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by

Uwe Cantner
Andreas Meder

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Friedrich Schiller University Jena
Carl-Zeiss-Str. 3
D-07743 Jena
www.uni-jena.de

Max Planck Institute of Economics
Kahlaische Str. 10
D-07745 Jena
www.econ.mpg.de

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Regional Effects on Cooperative Innovation Activities and the Related Variety of Regional Knowledge Bases*

Uwe Cantner†, Andreas Meder‡

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Abstract

The literature on "Innovation Systems" is divided into several directories. Differences occur through the definition of the system's borders. This paper introduces a methodology how to differentiate between regional and technological effects of cooperative innovation activities and analyzes furthermore how different dimensions of regional knowledge affect the regional effects on cooperative innovation activities. We find evidence that the related variety of knowledge available within a region and its combination with a proxy of the amount of knowledge foster regional effects of cooperative innovation activities. Additionally, we find that the development of German regions fits with the suggestions of the *Regional Innovation System (RIS)* approach.

JEL classification: C30; L14; O32

Keywords: regional development, regional effects of cooperative behavior, knowledge, related variety of knowledge

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† Department of Economics, Friedrich-Schiller-University, 07743 Jena, Germany mail: uwe.cantner@uni-jena.de; phone: +49 (0)3641 9-43201
‡ Thuringian Ministry of Economic Affairs, 99096 Erfurt, Germany mail: andreas.meder@tmwta.thueringen.de; phone: +49 (0)361 37-97213

1 Introduction

In the past decades the conditions of economic growth evolved to be focused on knowledge, learning and innovation as the driving forces. Through improvements in communication and transport technologies the traditional production factors labor and capital become minor important. The wealth of a nation relies on the ability to create new knowledge and commercialize such knowledge (OECD, 1996; Acs, 2002; Sharpe and Martinez-Fernandez, 2006). Innovations are characterized as new products or processes with a certain expected economic value (Cooke et al., 2004). Several analytical frameworks deal with conditions, requirements and environments of creating and developing innovations.

This paper focuses on the "Regional innovation system" – approach, a concept developed in the last 15 years stressing the importance of regional factors for the innovative capability of firms. Based on a survey of recent literature we conclude that this approach recognizes the importance of regional interactions between certain kinds of actors, but is less able to explain the specific circumstances and incentives of an actor to engage in an interactive process with other actors. As the concept is on the regional innovative capability, we are interested in the development of German regional interactive structures. Based on the concepts of the learning and knowledge based economy we argue that regional interactive structures and their development depend on the respective regional knowledge bases in general and on the heterogeneity of the knowledge within a region in particular.

Our analysis is organized as follows. In section 2 we introduce the theoretical concepts and the roots of the RIS-approach. Based on a critical survey of the theoretical and empirical literature on this topic, we formulate three hypotheses. In section 3 we concentrate on methodological issues and introduce a measure of regional effects on cooperative innovation activities as well as a concept of how to measure the dimensions of regional knowledge. The statistical and econometric results obtained are presented in section 4. Section 5 summarizes and interprets our findings and put them into perspective.

2 Theoretical background

This section reviews approaches to regional innovation systems (RIS) and their performance by focussing on the factors determining their functioning and their success. While the increasing popularity of RIS and related concepts leads to a confusing jungle of definitions, the presence of such innovation systems in real world remains obscure (Doloreux et al., 2004, p.143). In this section a shaped concept is suggested starting with a rather abstract definition of a system. Based on that, we then consider systems in the context of innovation and here focus on their regional dimension.

2.1 Systems of Innovation

Starting rather generally, a system may be defined as a set of entities, real or abstract, comprising a whole where each component interacts with or is related to at least one other component. As a system forms a more or less dense "whole", one should be able to discriminate between the system and the rest of the world (Edquist, 2001, p.4). A straightforward solution does not exist as different systems serve different purposes, so that the observed variety of

systems is not surprising (Carlsson et al., 2002, p.233). Hence, any specification of this abstract definition of a system requires a differentiation between important and unimportant entities and interactions. The identification of what is unimportant depends on the purpose of the system.

Applying the idea of a system to innovative activities acknowledges that the majority of those activities are not pursued by individuals in isolation but that generating new ideas and economizing on them is a social and interactive process. Herein the behavior of a single actor is stimulated by his environment in general (Edquist, 2004) and by other actors in particular. The resulting interaction mainly refers to the interpersonal exchange of knowledge and information - on a formal as well as on an informal basis - with the ultimate aim to create new knowledge allowing for innovations. The entities or components of the systems are individual actors and organizations such as firms or public organizations on the one hand and on the other hand institutions (Edquist and Johnson, 1997, p.47) governing interaction among these organizations (Kubeczko et al., 2006, p.706). These institutions comprise trust, reciprocity and reputation, special technological fields and competence areas. They are developed within the system and further the overall function of an innovation system to finally create and commercialize new ideas (Asheim and Coenen, 2005).

This systemic view of innovative activities is based on "complicated two-way-relationship of mutual embeddedness between organizations and institutions" (Edquist, 2001, p.6). First, each component is related to the whole system, that is the behavior and development of organization like firms, universities or political actors, is driven by the set of institutions within the system. Second, the development of system's institutions based on the behavior and the decisions of the system's actors. This two-way-relationship is conducive to systemic interactions (Doloreux, 2004, p.483) among various actors and by this contributes to the principal goal of an innovation system to increase the innovative and economic performance of the actors involved as well as of the system itself.

On this basis any analysis of innovation systems has to take into account first that a system is a connected "whole" which cannot be divided into subsystems without loosing any interactions or relations: As Blanchard and Fabrycky (1990) show a system is more than the sum of its parts. Second, as institutions and organizations are related two-sided and there are feedback processes between relations and components, a system approach is always dynamic (Carlsson et al., 2002, p.234).

Based on this more general description of innovation systems, research in this field developed ways to categorize different systems. Here one mainly refers to the boundaries of a system with respect to the outside world. Initially this approach was used by Lundvall (1988, 1992) and Nelson and Winter (1982) to describe the development of certain national innovation systems. The discrimination between different systems is politically determined by the national borders. A second field, sectoral innovation systems justifies the boundaries by the specifities of sectors in terms of a certain knowledge base and key interactions within a sector (Malerba and Orsenigo, 1997). A third stream of research looks at the dynamics of innovative processes within regions. This concept will be introduced in the following subsection.

2.2 Regional innovation systems

The regional innovation system approach developed from the empirically based acknowledgement that innovation is a geographically bounded phenomenon (Asheim and Isaksen, 2002). The discovery of the importance of the regional scale and of regional resources in

stimulating the innovative capabilities of firms is the major issue this approach deals with (Asheim and Isaksen, 2002). Close spatial (often implying social) proximity promotes and eases the exchange of knowledge and information and thus contributes to collective learning and creation of knowledge. This applies especially in cases where we find a high degree of tacitness of knowledge, where direct personal contacts are required for transfer and exchange. The concepts of the learning economy (Lundvall, 2004) and the knowledge economy (Cooke, 2001; Raspe and van Oort, 2006) just emphasize this complexity as well as the path dependency of those processes.

As mentioned above a system has to have identifiable boundaries to become a whole different to the outside world. For the RIS concept those boundaries are given by the geographical term "region". Following Cooke (2001) a region is a meso-political unit above local governments and below nations. It might have a certain homogeneous culture and history (Cooke, 2001, p.953). The operationalization of this concept, however, is not any easy task and one more than often relies on political or administrative boundaries.

In view of this description of what a regional innovation systems broadly is all about, namely a regionally bound group of actors interacting in a specific way, the RIS approach may gain from a discussion of the individual incentives and requirements to engage in interaction and thus in research cooperation. To do so the following subsection dwells on the concepts of the learning economy and the resource-based theory of the firm. As a result of this discussion we achieve what we consider as the core of an RIS, the network of interactive actors.

