

Regional effects of cooperative behavior and the regional knowledge base*

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Abstract

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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 using patent data in order to distinguish between regional and technological effects of cooperative behavior and analyzes furthermore how different dimensions of regional knowledge affect the regional interaction structure. We find evidence that the amount of knowledge available within a region and its combination with a measure of the relatedness of knowledge foster regional effects of cooperative behavior. Additionally, we can show that the development of German regions fit with the suggestions of the *Regional Innovation System (RIS)* approach.

JEL classification: C30; L14; O32

Keywords: regional development, regional effects of cooperative behavior, knowledge, relatedness of knowledge

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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 & Martinez-Fernandez 2006). Innovations are characterized as new products or processes with a certain economic value (Cooke et al. 2004). Several analytical framework deal with the conditions, requirements and environments of creating and developing innovations.

This paper is focused on the "Regional innovation system" – approach. This concept developed in the last 15 years stress on the importance of regional factors for the innovative capability of firms. Based on a survey of recent literature we conclude that this approach recognize the importance of regional interactions between certain kind of actors, but doesn't explain the individual 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. With using concepts of the learning and knowledge based economy we argue that the regional interactive structure depends on the regional knowledge base and in particular on the heterogeneity of the knowledge present within a region.

The paper is organized as follows. First, a theoretical part, where we introduce the theoretical concepts and the roots of the RIS–approach, is presented. Through a critical survey of theoretical and empirical literature about this topic, we assume three hypotheses. Afterwards, we are concentrating on our methodology where a measure of pure regional effects and a concept of how to measure the dimensions of regional knowledge will be introduced. The results based on this methodology are presented in the last part of the paper.

2 Literature review

This paper attempts to analyze regional innovation systems, their performance, and the factors determining the working and the success of such systems. The increasing popularity of this and related concepts leads to a confusing jungle of definitions, while the presence of such innovation systems in real world remains obscure (Doloreux et al. 2004, p.143). In this section a shaped concept is provided starting with a rather abstract definition of a system. Based on that, we consider systems in the context of innovation and here focus on regional innovation system.

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). There a straightforward solution does not exist as different systems serve different purpose, 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 distinguishing 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 innovation issues acknowledges that the majority of innovative activities are not pursued by individuals in isolation but that innovation is a social

and interactive process, where the behaviour of a single actor is stimulated by his environment (Edquist 2004). Interaction in the context of innovation systems mainly refers to the 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 & 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 but also transfer bureaus. They are developed within the system and further the overall function of an innovation system to finally create and commercialize innovations (Asheim & Coenen 2005). The systemic view of innovation 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 behaviour 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 is a process due to the systems actors. In a nutshell, the principal goal of an innovation system to increase innovative and economic performance of a region is pursued by the systemic interactions (Doloreux 2004, p.483) of various actors.

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 losing any interactions or relations: As Blanchard & 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 & 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 specificities of sectors in terms of a certain knowledge base and key interactions within a sector (Malerba & 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 & Isaksen 2002). The discovery of the importance of regional scale and of regional resources in stimulating the innovative capabilities of firms is the major issue this approach deals with (Asheim & 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 & 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 at 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 & 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 & 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 & 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 specificity 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 & Levinthal (1990) existing knowledge is required to participate in a knowledge base external to the firm, the knowledge base of a region 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. An crucial question in this context refers to the criteria by which firms select other actors to engage in this exchange. Cantner & 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 from 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 & 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:

H1a: The degree of regional effects of cooperative behavior 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 & 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 & Ketchen 1999). According to the 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. Based on this the following hypothesis is suggested:

H1b: The more related the regional knowledge base the higher the regional effects in cooperation behavior.

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:

H1c: The combination of amount and relatedness of the regional knowledge called the regional knowledge base affects the regional effects in cooperation behavior positively.

