figure 2. Obviously, this facilitating function is more intense in the case of technological systems if one looks at regional clusters. It is of less importance for national systems of innovation.

3. Disentangling the Technological and Regional Impacts on Cooperative Invention

Based on the discussion of the proximity dimension above one may ask whether and how the effects of these dimension on cooperative invention and innovation can be disentangled. If, for example, one observes a region with an above average level of cooperative innovation, the question arises whether this higher performance is due to an appropriate mix or composition of industries and/or technologies located in that region or whether a specific regional effect can be identified. Or to put it in terms of overlapping innovation systems, are differences in regional cooperative invention and innovation related to the participation of regions' actors in one or several technological or sectoral systems, or are they related to the effects arising from the respective regional innovation systems?

A solution for this problem has been suggested and applied by Cantner/Meder (2008) in the case where one only needs to disentangle the effects of technological proximity and the one arising from spatial proximity. What we left out are the other proximity dimensions assuming their influence to be equally spread.

3.1 Index of Relative Regional Impact

Cantner/Meder (2008) suggests a procedure to identify the regional effect on cooperative invention / innovation by just separating the technological effect. The result of this procedure is an index of the relative regional impact on cooperative invention / innovation. They proceed as follows. First, for each industry or technology field the propensity to cooperate (intra- regionally) over all regions is computed. In doing so, this propensity includes not only the technology specific effect but the average (intra-) regional effect as well. For each region the respective technology / industry mix is used to compute the expected number of (intra-) regional cooperative innovations in a second step. This expected number is related in a third step to the observed number of (intra-) regional cooperative innovations. The resulting ratio accounts for the relative regional impact (RRI) on cooperative innovation, it indicates the strength of regional cooperative innovation (with respect to the average), and it can be interpreted as a measure of strength of a regional innovations system.

3.2 Application to German Patent Data

The methodology has been applied to a specific source of information about inventions, patent data. The sample contains data about patent applications for Germany between 1998 and 2003. This information is taken from the "Deutsche Patentblatt" publication which includes data from the German patent office (DPA) as well as data from the European patent office (EPO). Since we rely here on patent applications the activities leading to these applications are of an inventive type and not of an innovative one which would require also economising on the new idea. Consequently, in the following we investigate cooperative invention.

Technological dimension in patent data: Regarding the methodology introduced before, the first dimension of interest refers to differences in innovation and cooperation concerning different technologies. Therefore, the code according to IPC, the international patent classification, is used which allows classifying patents technologically. The characterizing codes are stated on each patent document. This classification, however, provides a rather detailed view on certain technologies. For our purposes the IPC classification appears to be too much differentiated. In order to reduce the number of dimensions, we use a concordance list developed by Schmoch et al. (2003) which in the end contains 43 main technological fields; those correspond well with NACE industry codes on a 3-digit level. On this basis the technological space comprises 43 technological fields.

The registration procedure at the EPO or the DPA allows to list more than one IPC class on a patent. Therefore, rather regularly a patent is classified for more than one IPC class. The transformation of the IPC assignment to the 43 technology classes obviously reduces the number of cases where several technological classes are "mentioned" – the remaining cases of co-classifications, however, are non-negligible. For those cases we assume that each of the technology fields addressed has the same weight.

Regional dimension in patent data: According to the regional dimension, patents have to be assigned to certain regions. The patent document allows for two modes of allocation, the address(es)(1) of the applicant(s) or (2) of the inventor(s). The first alternative has a strong weakness as many companies and institutions filing for a patent state the headquarters' addresses. This necessarily assigns a too high emphasis on agglomeration areas where headquarters are more common. An example proper is the city of Munich where the headquarters of Siemens as well as of the Fraunhofer and Max-Planck-Institute are located. Relying on applicants' addresses would push Munich in an exaggerated top position since not all inventions behind the patents by Siemens, Fraunhofer and Max-Planck were generated in the region "city of Munich". They were generated in many other places in Germany (or elsewhere), just the places where the inventors are located. Hence, the second alternative just overcomes this pitfall. Accordingly, a patent is allocated just to that region the addresses of the inventors listed on the patent document belong to.

Just like a patent may be filed for several technology fields, there may be more than one region the inventors of a patent are located. We accordingly assign the patent activity to all regions where the inventors come from. And to each region addressed the same weight will be assigned. For the spatial grid we use the concept of planning regions ("Raumordnungsregionen", ROR) developed by the Federal Office for Building and Regional Planning ("Deutsches Bundesamt für Bauwesen und Raumplanung"). Due to this concept Germany is divided into 97 regions with the objective of including all - or at least as much as possible - labour mobility within one region. Therefore, we assume that the residence and workplace address of an inventor lies within the same ROR.