2.3 Innovation, learning processes and the incentives to cooperate

The basic idea of the learning economy approach as well as the more static knowledge-based economy approach is that the knowledge base of firms is "the most strategic resource ... for competitiveness" (Asheim and Coenen, 2005, p.1174). This view is quite familiar with the theories of the resource-based view (RBV) of the firm going back on the initial work of Penrose (1959). This approach focuses on specific firm assets that determine the performance of a firm (Barney, 1991) and by her competitive advantage. These assets are called resources. Due to Combs and Ketchen (1999) those resources satisfy three criteria. First, they have to be valuable, that is there exists a demand which appreciates the resources' output. Secondly, an asset must be rare to be considered a productive resource in the sense of the RBV. Third, the resource has to be specific to a firm. Without a certain degree of uniqueness a firm will not be able to gain a competitive advantage over competitors (Combs and Ketchen, 1999, p.869). Within the RBV concept technological knowledge is considered an important intangible resource.

Both the learning economy concept and the resource-based view of the firm stress the process of knowledge generation/accumulation and describe this dynamics as an often path dependent and by this firm specific process (see for example Conner 1991; Lundvall, 2006). In this sense knowledge as a dynamic resource evolves over time and constitutes among others "the learning capacity of a firm" (Lockett, 2001, p.725). The path-dependent feature of knowledge accumulation provides firm specific technological know-how and competencies and thus for heterogeneity among firms. This specifity may in many cases contribute to the competitive advantage of a firm but in as many cases it may be constraining the opportunities for future own progress. Therefore, in pursuing further progress a firm may attempt to overcome this constraint by accessing knowledge generated by other firms or actors. Following the concept of the absorptive capacities introduced by Cohen and Levinthal (1990) existing knowledge is required to participate in a knowledge base external to the firm, the knowledge base of a re-

gion for example. In this sense knowledge a firm has accumulated and which serves as a learning capacity allows a firm to absorb knowledge generated elsewhere which then in turn combines with the own knowledge base to generate new knowledge.

These concepts of path-dependent knowledge accumulation, of absorptive capacities, and of the relevance of knowledge external to a firm offer the theoretical frame for an approach towards RIS based on individual decisions to access external knowledge and to exchange know-how and information. A crucial question in this context refers to the criteria by which firms select other actors to engage in this exchange. Cantner and Meder (2007) show that actors are more likely to cooperate when they differ at least to some degree in their knowledge bases, when the respective amount of knowledge received form the partner is comparably high, and when reciprocity is given, that is both benefit by the exchange.

These findings on the firm level can now be applied to the regional level of the RIS. There one observes that research activities with respect to their intensity and design are not equally distributed in space. These differences "can be more or less completely explained by R&D spillovers" (Fritsch and Franke, 2004, p.253). The intensity of regional R&D spillovers in turn is determined by the number of actors involved and their incentives to engage in knowledge exchange and networking.

Thus, regional differences in the affinities to cooperate in innovation and to exchange know-how may first be explained by the size of knowledge base available in a region. The more technological knowledge available in a region the more it may pay to search for a cooperation partner and to exchange-knowledge. This leads to the following hypothesis:

> H1: The degree of regional effects on cooperative innovation activities in innovating depends positively on the amount of knowledge available within the region.

In addition to this, however, for a beneficial exchange of knowledge it is required that each cooperation partner understands the knowledge he "receives". In this sense the regional knowledge pool has an individual value (Cantner and Meder, 2007) for all firms acting in this region. Assuming the case that the firms in a region hold highly idiosyncratic knowledge - that is the regional knowledge base is highly heterogeneous. In this case a firm's ability to understand and integrate others knowledge is rather low or there may be even no common understanding so that this value is zero for all firms. Hence, for a positive value the knowledge bases of the potential cooperation partners have to have some technological overlap (Mowery et al., 1998) in their knowledge bases and accordingly the regional knowledge base should show some homogeneity. As mentioned the path dependent nature of knowledge accumulation just provides for heterogeneity (Combs and Ketchen, 1999). According to Breschi et al. (2003) span innovative activities, like research cooperation, out of technologies innovators are currently involved in. This is due to the fact that learning over time generates knowledge which is close to the existing one and opens new opportunities for innovations. With respect to research cooperations this implies that with knowledge bases too dissimilar firms incentive to engage in the exchange of knowledge is low. On the other hand as the knowledge is seen as a rare and valuable firm asset (Barney, 1991) disadvantages in terms of involuntary knowledge flows can occur if the knowledge bases are too close related. More precisely, Mowery et al. (1998) and Wuyts et al. (2005) show on firm level analyses that the incentives to cooperate decreases if the knowledge bases of potential cooperation partner are too similar.

Based on this the following hypotheses are suggested:

H2a: The more related the regional knowledge base the higher the regional effects on cooperation innovation activities.

H2b: If the related variety of the regional knowledge base comes too close, the positive effect is dominated by disadvantages of possible knowledge drain and, thus, the effect on the strength of the regional innovation systems gets negative.

Breschi et al. (2003) show that the cumulation and relatedness of knowledge enhance innovative activities independently but that there is an additional effect if both dimensions of knowledge exist strongly at the same time. According the analysis of regional effects of cooperative behavior this implies the following hypothesis:

H3: The combination of amount and relatedness of the regional knowledge called the regional knowledge base affects the regional effects in cooperation behavior positively.

3 Methodology

3.1 Data sources and regional boundary

In order to test the hypotheses above we draw on two data sources which allow us to describe the regions under investigation. First, information about patents that are filed for Germany between 1994 and 2003 are provided from the German patent office. The second data source, taken from the German Federal Statistical Office, contains information about German inhabitants and GDP data on the regional level. The data are comprised to a panel data set including five 2-year-periods.

A first consideration refers to defining regional boundaries. A conceptual problem arises here as unified definitions of the RIS-approach are missing. Thus any empirical research on Regional innovation systems has to define the regional boundaries. As Cooke (2001) mentioned a region as a political unit above local and below federal units, we follow Fritsch and Franke (2004), who made an analysis of differences in the regional research efficiency, by using German planning regions (Raumordnungsregionen; ROR) as regional boundaries. These units defined by the "Bundesamt für Bauwesen und Raumordnung" (BBR) divide the federal states of Germany, the Bundeslnder, into 97 subunits. Our database contains information about those 97 regions between 1994 and 2003.

A second consideration refers to the usage of patent data. We use patent data in a threefold way, (a) for describing the interaction structure within a region, (b) for taking account of the regional technological performance, and (c) for the regional knowledge base. For that we use all the patents applied for by firms belonging to the same ROR region. We are aware of a controversial debate on the quality patent data possess to indicate the innovative output of firms, regions, networks or whatever.

As to (a) firm patents are suited to characterize the technological knowledge base of that firm and in this sense also indicate whether that firm is attractive for other firms to cooperate and exchange know-how. Two qualifications are obvious here. First, patent data do not represent the complete knowledge base of a firm, but they are a reasonably good indicator for her technological competitive advantages. In this sense patents satisfy the criteria Combs and Ketchen (1999) have claimed for competitive relevant resources: they are supposed to be rare, as well as valuable and specific in their nature. Second, other incentives influencing the choice of the

cooperation partner likewise exist. However, for our broad German-wide analysis firm structure variables as size, age or industry, first are not available or second are difficult to combine with the patent data we use.

As to (b) and (c) Griliches (1990) has shown that patents are sufficient indicator for the innovative output of firms. Acs et al. state that patents provide a fairly reliable indicator measure of innovative activities (Acs et al., 2002, p.1080). This reliability is restricted to technological innovations and has some shortcomings in regression fitness. Of course there some sceptical papers about using patents as innovative output measure (e.g. Encaoua et al., 2006). They mainly criticize the restricted manner of patents in comparison to the wide range of different types of innovation. Following Edquist (2001), process or organizational innovations are also part of the innovation system, but are not captured by counting patents. Nevertheless, we assume patents as a sufficient indicator for the innovative success of regions. And in the sense that innovation is knowledge driven phenomena where a firm cannot file for a patent without the appropriate knowledge, we conclude that patents are also an indicator for the knowledge base of a region.