2.4 Impact of regional interaction in innovating

Having settled the theoretical basis for regional interaction in innovating, in the following we focus on the impact of such kind of relationships on the innovative and the economic performance on the regional level. With respect to regional innovative performance the idea

is as follows: consider two regions which show the same number of innovative agents equally endowed with resources to innovate. In the first region those agents collectively innovate whereas in the second one innovation is based on individual activities. For an innovation system to have an additional impetus on innovative output one would expect the first region to outperform the second region. Following the concepts of the learning economy and the resource-based view interaction in innovating connects the innovative actors within a system. Following Blanchard & Fabrycky (1990) such a system as a whole shows super-additive effects on the innovative performance of the system. And going back to the roots of the RIS concept, (Cooke 2001, p.954) states that the existence of a regional innovation systems depends on its degree of "systemness" within a region, that is the degree by which actors are connected to each other. This interaction structure and consequently the implied collective learning processes have always been considered an important factor of regional innovative performance as a number of empirical studies such as Cooke (2001), Cooke et al. (2004), Fritsch & Franke (2004), Cantner & Graf (2006) show. So we will go in a line with these studies by assuming that the regional innovative performance is directly, positively connected with the regional attitude to learn in a collective way with other regional actors.

H2: There exists a positive relation between the degree of regional interaction in innovating and the innovative performance of that region.

Turning to the relationship between innovative interaction structures and economic performance of regions we refer first to Cooke (2001). There he suggests that a fully functional RIS has to have an outstanding economic performance (Cooke 2001, p.958). Careful reading of Cooke delivers that he suggests that there only three regions in Europe that are real regional innovation systems. We deviate from considering fully functional RIS and follow Doloreux and Parto who state that "arguably all regions, however defined, have some kind of innovation system" (Doloreux & Parto 2005, p.143). Thus, we consider any region to be a RIS although the degree of being a RIS as measured by the the degree of the interaction structure in innovating may differ. In this sense and following the argumentation of recent literature on the RIS-approach a higher regional economic performance is related to a region's ability to collectively innovate. Hypothesis 3 is just on this relationship:

H3: The economic performance of a region or a RIS is positively related to the degree of the interaction structure in innovating.

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 1998 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.

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 & Franke (2004), who made an analysis of differences in the regional research efficiency, by using

German Raumordnungsregionen (ROR) as regional boundaries. These units defined by the "Bundesamt für Bauwesen und Raumordnung" (BBR) divide the federal states of Germany, the Bundesländer, into 97 subunits. Our database contains information about those 97 regions between 1998 and 2003.

A second consideration refers to the usage of patent data. We use patent data in a three-fold 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 & 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 The measurement of regional effects on cooperative behavior

The "System of innovation" approach is divided into two main research interest fields, the technological and regional innovation system – concepts. As the effects of both kinds of systems are present in the economy at the same place in time, it is difficult to distinguish between regional and technological effects on cooperative behavior of actors involved in several systems at the same time. In existing empirical studies on the strength of regional innovation systems regions are often distinguished by the number of co-operations or the share of regional cooperations (Doloreux 2004, Almodovar & Teixeira 2004), which is in our opinion somehow insufficient. In counting the pure number of cooperation researcher in the field of regional innovation systems neglecting the importance of technological determinants affecting the cooperating behavior. We developed a methodology, which will be introduced now, in order to distinguish between regional and technological determinants of co-operation behavior.

This subsection presents a methodology to use patent data to test for "pure regional" effects

concerning the interaction structure exist. First, the information gathered from the patent documents are presented. Afterwards, the steps are introduced briefly¹.

The analysis on regional interaction structure is based on a patent data information. Therefore, we want to explain how the information on patent documents are included into the analysis. As mentioned above, we want to start with a German wide observation of differences in the patenting and cooperation behavior concerning different technologies. Regarding this, the IPC, the international patent classification, which is included in all patent documents is used. 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 classification to 43 technological fields that corresponds with NACE industry codes on a 3-digit level. The registration procedure at the EPO or the DPA allows to list more than one IPC class on a patent. Therefore, it is possible that a patent is classified for more than one technological field according our concordance list. In this case we assume a comparable value in all listed technological field and this patent is counted with an equal degree in all relevant technological fields.