Cooperative patents: Patent data can also be used to account for cooperative invention. Cooperative invention is understood here as any invention where more than one actor has been involved in the generation of new knowledge. This cooperation can be formal or informal, it can be explicitly stated or implicitly assumed.

In principle patent data allow to identify two modes of interaction between inventive actors, co-application and scientist mobility (Cantner/Graf 2006). Here we refer only to the former mode, co-application. This is given when on a patent document more than one actor is stated as applicant. With the data at hand we neither can distinguish between formal and informal cooperation nor can we differentiate between different kinds of actors. Hence, a co-application may be the result of a common R&D project among firms, between firms and public research institutes or among public research institutes. Even a co-application between an individual and one of these three kinds of actors can be observed, although this case is rather rare. Since we have no information at hand about the "creative" share of each applicant we consider their contribution as of the same "amount". Consequently, we weight each co-applicant equally.

3.3 Results

Cantner/Meder (2008) apply the method to data for 97 German regions from 1999 to 2003. In order to smooth variations over time, our approach is applied to moving periods with one year overlap. We use a moving 3-year average, leading to 4 sub-periods. To ease notation we label each of these sub-periods by the middle of the respective three years, hence, 1999, 2000, 2001, and 2002.

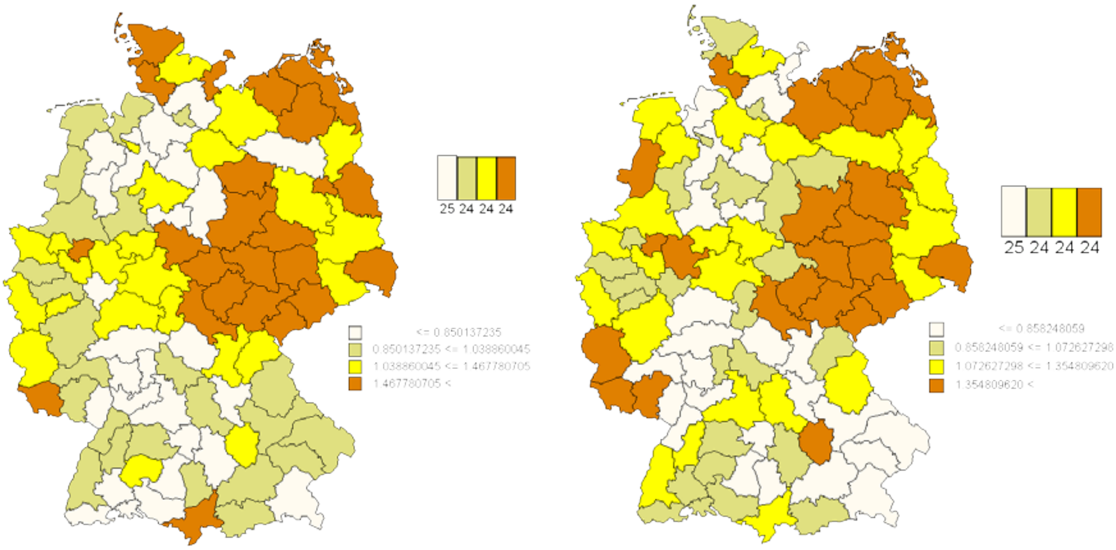

Figure 3: RRI Index for German Regions 1999 (left-hand figure) and 2002 (right-hand figure) (Cantner/Meder 2008)

Figure 3 contains the results. Here, the darker the colour of a region the more does the observed number of cooperative invention exceed the expected number and, hence, the stronger is the relative regional impact on cooperative invention. The two figures belong to the years 1999 and 2002. There obviously is not much change over time. Clearly, the RRI index is much higher in east compared to west regions. There also is a slight decline of this index from the North to the South.

4. Regional Effects on Cooperative Invention and Their Determinants

4.1 Hypotheses

In this section we attempt to identify the determinants of the RRI index. Differences in (regional innovation and) regional cooperative innovation can be explained by spillovers; their levels depend on the

- number of inventions / actors involved and hence on the amount of knowledge available;

- incentives to engage in knowledge exchange and networking which depend on the "quality" / relatedness of the knowledge available.

Based on these two main determinants we extracted hypotheses from the literature:

H1: The degree of regional effects on cooperating in invention is positively related to the amount of knowledge available within the region.