3.2 Measuring regional effects on cooperative innovation activities

Our main focus in this paper is on regional effects on cooperative innovation activities, or put more precisely, we are interested in whether features of the regional knowledge base have an impact on differences of cooperative innovation among regions. The easiest indicator for the latter is to take the number of regional cooperation, measured in whatever way. To avoid systematic discrepancies through level effects, the ratio between cooperations and innovations can be used as an indicator of regional cooperation behavior.

Considering the existence of two concepts of innovation systems, regional and technological innovation systems, at the same point in time and space, these rough indicators seems, however, to be insufficient. In order to avoid misinterpretations of differences in cooperation behavior among regions that are in fact driven by technological effects, we apply now a methodology how the measure differences in the regional cooperative innovation where technological effects are absent.

Thus, differences of cooperative innovation among technologies are a core assumption of this paper. To apply this methodology information about the technological and regional distribution as well as information about the number of actors involved are required for each innovation. Although we will use patent data for applying this method to test our hypotheses, it can be applied to other kind of data bases where this information is given, like firm survey data for example.

Before describing single steps of this method, the required information are related to the available patent data. First, information about the technological space a patent is concerned with is gathered from the "International Patent Classification" (IPC) code which are listed on each patent document. This classification allows a detailed view on certain technologies, but it is much too widespread to be used in our analysis. Therefore, we use a concordance list developed by Schmoch et al. (2003) in order to reduce the widespread IPC to 43 technological fields which are related to NACE industry code on 2- and 3-digit-level. The registration procedure at the EPO or DPA allows listing more than one IPC on a patent application[1]. Thus,

[1] These listed IPCs are differentiated by one main and several sub-classes. We do not follow this differentiation here and, therefore, we weight all listed classes equally.

more than one technological field can be listed on a patent document. In this case the patent is equally distributed over all involved technological fields.

The regional distribution is based on the inventor addresses listed on a patent document. As especially larger firms (like Siemens) or research institutes (like Fraunhofer or Max-Planck-Institutes) commonly file for a patent using the address of the headquarters, we do not use the applicant addresses for regional distribution. Comparable to the technological distribution, it is possible that a patentable improvement has been developed by inventors located in more than one region. In this case the patent is allocated to a region according to the share of inventors located there. The final information which is required to apply our methodology is on the collaborative nature of an innovation. Regarding to the given data base, a cooperation is defined as a co-application of a patent by at least two economic actors.

The methodology to be introduced includes three steps. First, the cooperation propensity of each technology is calculated by dividing the total number of cooperations by the total number of innovations within a technology. This first step accounts of specific technological effects whose impact on the cooperative innovation is assumed.

In the second step, the innovations are assigned to the regions of their inventors. This distribution reflects to technological endowment of each region. This endowment is used in a third step to calculate an *expected cooperation value*. This value indicates to number of cooperations that can be expected within a region due to the number of innovations in each technology for this region and the respective cooperation propensities for these technologies which have been calculated in the first step.

In the final step, for each region the number of observed cooperation is divided by the expected cooperation value. This calculated ratio indicates the *"relative regional impact (RRI) on cooperative innovation"*. The RRI values show whether the regional effects are below or above the German wide average with an absence of technological effects at all. We can not measure the regional values themselves, but this RRI value indicates how strong the strengths of the regional effects differ among German regions. In the case that all values are more or less equal to one, the conclusion would be that the strength is always the same and that differences in the cooperative innovation respectively the innovative success among regions are only due to differences in the regional endowment. Furthermore, this RRI has the advantage of being size independent and it is independent of the data base which is used.

3.3 Measuring the size and related variety of regional knowledge bases

The main aim of this paper is to detect the impact of the regional knowledge base and its related variety to regional effects of cooperative behavior. This subsection deals with the quantification of the former.

Following recent literature on the learning economy, both dimensions of the regional knowledge base have a positive impact on the innovative success of the regional innovation system[2]. Thus, we assumed in our hypotheses that both dimensions affect positively the regional effects of cooperative behavior.

[2] Breschi et al. (2003) use the terms "*cumulativeness and proximity*" for both dimensions. We consider these as equivalent to size and related variety of the regional knowledge base.

The cumulativeness or, in our terms, the size of regional knowledge, is measured in number of patent applications *(ln(App))*. According to the resource-based-view concept, knowledge is developed in a path dependent process (Combs and Ketchen, 1999). Taking this into account, the amount of valuable knowledge available within a region is indicated by the innovative success of its actors in the former period *t*-1. To avoid influences of extreme values we use the natural logarithm of the number of patents. We are aware of the simplification we use to indicate the amount of the regional knowledge base. Although their later economics value will be very different, all patents are weighted equally.

The second relevant dimension of knowledge affecting regional effects of cooperative behavior is the related variety of the knowledge base. In our analysis the actors can file for patents in 43 different technologies. To indicate how easily one regional actor can participate on the amount of regional knowledge, it is first necessary to analyze how related are these technologies in general and to apply this general relatedness to the knowledge available within a certain region. We use the Cosine index ($Cosine_t$) concept to evaluate the relatedness of the 43 technological fields. Therefore, we generate a 43x43 matrix including values of the relatedness of all technologies available using this concept at time t–1. This index measures the closeness ($cosine_{ij}$) among technological fields i and j which does not depend on the number of patents[3]. It measures the *angular separation between the vectors representing the co-occurrences of technological classes* App_i *and* App_k (Breschi et al., 2003, p.13).

$$Co\sin e_{ik} = \frac{\sum_{l=1}^{43} App_{il} * App_{kl}}{(\sqrt{\sum_{l=1}^{43} App_{il}^2})\sqrt{\sum_{l=1}^{43} App_{kl}^2}} \quad (1)$$

Typically, $Cosine_{ik}$ is a relatedness measure with a positive value and may be thought of as the strength of technological relationship between technologies i and k, or relatedness (Nesta 2005). Ronde and Hussler (2005) argue that a Cosine index value above 0.25 indicates a technological neighborhood of two technologies. The table in appendix B all cosine values are presented for the year 1999. Technological field 8 (Petroleum products) seems to be an essential chemical input for several other products, because it shows the highest average relatedness to other fields. Energy machinery (Field 20) and motor vehicles (41) show the highest relatedness (0.422) in comparison to all other possible combination of technologies.

After calculating the relatedness of technological fields in general, information about specific related variety of each regional knowledge base are required for testing our hypotheses. Therefore, in a first step the shares of all technologies on the whole regional endowments are calculated. Then, the product of the shares of technology i and k is multiplied with the general cosine value $Cosine_{ij}$. Finally, this product is added for all combinations for each region j for each time period t. These three steps are summarized in equation 2.

$$Cos_{jt} = \sum_{i=1}^{43}\sum_{k=1}^{43} Co\sin e_{ikt} * \left(\frac{\mathrm{Re}\,g - Appl_{ijt} * \mathrm{Re}\,g - Appl_{kjt}}{\mathrm{Re}\,g - Appl_{jt}} \right) \quad (2)$$

[3] For a detailed description of this index, please see Breschi et al. (2003).

Each value of Cos_{jt} is strictly positive and the higher the more related the regional knowledge base in a certain region is.

In a final step, according to hypothesis H3, the amount $(ln(App)_{jt})$ and the indicator of the related variety of a region (Cos_{jt}) are combined through multiplication. The new variable QKB_{jt} indicates what we called the quality of the regional knowledge base, because it conjoins both dimensions of knowledge Breschi et al. (2003) have claimed as relevant with respect to the regional effects on cooperative innovation.

$$QKB_{jt} = \ln(App)_{jt} * Cos_{jt} \tag{3}$$

3.4 Control variables

Population density (Density)

Starting in the early nineties of the last century, a vast quantity of empirical research has accumulated on the issue of agglomeration externalities (Raspe and van Oort, 2006). A general statement in this body of literature is that agglomeration areas have an advantage for innovative success and economic growth in comparison the rural areas. This advantage is based on hard factors like a better infrastructure as well as on soft factors like an easier recruitment of external high-qualified employees (Acs, 2002). Thus, we expect a positive relationship between the population density and the strength of the regional innovation system. In order to account for agglomeration effects independently of patent activities we include the number of inhabitants per square kilometer as control variable. These data are gathered from statistics of the German Federal Statistic Office.