In the first step all German patents are classified into 43 technological fields i for every time period t ($Appl_{it}$). If more than one field is listed on a patent document, the patent is divided into the named fields equally. Doing the same with the co-applications ($Coap_{it}$), which are the research cooperations observed in this paper, and with dividing co-applications through patent applications we get a cooperation propensity ($P(Coap)_{it}$) for every technological i field over time t :

$$P(Coap)_{it} = \frac{Coap_{it}}{Appl_{it}} \quad (1)$$

In a second step each vector of patent application per technological field, which has a length of 43, is spanned out over all regions j in a 43×97 matrix ($Reg - Appl_{ijt}$) for every time period t . The same we are doing with all co-application vectors ($Coap_{it}$) and getting ($Reg - Coap_{ijt}$). With summing up the results of multiplying both matrixes $P(Coap)_{it}$ and $Reg - Appl_{ijt}$, one gets a value of what we called expected cooperation value ($E(Coap)_{jt}$) for every region j and each time period t .

$$E(Coap)_{jt} = \sum_{i=1}^{43} P(Coap)_{it} * Reg - Appl_{ijt} \quad (2)$$

In a final step we compose a ratio ($Ratio_{jt}$) for every region j and time period t between the sum of $Reg - Coap_{ijt}$ over all technological fields and the expected cooperation value ($E(Coap)_{jt}$):

$$Ratio_{jt} = \frac{\sum_{i=1}^{43} Reg - Coap_{ijt}}{E(Coap)_{jt}} \quad (3)$$

This ration enables us to indicate whether the number of regional cooperations is higher ($Ratio_{jt} > 1$) or lower ($Ratio_{jt} < 1$) than one could expect from the regional activities in certain technological fields. We argue that there exist regional effects of cooperative behavior if the ratio values differ between German regions significantly. Figure 1 shows the ratio values for all 97 German Raumordnungsregionen for the year 1999.

It is obvious that there are huge differences between regions in Germany. This value indicates the strength of region innovation systems beyond technological and size effects. We conclude that the ratio index enables us to identify regional effects in a much proper way than the pure counting of co-applications within a region. Furthermore, this index excludes

¹An more explicit description can be found in appendix A.