H2a: The more related is the regional knowledge base the higher are the regional effects on cooperating in invention. (Mowery et al. 1998, Breschi et al. 2003)

H2b: If the relatedness of regional knowledge base comes too close, the positive effect is dominated by disadvantages of possible knowledge drain and, thus, the effect on cooperating in invention diminishes. (Mowery et al. 1998, Wuyts et al. 2005)

H3: The combination of the level and the relatedness of the regional knowledge – the so-called regional knowledge base - affects regional cooperating in invention positively. (Breschi et al. 2003)

4.2 Data and Variables

These hypotheses are tested on a data base including patent applications from 1994 to 2003 and data on regional level gathered from the Federal Statistic Office. We apply panel data analysis and use the GMM estimator (Arellano/Bover 1995, Blundell/Bond 1998). As dependent variable we use the logarithm of the RRI index introduced in the previous section.

Explanatory variables are the amount and quality of knowledge, the knowledge base of the region, and a couple of control variables. The amount of knowledge *App* available in a region is proxied by the number of regional patent applications indicating the amount of valuable knowledge. We just took the logarithm and get ln(*App*). To account for the quality or relatedness of the knowledge available in a region we computed the cosine index, *cos*. This index measures the closeness among technology fields i and j independent of the number of patents (Breschi et al. 2003). Combining the amount of knowledge in a region and its quality or relatedness leads to the variable *KB*. It is simply the product of ln(*App*) and *cos*.

Three control variables are included. We first take into account the density of the region by the variable *Density*. It is simply the number of inhabitants per square kilometre. Secondly, we include the economic strength of a region by the variable *GDP* which is gross domestic product measured in thousand € per capita. Finally, the drop in the number of patent applications in 2002 is taken into account by the dummy variable D_{2002}.

Table 1 contains the descriptive statistics of the variables used. The regional knowledge base is measured according its size (ln(*App*)) and related variety (*cos*). There are patent applications in all regions in all time periods; the minimum number of patent applications is 11.33 in the fifth period (burst of the dot-com bubble) in the region of Altmark in Saxony-Anhalt (ROR 31). The most patents (6780) have been filed for in the third period in Stuttgart in Baden-Württemberg (ROR 72). The highest related variety (0.31) was calculated for the region Braunschweig in Lower Saxony (ROR 22) in the fourth period. The regional knowledge base of Hochrhein-Bodensee (ROR 78) shows the lowest related variety value (0.082) in the fifth period. The quality of the regional knowledge base variable (KB) which is the product of ln(*App*) and *cos* shows the highest value (2.397) again in Braunschweig. Berlin (ROR 30) has the most inhabitants per square kilometre (3889) and the region of Vorpommern in Mecklenburg-Western Pomeranian (ROR 8) shows the lowest density value (49,925). The regions Hamburg (ROR 6) and Munich (ROR 93) have the highest GDP per capita over time. The lowest value (8,918) was measured for Eastern Thuringia (ROR 56). There exists an East–West divide as well as – except Hamburg – a North–South divide in our data. The gap of the East–West divide is getting smaller over time, but is still tremendous in the last period.

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
ln(RRI)	485	0.014	-0.027	0.497	-2.277	1.605
ln(App)	485	5.864	5.927	1.107	2.428	8.822
cos	485	0.118	0.109	0.033	0.082	0.31
KB	485	0.699	0.635	0.272	0.37	2.397
Density	485	327.958	179.343	492.676	49.494	3.889.402
GDP	485	22.488	22.271	5.399	8.918	44.925

Table 1: Descriptive Statistics of the Variables

4.3 Results

Applying panel data analysis the explanatory variables except the control variables are used with a one-period lag. We also include the one period lagged dependent variable ln(*RRI*) as an explanatory variable allowing for autoregressive effects. The results are found in table 2.

We distinguish 5 models, M1 to M5. In M1 we look only at the autoregressive effect ($\ln(App)_{t-1}$) which is significantly positive. Hence, for the relative regional impact we find path-dependence. In M2 we additionally look at the impact of the control variables. Here, the density variable (*Density*) shows up significantly negative whereas coefficients for the GDP per capita (*GDP*) and the dummy for 2002 (D_{2002}) are insignificant.