GDP per capita (GDP)

Over fifteen years after unification the former socialist parts of Germany are still lagging behind considerably in their economic potential, although large subsidies are still transferred from the western part of Germany (Roehl, 2000). Fritsch and Mallok (2002) show, that the way how the existing physical capital stock is used differs between both parts of Germany. To account for the existence of these two growth regimes (Fritsch, 2004) and to test for the presence of a catch-up process in Eastern Germany, we include the GDP per capita (GDP). As we will later on use dynamic panel data estimations a time invariant dummy variable would be an inappropriate indicator.

Dummy for dot-com bubble (Dot–com–bubble)

The "dot-com bubble" was a speculative bubble covering roughly 1995–2001 during which stock markets in Germany as well as in other countries of the Western hemisphere saw their value increase rapidly from growth in the new Internet sector and related fields. The period was marked by the founding (and, in many cases, spectacular failure) of a group of new internet-based companies commonly referred to as dot-coms. The bursting of the dot-com bubble in 2001 marked the beginning of a relatively mild yet rather lengthy early 2000s recession in the developed world. We account for this development on the stock market and at least in the whole economy by including a binary variable which has a value of 1 in the last period (2002–2003) and 0 otherwise.

3.5 Descriptive statistics

The strength of the regional innovation system indicated by RRI is in fact an indicator of the differences in the strength of the regional innovation system. Therefore, the RRI values fluctuates around 1 and the natural logarithm of these values around 0. The mean of RRI, which is shown in table 1, is slightly above 0 while the median is below 0. This implies that there are more extreme high values and relatively few extreme low values. More precisely, the majority of all regions are cooperating less than expected, but there are some regions with an extraordinary high cooperative behavior.

Table 1: Descriptive Statistics. Pooled Sample

Variable	Explanation	Obs	Mean	Median	Std. Dev.	Min	Max
ln(RRI)	The natural logarithm of the ratio between real and expected amount of regional cooperations which are measured in number of co-applications. The expected amount of regional cooperations is composed of the cooperation propensity per technological field in general and the patent application behavior of the regional actors.	485	0.01	-0.03	0.50	-2.28	1.61
ln(Pa)	The natural logarithm of the number of regional patent applications indicating the amount of valuable knowledge available within the region.	485	5.864	5.927	1.107	2.428	8.822
Cos	This variable indicates the related variety of knowledge available within a region. It is the sum of all products between the general relatedness between two technologies and the product of their shares of patent applications within a region.	485	0.118	0.109	0.033	0.082	0.31
QKB	This variable called "knowledge base" is an indicator for the quality of the regional knowledge base and the product of cos and ln(Pa)	485	0.699	0.635	0.272	0.37	2.397
Density	The number of inhabitants per square kilometer. (rounded values	485	328	179	492	49	3889
GDP	The Gross domestic product measured in mio. Euro per inhabitant.	485	22.5	22.3	5.4	9.0	44.9
Dot-com-bubble	Dummy variable for the last period	485	0.2	0	0.401	0	1

The regional knowledge base is measured according its size *(ln(Pa))* 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 patent (6780) have been filed for in the third period in Stuttgart in Baden-Württemberg (ROR 72). The highest related variety (0.31) was observed for the region Braunschweig (strong automobile cluster) in Lower Saxonia (ROR 22) in the fourth period. The regional knowledge base of Hochrhein-Bodensee (ROR 78) has the lowest related variety value (0.082) in the fifth period. The quality of the regional knowl-

edge base variable *(QKB)* which is the product of *ln(Pa)* and *Cos* shows the highest value (2.397) again in Braunschweig.

Berlin (ROR 30) has the most inhabitants per square kilometer (3889) and the region of Vorpommern in Mecklenburg-Western Pomerania (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, but with exception like 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. The third control variable *Dot-com-bubble* is only included for the sake of completeness.

4 Empirical tests

The hypotheses made in section 2 will be tested with the data base introduced in the former section. There, it was already mentioned that it is a panel data set which implies specific requirements to the used estimation models. Innovation development in general is a dynamic process, so we have to take time lags between dependent and independent variables into account. We assume that the actor's decisions are made with the knowledge of features from the last period. Thus, the *RRI* indicating the regional effects on cooperative innovation activities depends on regional characteristics of period t–1. To test for these relationships we are using a dynamic panel-data model based on Arellano and Bover (1995) and Blundell and Bond (1998). This model is based on Arellano and Bond (1991) who developed a "Generalized Method of Moments"-estimator that treats the model as a system of equations, one for each time period. The equations differ only in their instrument/moment condition sets. The predetermined and endogenous variables in first differences are instrumented with suitable lags of their own levels. Blundell and Bond (1998) show that the widely used linear generalized method of moments (GMM) estimators are biased on show poor precision for certain panel data structures. These distortions of the estimators occur for data sets where the autoregressive parameter is moderately large and the number of time series observations is moderately small (Blundell and Bond, 1998, p.115). They propose an extended linear GMM estimator that uses lagged differences as instruments for equations in levels, in addition to lagged levels as instruments for equations in first differences according to Arellano and Bover (1995). This estimator shows for panel data sets with 100 observations and 4 time periods a dramatic improvement on the performance of the usual first-difference GMM estimator. The data set used in this paper includes 97 observations over five periods. Therefore, we have to test first a test for serial correlation to decide about an appropriate estimator to test our hypotheses. We use a method described by Wooldrige (2002) which performs a Wald test of the null hypothesis of no serial the residuals from the regression of the first-differenced variables should have an autocorrelation of -.5. This null hypothesis for *RRI* can be rejected with an error probability of 0.008, so we conclude that the variable indicating the strength of a regional innovation system follows a path in its development. Thus, we apply a so called Arellano-Bover/Blundell-Bond linear dynamic panel-data estimation which is a system estimator that uses additional moment conditions based on the work of Blundell and Bond (1998).

The system GMM estimations are presented in Table 2. To test the validity of the instruments we apply a Sargan test for each regression model which tests for overidentifying restrictions. The hypothesis being tested with the Sargan test is that the instrumental variables are uncorrelated to some set of residuals, and therefore they are acceptable, healthy, instruments. If the

null hypothesis is confirmed statistically (that is, not rejected), the instruments pass the test; they are valid by this criterion. This requirement is fulfilled for all five system GMM estimations. A second test we run to show the structure and quality of our models we run Arellano-Bond tests for serial correlation in the first-differenced residuals. The moment conditions of these GMM estimators are valid only if there is no serial correlation in the idiosyncratic errors (Arellano and Bond, 1991). Because the first difference of white noise is necessarily autocorrelated, we need only concern ourselves with second and higher autocorrelation. The high p-values for the AR(2) in Table 2 suggest that there are no problems of AR(2) errors in our estimation models.