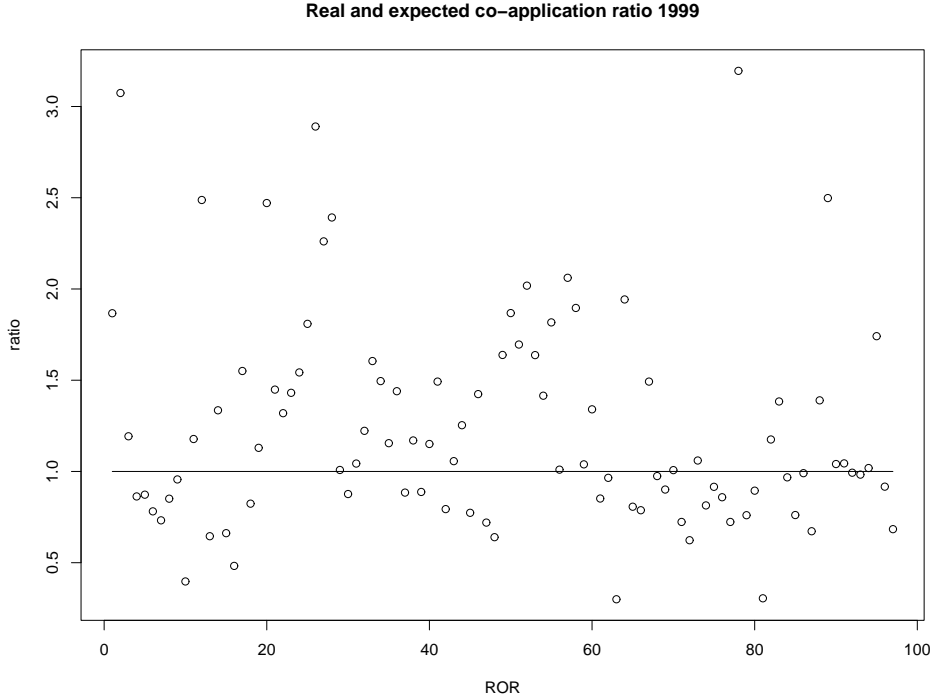


Figure 1: Ratio for 97 regions in 1999

all technological driven effects, so we do not have to check whether there exists a certain technology in a certain region.

To use linear regression models for estimating regional effects on $Ratio_t$ we use the natural logarithm of the ratio value, so this variable fluctuates between minus and plus infinitely.

3.3 Measuring the regional knowledge base

This paper examines the patterns of regional interaction structures and factors affecting the extent of interaction. The basic point of this paper is that a major drive for regional interaction is knowledge. Following the concept of the learning economy (Cooke 2001, Raspe & van Oort 2006) the regional development is affected by two dimensions of knowledge: *cumulativeness and proximity* (Breschi et al. 2003). Both dimensions are captured in our hypotheses.

The cumulativeness or, in our terms, the amount 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 & 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.

The second relevant dimension of knowledge affecting regional effects of cooperative behavior is the relatedness of knowledge. 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 . This index measures the closeness ($cosine_{ij}$) among

technological fields i and j which does not depend on the number of patents². 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).

$$Cosine_{ik} = \frac{\sum_{l=1}^{43} App_{il} * App_{kl}}{(\sqrt{\sum_{l=1}^{43} App_{il}^2})\sqrt{\sum_{l=1}^{43} App_{kl}^2}} \quad (4)$$

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 & Hussler (2005) argue that a Cosine index value above 0.25 indicates a technological neighborhood of two technologies. In table B in appendix B all Cosine values are presented for the year 1999. Some technologies are related to several other technologies, for example Basic chemicals (TF 10) has three technological neighbors whereas others technologies do not have any technological neighbor (e.g. food and beverage (TF 1)).

In order to get an indicator of the relatedness of the knowledge in a certain region we multiplied the cosine matrix with the sum of each shares of each technological fields. The new variable (COS_t) indicates the relatedness of the regional knowledge base for each region j for every time period t .

$$COS_{jt} = \sum_{i=1}^{43} \sum_{k=1}^{43} Cosine_{ikt} * \left(\frac{Reg - Appl_{ijt} + Reg - Appl_{kjt}}{Reg - Appl_{jt}} \right) \quad (5)$$

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 H1c, the cumulativeness ($\ln(App)_{jt}$) and relatedness variables (COS_{jt}) are combined through multiplication. The new variable $\ln(KB)_{jt}$ indicates what we called regional knowledge base, because it conjoins both dimensions of knowledge Breschi et al. (2003) have claimed as relevant with respect to the regional effects of cooperative behavior.

Regional innovative success ($\ln(App)_t$)

The regional innovative success - as mentioned above - is measured by the number of patents which regional actors have been filed for in period t . To avoid influences of extreme values we use the natural logarithm of the number of patents.

Regional economic success (ΔGDP_t)

The RIS approach is popular in part because it provides a narrative on the intangible dimension of local economic development and the processes of knowledge circulation and learning at the more manageable regional scale (Doloreux & Parto 2005, p.137). So as a consequence after analyzing the impact of regional interaction on the innovative capability and success of a region, we have to draw attention on the economic development of the observed German regions. The economic development is measured in terms of GDP growth. The variable ΔGDP indicates the growth rate of the regional GDP from period t-1 to period t.

3.4 Control variables

Regional size ($Size_t$)

In order to capture agglomeration effects independently of patent activities we use the

²For a detailed description of this index, please see Breschi et al. (2003)

number of inhabitants of a region. The variable $Size_t$ account for this in each period. These data are taken from statistics of the German Federal Statistic office and are related to each ROR over time.