Model Method dep.Variable	M1 System GMM ln(RRI)	M2 System GMM ln(RRI)	M3 System GMM ln(RRI)	M4 System GMM ln(RRI)	M5 System GMM ln(RRI)
$ln(RRI)_{t-1}$	0.148** (0.021)	0.128* (0.054)	0.140** (0.043)	0.155** (0.029)	0.155** (0.033)
$ln(App)_{t-1}$			0.122 (0.49)		
cos_{t-1}				9.012** (0.029)	
$(cos_{t-1})^2$				-24.85* (0.067)	
KB_{t-1}					1.319* (0.053)
$(KB_{t-1})^2$					-0.521** (0.037)
$Density_t$		-0.001* (0.068)	-0.001* (0.070)	-0.001* (0.057)	-0.001** (0.025)
GDP_t		0.015 (0.23)	-0.004 (0.89)	-0.007 (0.65)	0.001 (0.97)
D_{2002}		0.046 (0.38)	0.061 (0.29)	0.063 (0.25)	0.062 (0.25)
			p – values		
Sargan test	0.223	0.268	0.311	0.504	0.442
serial auto-correlation *AR(1)* *AR(2)*	 0.000 0.833	 0.000 0.921	 0.000 0.891	 0.000 0.881	 0.000 0.810
Observations	388	388	388	388	388
# of ROR	97	97	97	97	97

Robust z statistics in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1

Table 2: GMM Estimates for the RRI Index

In model M3 we additionally include the lagged amount of knowledge available in a region, $\ln(App)_{t-1}$. This does not change the significance and the magnitude of the other coefficients. For $\ln(App)_{t-1}$ no significant coefficient is found. This implies that it is not the amount of knowledge available in a region which determines the RRI. Consequently hypothesis 1 has to be rejected.

Model M4 runs without $\ln(App)_{t-1}$ and includes instead the lagged relatedness variable cos_{t-1}. Again, the coefficients of the other variables do not change in sign, magnitude and significance. For the relatedness variable we estimate a coefficient which is positively significant. Hence, the higher the relatedness between the technologies used in a certain region the higher is the RRI index. Hypothesis 2a therefore cannot be rejected. In addition and with respect to hypothesis 2b we are interested in whether this relationship is really linear. The variable $(cos_{t-1})^2$ just renders this. The estimated coefficient is negatively significant. Hence, in combination with the positive coefficient of cos_{t-1} we find a non-linear relationship between RRI and the technological relatedness which is inverted-U. Consequently, hypothesis

2b cannot be rejected. However, one nevertheless should check whether this non-linearity is relevant for the range of cos_{t-1}. For cos_{t-1} we find that relevance as the maximum of the inverted-U lies in between the minimum and the maximum observed values. This result quite nicely sustains the idea that proximity if too close or if too far may have a lower effect on the regional cooperative invention than an intermediate level.

In model M5 we use instead of cos_{t-1} and $\ln(App)_{t-1}$ the variable KB_{t-1} representing the knowledge base of the region. With this variable included as KB_{t-1} and $(KB_{t-1})^2$ we find an inverted-U relationship between RRI and the regional knowledge base. Hence, we cannot reject hypothesis 3.

5. Conclusion

In this paper we are concerned with cooperative invention and innovation which is at the heart of innovation systems. We discuss these activities in the light of several proximity concepts which influence the generic potential of cooperative activities (cognitive proximity) and allow controlling the exchange of knowledge (organizational, institutional and social proximity). A fifth dimension, geographical proximity, is considered to have a facilitating function especially with respect to controlling the exchange of knowledge.

Obviously, for any cooperative invention and innovation observed, those proximity concepts overlap. This first allows distinguishing between different concepts or levels of innovation systems, ranging from the national to the sectoral and to the regional level. Secondly, this overlap of several proximity dimensions leads to the question whether their respective effects can be disentangled and identified. For this second issue we suggest a procedure to disentangle the effects of cognitive or technological proximity and the one from geographical proximity. This method has been applied to German cooperative invention. An index called RRI delivers information about the specific regional impact on cooperative invention.

In a final step the determinants of the RRI have been investigated. Most importantly, it is the technological relatedness within a region which has a significant impact. The relationship shows up as inverted-U. There also is to be observed over time a considerable path-dependence in the RRI.

Obviously our study is only a first step into identifying the very determinants of cooperative and systemic invention and innovation. Further steps will include accounting more closely the (regional) social network, distinguishing between social proximity and geographical proximity, and relating our results to the economic performance of regions.

References

Allen, R. (1983): “Collective invention”, Journal of Economic Behavior and Organization 4, 1-24.

Arellano, M. / Bover, O. (1995): “Another look at the instrumental variable estimation of error components models”, Journal of Econometrics 68, 29-51.

Barney, J. (1991): “Firm resources and sustained competitive advantage”, Journal of Management 17 (1), 99-120.

Baum, J. / Calabrese, T. / Silverman, B. (2000): “Don't go it alone: alliance network composition and start-ups' performance in Canadian biotechnology”, Strategic Management Journal 21, 267-294.