Table 2: Estimation results

model	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**
dep. Var.	**System GMM** ***ln(RRI)***	**System GMM** ***ln(RRI)***	**System GMM** ***ln(RRI)***	**System GMM** ***ln(RRI)***	**System GMM** ***ln(RRI)***	**OLS** ***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)	
$ln(Pa)_{t-1}$			0.122 (0.49)			
Cos_{t-1}				9.012** (0.029)		
Cos^2_{t-1}				-24.85* (0.067)		
QKB_{t-1}					1.319* (0.053)	-0.067 (0.914)
QKB^2_{t-1}					-0.521** (0.037)	-0.022 (0.918)
$density_t$		-0.001* (0.068)	-0.001* (0.070)	-0.001* (0.057)	-0.001** (0.025)	-0.003 (0.114)
GDP_t		0.015 (0.23)	-0.004 (0.89)	-0.007 (0.65)	0.001 (0.97)	0.001 (0.76)
D_2002		0.046 (0.38)	0.061 (0.29)	0.063 (0.25)	0.062 (0.25)	0.061 (0.28)
Intercept						0.664 (0.35)
			p - values			
Sargan test	0.223	0.268	0.311	0.504	0.442	
serial auto-correlation						
AR(1)	0.000	0.000	0.000	0.000	0.000	
AR(2)	0.833	0.921	0.891	0.881	0.810	
Observations	383	383	485	383	383	383
Number of ror	97	97	97	97	97	97
Robust z statistics in parentheses		*** p < 0.01, ** p < 0.05, * p < 0.1				

Our primary interest is to elucidate the nature of the statistical relationship between the regional knowledge base according to two dimensions and the interaction structure of the regional innovation system. More precisely, we want to know whether the related variety of the knowledge base affects the strength of the regional interaction system.

An actor who is willing to cooperate has to offer valuable knowable by himself to become an attractive research partner, as we have show in an analysis on firm level basis (Cantner and Meder, 2007). Transferring this insight to a regional level, we assume that a large amount of valuable knowledge which is available within a region increases the incentives to cooperate of regional actors. This assumption is contributed by suggestions of the learning economy approach where innovative activities like cooperation in research and development are determined among other things by the cumulative base of knowledge (Lundvall, 1992; Sharpe and Martinez-Fernandez, 2006). Concerning this approach, an actor recognizes the potential external knowledge base in his surrounding and the more external knowledge is accessible, the more this actor is willing to participate in it. Analyzing this relationship we have to take into account a time lag between the knowledge base available in the region and the engagement within a research cooperation. Therefore, as already mentioned before, the regional effects of cooperation behavior $(ln(RRI)_t)$ depends on the knowledge amount $ln(Pa)_{t-1}$, its related variety Cos_{t-1} and its regional knowledge base QKB_{t-1} of the former time period.

In Table 2 we use system GMM estimator to test for the hypotheses H1, H2a, H2b and H3. The first regression model (M1) shows once more the endogeneity effects that are given for the dependent variable $ln(RRI)_t$. The lagged dependent variable $ln(RRI)_{t-1}$ has significant positive impact on the dependent variable.

In the regression model the three control variables are included. The coefficients of *density* show a weak significant negative influence on the dependent variable. These results for all system GMM estimations do not contribute the literature dealing with agglomeration effects like Acs et al. (2002); Sorenson et al. (2006) or Bettencourt etal. (2007). Neither *GDP* nor the dummy variable for the last period show a significant influence on the strength of the regional innovation system variable. So we find no differences between East and West Germany (*GDP*) and no structural break for the last period.

The third regression model refers to hypothesis H1. Although the coefficient of the variable indicating the available regional knowledge *ln(Pa)* has a positive sign, as it has no significant influence on regional effects of cooperative behavior we cannot reject the null hypothesis that there is no relationship between both variables for this data base. So we have to reject hypothesis H1 for our sample. This finding is contrary to results in other empirical studies like Fritsch and Franke (2004) or Asheim and Gertler (2004) and the theoretical statements made by the learning economy approach (e.g. Lundvall, 2004, 2006). One possible explanation of this non-significance could be the mention by Jaffe (1986) and Griliches (1990) who suggest that such using count patent data as regional knowledge base is a too rough measure and therefore not appropriate. We try to find a more convenient measure of the regional knowledge base with including information about the related variety of the regional knowledge base.

So the main focus of this paper is on the hypotheses H2a and H2b. The findings are embodied in the coefficients of Cos_{t-1} in the regression model M4 to test for hypothesis H1a and in the coefficients of Cos^2_{t-1} to test for the inverted-U relationship as assumed in hypothesis H2b. The coefficient of the linear cosine term is significant positive, so we can not reject hypothesis H2a for our sample. This finding contributes suggestions by studies dealing with the learning economy approach (Breschi et al., 2003; Lundvall, 2004) as well as empirical studies on firm level (Mowery et al., 1998; Wuyts et al., 2005). In H2b we assume that the relationship between the related variety of the regional knowledge base and the strength of the regional innovation system is not a strict positive one as the negative effects of a too similar knowledge base can dominate the positive effects if the related variety indicator exceeds a certain

threshold. To test for this, we include in model M4 a squared term for *Cos* called Cos^2. The inverted-U relationship which is assumed in hypothesis H2b is given in our data the linear term has to be positive and the squared term has to show a negative coefficient. The results for model M4 presented in Table 2 show these assumed signs. So we cannot reject hypothesis H2b for our sample. This finding is in a line with existing empirical studies on firm level (Mowery et al., 1998; Wuyts et al., 2005; Cantner and Meder, 2007). The alluded threshold from which on the relationship turns out to be negative is for our sample around 0.182. This threshold is exceeded by 8 regions in at least one period. The left graphic in figure 1 present this relationship without absolute term so that the values for *ln(RRI)* are strictly positive but the maximum of the curve is not affected by this.

Finally, we follow in hypothesis H3 the argumentation of Breschi et al. (2003) that the combination of both dimensions of the regional knowledge base. Therefore, the product of *ln(Pa)* and *Cos* representing the regional knowledge base *(QKB)* is introduced into the model in M5. As the linear term is positive and significant and the squared term has a negative significant coefficient, we cannot reject hypothesis H3 on the influence of the structure of the regional knowledge base on the strength of the regional innovation system. The relationship between the regional knowledge base variables (*QKB* and QKB^2) and *ln(RRI)* is shown in the right graphic of Figure 1. So we find evidences for the arguments Breschi et al. (2003) made about the importance of two dimensions of the regional knowledge base on the interaction structure.

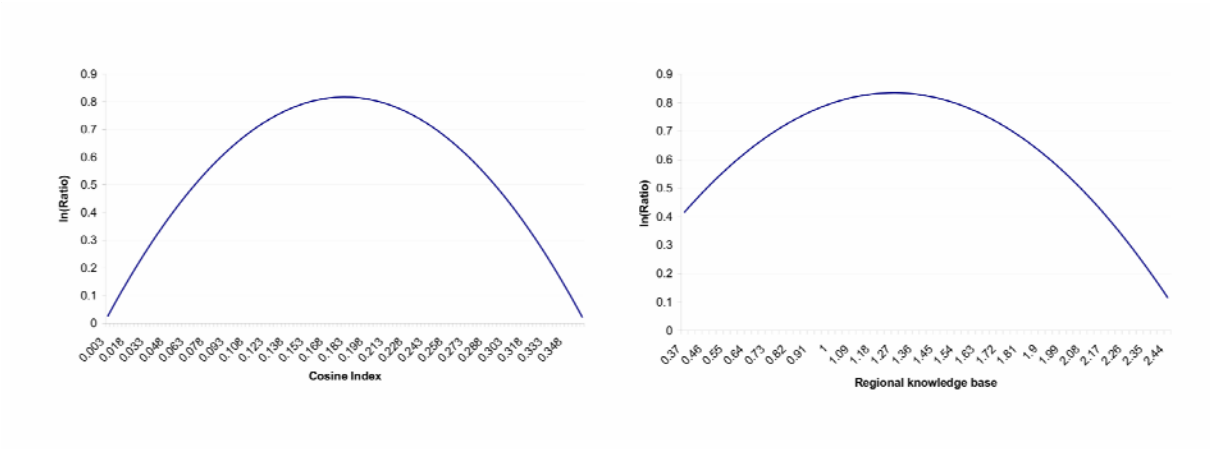

Figure 1: Relationships between the related variety (left side) and the quality of the regional knowledge base (right) and strength of regional innovation system

Again, we find for the regional knowledge base an inverted-U influence on the strength of the regional innovation system (*ln(RRI)*). For our empirical model *QKB* has its maximum in 1.27, as it is shown in the right graphic of Figure 1. As the mean (0.699) as well as the median value (0.635) of *QKB* are below this value, we can conclude that for the majority of our sample the positive influence of a larger and more related knowledge base on the strength of the regional innovation system is given.