Gross domestic product (GDP_t)

Although we start our analysis in 1998, 8 years after the political reunification, we consider catch-up processes active between both German parts still to work out. We assume that these catch-up processes have an impact on the innovative as well as on the co-operative behavior of actors. Therefore, we include the variable GDP_t which is the regional Gross domestic product (in mio.) per capita (in thousand inhabitants).

Public research ($PubRes_t$)

There exists a huge body of literature dealing with the specific role of public research institutes for regional development (Dahlstrand 1999, Fritsch & Schwirten 1999, Hall et al. 2000, Graf & Henning 2006). We consider the role of these non-market oriented actors with including the variable $PubRes_t$. Here the number of students on universities and applied universities are used as a proxy of the strength of public research institutions in a certain region.

3.5 Data Base

The regional effects of cooperative behavior are indicated by $Ratio$. If the regional effects influence the cooperative behavior positively, this value is above 1 which means that there are more co-applications than expected according to the regional patent applications. Taking the natural logarithm this threshold between positive and negative regional effects is now 0. The unweighted average of all regions over time is slightly above 0 which means that smaller regions tend to have a higher ratio value. Table 1 shows that the values of $\ln(Ratio)$ fluctuate between -1.204 and 1.340. The pooled sample in table 1 displays strong difference in the number of patent applications ($\ln(App)$) in our sample. Actors located in the region Altmark in Saxony-Anhalt filed for 7 patents in the last period whereas the actors located in the region Munich filed for 5675 patents in the second period. This implies furthermore contributes are arguments made above that size independent variables are necessary to test for regional effects with the whole sample of German regions and their development.

The values of the relatedness indicated by $\ln(Cos)$ do not differ that much between the German regions. All values are above 0 and below 1. The combination of relatedness ($\ln(Cos)$) and the amount of knowledge ($\ln(App)$), what we called regional knowledge base ($\ln(KB)$), has a mean value of 5.712 in our sample. The values fluctuate between 2.66 and 9.371. In order to control for differences between both former German countries we include the GDP per capita (GDP) as one control variable. Table 1 shows that there exists strong differences within Germany. The highest value of 0.129 is nearly ten times higher than the lowest value of 0.014. According to the regional size ($Size$) measured in the natural logarithm of number of inhabitants there are similar differences between German "Raumordnungsregionen". The smallest region (again "Anklam" in Saxony-Anhalt) has around 236000 inhabitants, whereas 4.1 million people live in the biggest region. The last included variable ($PubRes$) indicates the strength of the regional public research actors. For this purpose, we use the number of students of universities and universities of applied science as a proxy. Six of the 97 regions have none of these institutes and therefor no students at all. Berlin has the most students of all regions. All control variables are included without any time delay. If these are included in our regression models below, the number of observations will differ according to the length of

Table 1: Descriptive Statistics. Pooled Sample

Variable	Explanation	Obs	Mean	Std. Dev.	Min	Max
$\ln(Ratio)$	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.	388	0.139	0.437	-1.204	1.340
$\ln(App)$	The natural logarithm of the number of regional patent applications.	388	5.069	1.180	1.945	8.644
$\ln(Cos)$	The natural logarithm of the Cosine index.	388	0.710	0.059	0.553	0.911
$\ln(KB)$	The multiplication of relatedness ($\ln(Cos)$) and the amount of knowledge ($\ln(App)$), what we called regional knowledge base ($\ln(KB)$).	388	5.712	1.195	2.660	9.371
GDP	The Gross domestic product measured in Million Euro per thousand inhabitants.	388	0.024	0.008	0.014	0.129
$Size$	The natural logarithm of the number of inhabitants.	388	13.503	0.619	12.373	15.232
$PubRes$	The natural logarithm of the number of students in a region indicating the strength of the public research institutions within that region.	388	7.777	5.708	- 13.815	11.848

the delay.