Blundell, R. / Bond, S. (1998): “Initial conditions and moment restrictions in dynamic panel-data models”, Journal of Econometrics 87, 115-143.

Boschma, R. (2005): “Proximity and innovation: A critical assessment”, Regional Studies 39, 61-74.

Breschi, S. / Lissoni, F. (2001): “Knowledge spillovers and local innovation systems: a critical survey”, Industrial and Corporate Change 10 (4), 975-1005.

Breschi, S. / Lissoni, F. / Malerba, F. (2003): “Knowledge proximity and technological diversification”, Research Policy 32, 69-87.

Camagni, R. (1991): Innovation Networks: Spatial Perspectives, Harvard University Press.

Cantner, U. Graf, H. (2006): “The network of innovators in Jena: An application of social network analysis”, Research Policy 35 (4), 463-480.

Cantner, U. / Meder, A. (2008): “Regional and technological effects of cooperation behaviour”, JERP 2008-014.

Carlsson, B. / Stankiewicz, R. (1991): “On the nature, function and composition of technological systems”, Journal of Evolutionary Economics 1, 45-65.

Cohen, W. / Levinthal, D. (1990): “Absorptive capacity: a new perspective on learning and innovation”, Administrative Science Quarterly 35 (1), 128-152.

Deeds, D. / Hill, C. (1996): “Strategic alliances and the rate of new product development: An empirical study of entrepreneurial biotechnology firms”, Journal of Business Venturing 11, 41-55.

Fischer, M. / Diez, J. / Snickars, F. (2001): Metropolitan Innovation Systems; Theory And Evidence From Three Metropolitan Regions In Europe, Springer.

Freeman, C. (1988):‘Japan: A new national innovation system?’, in G. Dosi, C. Freeman, R. R. Nelson, G. Silverberg and L. Soete (eds.) Technology and economy theory, London: Pinter, 331-348.

Griliches, Z. (1992): “The search of R&D spillovers”, Scandinavian Journal of Economics 94, 29-47.

Imai, K.-I. / Yamazaki, A. (1992): “Dynamics of the Japanese industrial system from a Schumpeterian perspective”, In: M. Perlman, Y. Shionoya, Innovation in Technology, Industries, and Institutions, Michigan University Press, 1992, 217-252.

Kline, S. / Rosenberg, N. (1986): “An overview of innovation”, In: Landau, R., Rosenberg, N. (Eds.), The Positive Sum Strategy. National Academy Press, pp. 275-305.

Lundvall, B. (1992): National Systems of Innovation: Towards a theory of innovation and interactive learning, London: Pinter.

Malerba, F. / Orsenigo, L. (1997): “Technological regimes and sectoral patterns of innovative activities”, Industrial Corporate and Change 6 (1), 83-117.

Marshall, A. (1920): Principles of Economics. Macmillan, London.

Mowery, D. / Oxley, J. / Silverman, B. (1998): “Technological overlap and interfirm cooperation: implications for the resource-based view of the firm”, Research Policy 27 (5), 507-523.

Nelson, R. (1992): “National innovation systems: A retrospective on a study”, Industrial Corporate and Change 1, 347-374.

Nooteboom, B. (1999): “Innovation and inter-firm linkages: new implications for policy”, Research Policy 28, 793-805.

Penrose, E. (1959): The theory of the Growth of the firm. Wiley & Sons, New York.

Schmoch, U. / Laville, F. / Patel, P. / Frietsch, R. (2003): “Linking technology areas to industrial sectors”, Final Report to the European Commision DG Research.

Schumpeter, J. A. (1912): Theorie der wirtschaftlichen Entwicklung. Eine Untersuchung über Unternehmergewinn, Kapital, Kredit, Zins und den Konjunkturzyklus. Duncker & Humblot, Berlin.

Schumpeter, J. A. (1942): *Capitalism, Socialism, and Democracy*. New York: Harper and Brothers.

Teece, D. (1986): “Profiting from technological innovation: Implication for integration, collaboration, licensing and public policy”, Research Policy 15, 285-305.

von Hippel, E. (1987): “Cooperation between rivals: informal know-how trading”, Research Policy 16 (5), 291-302.

Wernerfelt, B. (1984): “A resource-based view of the firm”, Strategic Management Journal 5, 171-180.

Wuyts, S. / Colombo, M. / Dutta, S. / Nooteboom, B. (2005): “Empirical tests of optimal cognitive distance”, Journal of Economic Behavior and Organization 58, 277-302.