5 Concluding remarks

This paper contains an analytical and empirical exploration of the RIS approach. The main objective is to explore the effects of the regional knowledge base and its characteristics on the strength of the regional innovation system. Following the literature on system approaches, the increase of interactions as relations connecting the entities of a system is the principal goal of

a regional innovation system. Based on the analysis of regional development in Germany, the following conclusions can be drawn with respect to the theoretical assumptions:

1 For regional cooperative activities in terms of regional co-application, we find evidences for positive but not significant influence of the amount of knowledge present with the region.

2 Contrary, the related variety of the knowledge base indicated by a method based on the Cosine index concept does affect the strength of the regional innovation system significantly.

3 The combination of both indicators representing the overall regional knowledge base has an inverted-U influence on the strength of the regional innovation system.

As we are mainly interested in explaining the strength of the regional innovation system with the regional knowledge base available within the region, we combine theoretical and empirical results mainly of firm level analysis with the RIS approach. As knowledge is a factor affecting the competitiveness of firms and regions, we have to take into account the nature of knowledge and its development over time more seriously.

With this German wide analysis we are going an unusual way of RIS analysis. Recent literature emphasizes the importance of institutions and regional specifities, factors which we have totally neglected in this study. This makes an objective analysis of more than a few regions quite difficult. So mainly empirical studies are concentrating on comparing a couple of preselected regions in order to cover regional institutions and specificizes (e.g. Sternberg, 2000; Doloreux and Parto, 2005; Asheim and Gertler, 2004; Sharpe and Martinez-Fernandez, 2006). We attempt to find evidence on a more abstract and general level. Of course, doing so, we can not include much information that might explain the interaction within the regional innovation system in certain regions, as do results stemming from case studies. Nevertheless, we have found general results from an economic point of view if the regional innovation systems approaches will be considered seriously. Beside the methodological improvements the general view is one main advantage of this paper, at least in our opinion.

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Appendix

A Concept of Ratio value

In this section we introduce a method to exclude technological effects of cooperation behavior in order to extract pure regional effects of cooperation behavior. Later on, we will apply this methodology to a time series data base. But as this concept does not include any time delays yet, we skipped for simplification all time indices t.

A.1 Given Information

Innovations differ in economic literature in several dimensions. Following both concepts of systems of innovation respective distinctive information is of interest: First, all innovations $N = \{1,...,n\}$ among a technological space $F = \{1,..,f\}$ which is divided into f different fields. Here it is possible that innovation $i \in N$ affects more than one technology j *in* F. Further information of interest in dealing with the system of innovation approaches is a spatial differentiation of novelty. As a second dimension, beside a technological space, a spatial space in terms of regions $R = \{1,..,r\}$ is introduced. Here it is possible that the R&D activities for innovation i have taken place in more than one region $k \in R$. This is either due to actor-internal cooperations (e.g. cooperation between two branches) or it is due to cooperation between independent actors located in different regions. In order to distinguish between both possibilities information about the number of actors involved in the R&D process of innovation i are included.

According to this information the following data are included in the analysis:

Information about the technological space F all innovations N have been developed in are summarized in the $n \times f$-matrix **A**.

A is a $n \times f$ matrix with a typical element:

$$a_{ij} = \begin{cases} 1 \; if \;\; innovation\, i \; has \; been \; developed \; in \; techonology \;\; j \\ 0 \qquad\qquad\qquad otherwise \end{cases} \tag{4}$$

As a second dimension of diversity between innovations, the spatial distribution are described in the $n \times r$-matrix **B**. Here all innovations N are distributed over all regions R.

B is a $n \times r$ matrix with a typical element:

$$b_{ij} = \begin{cases} 1 \; if \;\; innovation\, i \; has \; been \; developed \; by \; actors \; located \; in \; region \; r \\ 0 \qquad\qquad\qquad\qquad\qquad otherwise \end{cases} \tag{5}$$

A spatial distribution of one innovation i occurs if different research groups cooperated in a R&D project resulting in innovation i. Whether these research groups work for the same economic actor (e.g. rms or universities) is indicated in vector $\boldsymbol{\gamma}$ which has a length of n.

$\boldsymbol{\gamma}$ is a vector of length n with a typical element:

$$\gamma_i = \begin{cases} 1 \quad if \;\; innovation\, i \; has \; been \; developed \; by \; more \; than \; one \; actor \\ 0 \qquad\qquad\qquad\qquad otherwise \end{cases} \tag{6}$$

These given information are used to detect regional effects of cooperation behavior in contrast to technological effects of cooperation behavior. Thus, in the next step activities among technologies are observed.

A.2 Activities among technologies

This subsection is the first methodological step in detecting regional effects of cooperation behavior. Here, the technological dimension of innovations is analyzed in order to indicate conventional innovating and cooperating behavior among technologies.

First, the innovating activities are weighted among technologies. The information included in matrix **A** are unweighted values. Now, these values become weighted in matrix $\mathbf{A}^{\omega}$.

$\mathbf{A}^{\omega}$ is a $n \times f$ matrix with a typical element:

$$a_{ij}^{\omega} = \frac{a_{ij}}{\sum_{h=1}^{f} a_{ih}} \tag{7}$$

In order to distinguish between innovative and cooperative activities among technologies, each row of this weighted matrix $\mathbf{A}^{\omega}$, including data about each innovation i is multiplied with the corresponding value of vector γ. The result is a $n \times f$-matrix $\mathbf{A}^{\omega c}$, comprising data about the technological distribution of cooperations between independent actors.

$\mathbf{A}^{\omega c}$ is a $n \times f$ matrix with a typical element:

$$a_{ij}^{\omega c} = \begin{cases} \dfrac{a_{ij}^{\omega} \times \gamma_i}{\sum_{h=1}^{f} a_{ih}^{\omega} \times \gamma_i} & if\ \gamma_i = 1 \\ 0 & otherwise \end{cases} \tag{8}$$

Both matrixes are now used to determine average cooperation behavior among technologies. Vector $\mathbf{p}^{c}$ has a length of f and indicates the cooperation propensity of each observed technology. We assume that there is at least one innovation in each technology.

Therefore, we do not quote different cases in equation (9)

$\mathbf{p}^{c}$ is a vector of length f with a typical element:

$$p_j^{c} = \frac{\sum_{i=1}^{n} a_{ij}^{\omega c}}{\sum_{i=1}^{n} a_{ij}^{\omega}} \tag{9}$$

A.3 Regional innovative and cooperative behavior

After allocating innovations and cooperations among the technological space we introduce now a second dimension of interest in the systems of innovation approach, the spatial dimension. Similar to the procedure introduced above, all innovation are weighted by the quantity of regions $k \in R$ where actors on innovation n have been located.

$\mathbf{B}^{\omega}$ is a $n \times r$ matrix with a typical element:

$$b_{ik}^{\omega} = \frac{b_{ik}}{\sum_{l=1}^{r} b_{il}} \tag{10}$$

Corresponding to the procedure in analyzing the behavior among technologies, matrix **B** is now multiplied cell by cell with vector **γ**, indicating whether innovation has been detected as a cooperation ($\gamma_i = 1$).

$\mathbf{B^{\omega c}}$ is a $n \times r$ matrix with a typical element:

$$b_{ik}^{\omega c} = \begin{cases} \dfrac{b_{ik}^{\omega} \times \gamma_i}{\sum_{l=1}^{r} b_{il}^{\omega} \times \gamma_i} & if\ \gamma_i = 1 \\ 0 & otherwise \end{cases} \tag{11}$$

A.4 Technological and regional activities

In order to analyze regional effects of cooperation behavior we want to exclude conventional technological effects. Thus, both dimensions (technological and spatial) present on each innovation have to be combined in a $r \times f$ matrix $\mathbf{C^{\omega}}$ including information about the no. of innovations *i* that have been developed in technology *j* by actors from region *k*.

$\mathbf{C^{\omega}}$ is a $r \times f$ matrix composed of:

$$C^{\omega} = B^{\omega'} A^{\omega} \tag{12}$$

This multiplication of transposed matrix $\mathbf{B^{\omega}}$ and matrix $\mathbf{A^{\omega}}$ can now be used to create an indicator of what we called "expected cooperation value" (e^c_k) of region *k*. This value indicates how many cooperations could be expected in region *k* according to its innovation behavior. Vector $\mathbf{e^c}$ shows the expected cooperation values for all regions *k*.

$\mathbf{e^c}$ is a vector of length r with a typical element:

$$e_k^c = \sum_{j=1}^{f} c_{kj}^{\omega} \times p_j^c \tag{13}$$

If the number of cooperations within a region is solely affected by technological determinants, which would imply that their are no regional effects of cooperation behavior, this number of cooperations has to be identical to the expected cooperation value for this region. Therefore, in a final step the ratio between real and expected cooperation value is composed. The resulting vector (**v**) has a length of r and includes the ratio values for all regions *k*.

v is a vector of length *r* with a typical element:

$$v_k = \frac{\sum_{i=1}^{n} b_{ik}^{\omega c}}{e_k^c} \tag{14}$$

This ratio value fluctuates between 0 and infinite, whereas a value of 1 indicates that the number cooperations observed in a region fits perfectly with the expected cooperation value. Later on the natural logarithm of this ratio will be used as an indicator of regional effects of cooperation behavior. This ratio value has two advantages. First, it is independent of the data base. We will use patent data to test whether these regional effects of cooperation exist, but this method can be applied to any other data base on innovation activities which includes in-

formation about technology, spatial distribution and cooperations. Second, this indicator is size independent. It is difficult to test for agglomeration effects if just the number of cooperations is observed in a region. Even with using a ratio between cooperation per innovation all differences among technologies are neglected. Because of these advantages, this ratio is as from now used to indicate the strength or weakness of a regional innovation system.

B Differences in the strength of regional innovation systems among Germany

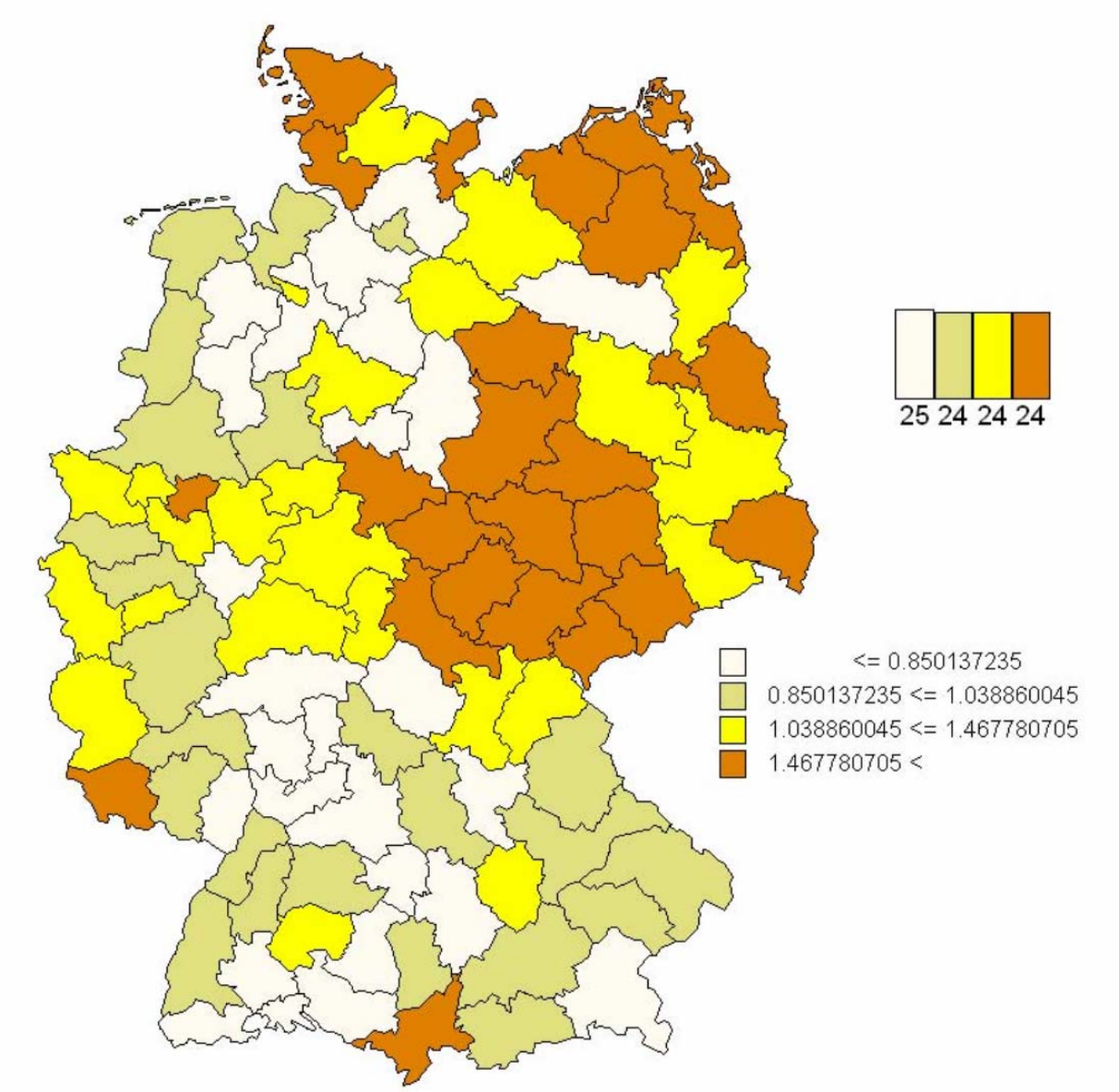

Figure 2: Ratio values 1999

C Tables

Tabelle 3: Relatedness of field numbers (FiNo) for 1999 based on Cosine index

FiNo	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1	0,046	0,111	0,031	0,016	0,028	0,068	0,08	0,203	0,152	0,057	0,269	0,1	0,093	0,106	0,071	0,042	0,038	0,024	0,019	0,097	0,059
2		1	0,061	0,033	0,018	0,021	0,064	0,026	0,026	0,005	0,014	0,007	0,017	0,046	0,034	0,11	0,025	0,034	0,027	0,06	0,054	0,049
3			1	0,161	0,051	0,111	0,213	0,13	0,442	0,169	0,204	0,225	0,215	0,229	0,377	0,141	0,257	0,092	0,059	0,034	0,108	0,079
4				1	0,104	0,055	0,068	0,043	0,086	0,024	0,058	0,027	0,032	0,078	0,085	0,1	0,105	0,056	0,173	0,029	0,06	0,036
5					1	0,026	0,023	0,02	0,039	0,014	0,066	0,015	0,011	0,022	0,033	0,097	0,043	0,034	0,03	0,01	0,05	0,036
6						1	0,088	0,043	0,089	0,021	0,144	0,025	0,022	0,08	0,073	0,11	0,342	0,088	0,157	0,055	0,139	0,042
7							1	0,088	0,208	0,055	0,129	0,076	0,082	0,133	0,14	0,118	0,144	0,066	0,08	0,031	0,082	0,043
8								1	0,303	0,095	0,092	0,147	0,086	0,208	0,158	0,076	0,068	0,065	0,069	0,046	0,156	0,062
9									1	0,331	0,325	0,396	0,289	0,424	0,555	0,175	0,209	0,117	0,071	0,034	0,226	0,099
10										1	0,18	0,555	0,26	0,132	0,153	0,036	0,052	0,023	0,018	0,005	0,053	0,057
11											1	0,096	0,091	0,173	0,194	0,049	0,206	0,045	0,053	0,01	0,054	0,113
12												1	0,278	0,164	0,163	0,039	0,05	0,028	0,016	0,008	0,062	0,046
13													1	0,126	0,159	0,039	0,047	0,034	0,019	0,012	0,051	0,034
14														1	0,236	0,109	0,163	0,094	0,084	0,035	0,131	0,05
15															1	0,121	0,193	0,074	0,044	0,04	0,122	0,072
16																1	0,172	0,17	0,136	0,094	0,136	0,055
17																	1	0,194	0,219	0,046	0,147	0,077
18																		1	0,15	0,068	0,172	0,057
19																			1	0,138	0,128	0,058
20																				1	0,112	0,068
21																					1	0,092
22																						1
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Tabelle 4: Relatedness of field numbers (FiNo) for 1999 based on Cosine index

FiNo	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
1	0,046	0,153	0,011	0,079	0,018	0,018	0,009	0,029	0,014	0,014	0,026	0,008	0,008	0,07	0,052	0,023	0,026	0,008	0,022	0,014	0,023
2	0,029	0,158	0,022	0,023	0,016	0,033	0,018	0,01	0,024	0,024	0,022	0,012	0,008	0,036	0,029	0,032	0,021	0,009	0,113	0,03	0,04
3	0,071	0,277	0,032	0,055	0,028	0,027	0,015	0,07	0,028	0,032	0,049	0,021	0,012	0,065	0,046	0,029	0,047	0,008	0,039	0,029	0,04
4	0,047	0,137	0,051	0,049	0,027	0,029	0,021	0,022	0,037	0,033	0,028	0,033	0,022	0,135	0,031	0,037	0,068	0,031	0,05	0,075	0,265
5	0,014	0,04	0,009	0,024	0,014	0,009	0,01	0,007	0,017	0,011	0,01	0,009	0,011	0,131	0,018	0,043	0,022	0,021	0,01	0,014	0,226
6	0,157	0,11	0,024	0,054	0,019	0,026	0,017	0,025	0,034	0,028	0,031	0,015	0,008	0,04	0,047	0,033	0,034	0,011	0,043	0,035	0,06
7	0,067	0,287	0,025	0,041	0,158	0,03	0,021	0,054	0,034	0,045	0,054	0,061	0,052	0,04	0,061	0,051	0,112	0,051	0,03	0,023	0,058
8	0,057	0,136	0,101	0,047	0,125	0,058	0,046	0,076	0,053	0,183	0,091	0,1	0,068	0,112	0,314	0,138	0,089	0,063	0,112	0,049	0,039
9	0,051	0,193	0,025	0,063	0,052	0,024	0,017	0,163	0,037	0,041	0,084	0,026	0,017	0,107	0,082	0,04	0,08	0,012	0,047	0,032	0,033
10	0,012	0,043	0,005	0,018	0,012	0,004	0,002	0,04	0,009	0,009	0,018	0,004	0,005	0,092	0,045	0,009	0,022	0,004	0,008	0,006	0,012
11	0,023	0,089	0,015	0,021	0,015	0,008	0,004	0,053	0,017	0,012	0,027	0,006	0,006	0,077	0,02	0,009	0,029	0,007	0,009	0,012	0,067
12	0,015	0,059	0,013	0,021	0,027	0,008	0,006	0,048	0,012	0,022	0,032	0,011	0,014	0,137	0,141	0,029	0,041	0,013	0,014	0,009	0,013
13	0,02	0,128	0,008	0,034	0,012	0,009	0,003	0,039	0,009	0,008	0,025	0,005	0,004	0,049	0,025	0,01	0,023	0,002	0,013	0,008	0,01
14	0,061	0,183	0,161	0,038	0,04	0,028	0,025	0,078	0,042	0,034	0,112	0,038	0,038	0,078	0,066	0,041	0,104	0,015	0,056	0,039	0,028
15	0,049	0,225	0,018	0,05	0,03	0,021	0,01	0,087	0,023	0,034	0,047	0,012	0,009	0,067	0,035	0,021	0,048	0,006	0,028	0,021	0,049
16	0,095	0,201	0,037	0,121	0,061	0,051	0,135	0,047	0,076	0,066	0,056	0,065	0,027	0,094	0,085	0,085	0,104	0,031	0,13	0,08	0,1
17	0,11	0,154	0,049	0,088	0,036	0,035	0,03	0,061	0,063	0,049	0,088	0,035	0,017	0,053	0,047	0,036	0,071	0,015	0,051	0,056	0,056
18	0,144	0,194	0,04	0,072	0,037	0,057	0,086	0,039	0,059	0,058	0,107	0,05	0,025	0,052	0,068	0,054	0,08	0,019	0,073	0,069	0,049
19	0,21	0,106	0,056	0,114	0,063	0,111	0,081	0,046	0,091	0,102	0,065	0,068	0,031	0,064	0,072	0,106	0,079	0,049	0,193	0,118	0,133
20	0,134	0,101	0,05	0,082	0,041	0,239	0,059	0,024	0,077	0,081	0,077	0,048	0,023	0,056	0,102	0,111	0,054	0,026	0,422	0,169	0,067
21	0,135	0,217	0,043	0,183	0,049	0,082	0,035	0,05	0,053	0,069	0,071	0,041	0,02	0,094	0,11	0,091	0,051	0,021	0,182	0,114	0,062
22	0,06	0,125	0,022	0,043	0,029	0,04	0,019	0,022	0,031	0,04	0,028	0,02	0,013	0,045	0,064	0,048	0,032	0,021	0,125	0,04	0,031
23	1	0,184	0,033	0,05	0,044	0,063	0,047	0,024	0,033	0,047	0,077	0,059	0,026	0,061	0,092	0,103	0,076	0,028	0,106	0,05	0,035
24		1	0,054	0,079	0,075	0,09	0,031	0,053	0,029	0,046	0,14	0,039	0,035	0,098	0,112	0,079	0,085	0,017	0,072	0,057	0,06
25			1	0,022	0,057	0,039	0,028	0,021	0,044	0,08	0,039	0,053	0,041	0,029	0,132	0,07	0,05	0,04	0,133	0,056	0,045
26				1	0,063	0,069	0,079	0,02	0,132	0,087	0,06	0,063	0,026	0,059	0,081	0,113	0,053	0,065	0,113	0,051	0,12
27					1	0,091	0,093	0,049	0,053	0,232	0,136	0,375	0,328	0,103	0,19	0,276	0,209	0,262	0,108	0,05	0,078
28						1	0,123	0,032	0,079	0,219	0,14	0,125	0,066	0,049	0,115	0,154	0,052	0,05	0,247	0,099	0,045
29							1	0,044	0,132	0,128	0,121	0,264	0,08	0,027	0,098	0,121	0,063	0,091	0,13	0,039	0,035
30								1	0,034	0,069	0,051	0,123	0,05	0,031	0,11	0,066	0,042	0,037	0,057	0,03	0,013
31									1	0,189	0,096	0,08	0,056	0,073	0,095	0,088	0,212	0,046	0,197	0,074	0,074
32										1	0,135	0,275	0,196	0,08	0,277	0,277	0,115	0,154	0,237	0,106	0,048
33											1	0,201	0,103	0,074	0,187	0,157	0,111	0,064	0,095	0,042	0,027
34												1	0,429	0,06	0,184	0,35	0,151	0,273	0,123	0,046	0,047
35													1	0,118	0,154	0,177	0,207	0,16	0,067	0,029	0,036
36														1	0,232	0,105	0,156	0,085	0,054	0,045	0,127
37															1	0,363	0,192	0,149	0,244	0,094	0,046
38																1	0,123	0,169	0,279	0,09	0,052
39																	1	0,105	0,094	0,054	0,065
40																		1	0,081	0,028	0,091
41																			1	0,232	0,091
42																				1	0,067
43																					1