3.6 Estimation models

In the hypotheses 1 the collective creation of innovations is considered as functionally dependent on the available knowledge base of a certain region, the technological heterogeneity herein and the innovative success in terms of patent applications. Since the development of innovations is a dynamic process we have to take into account several time lags. Hence, if actors experience innovative success in period t then this the respective collaboration started earlier. Thus, whenever an actors incentive to cooperate in innovation is dependent on the amount ($\ln(App)$) and the relatedness ($\ln(Cos)$) of the regional knowledge base, this regional knowledge had to exist already earlier. To test for hypothesis H1c, we include the variable $\ln(KB)$. We use the time lagged variables $\ln(App)_{t-1}$, $\ln(Cos)_{t-1}$ and $\ln(KB)_{t-1}$ as well as the control variables $Size_t$, GDP_t and $PubRes_t$ for time period t . In a fixed effect linear panel model we estimate the regional effects of cooperation behavior as follows:

$$\begin{aligned} \ln(Ratio)_t = & \beta_0 + \beta_1 \cdot \ln(App)_{t-1} + \beta_2 \cdot \ln(Cos)_{t-1} \\ & + \beta_3 \cdot \ln(KB)_{t-1} + \beta_4 \cdot Size_t + \beta_5 \cdot GDP_t + \beta_6 \cdot PubRes_t \end{aligned} \quad (6)$$

Hypotheses H1a, H1b and H1c imply a positive sign for the variables $\ln(App)_{t-1}$, $\ln(Cos)_{t-1}$ and $\ln(KB)_{t-1}$. In accordance with the RIS concept and the pivotal role of universities in RIS we expect a positive sign for $PubRes_t$. For GDP_t we expect a negative sign.

The second step refers to hypothesis H2 and the regional innovative success. Here as determining factors we consider the regional effects of cooperative behavior in innovating $\ln(Ratio)$ as well the size of the region. Again we take into account time lags, here for the interaction variable $\ln(Ratio)_{t-1}$. Again the control variables $Size_t$, GDP_t and $PubRes_t$ are included. The model we estimate by fixed effects panel data regression is the following:

$$\ln(Appl_t) = \beta_0 + \beta_1 \cdot \ln(Ratio)_{t-1} + \beta_2 \cdot Size_t + \beta_3 \cdot GDP_t + \beta_4 \cdot PubRes_t \quad (7)$$

Due to hypothesis H2 the sign to be expected for $\ln(Ratio)_{t-1}$ is positive. With agglomeration effects having a positive effect on a region's innovative output we expect for $Size_t$ also a positive coefficient.

In order to test hypothesis H3 we use the GDP growth (ΔGDP) as indicator of regional economic success. Besides the determining factors already introduced here we have to take into account an additional effect, the long run adaptive development of GDP and thus of GDP growth. Thus, the GDP growth in period t is also dependent of the GDP of the previous period, GDP_{t-1} . Consequently, we have to apply an estimation technique taking into account the lagged dependent variable as an additional explanatory variable. An Arellano-Bond estimator just allows us to do so and we estimate the following model:

$$\Delta GDP_t = \beta_0 + \beta_1 \cdot GDP_{t-1} + \beta_2 \cdot \ln(Appl_{t-1}) + \beta_3 \cdot Size_t + \beta_4 \cdot PubRes_t \quad (8)$$

Following the RIS concept regions showing more innovative interaction and higher innovative success should have an superior economic performance (Cooke 2001). Hence, the coefficient for $\ln(Appl_{t-1})$ are expected to be positive. If there exists a path dependency in the GDP growth rate, the coefficient for GDP_{t-1} should also be positive. Otherwise, if there exists a catch up process in Eastern Germany, where nowadays the GDP per capita is smaller than in Western Germany, the coefficient for GDP_{t-1} has to be negative.

4 Descriptive and estimation results

4.1 Descriptive results

As a first step of our analyses the relationship between all used variables in terms of correlation values is presented. Table 2 provides a correlation matrix of all variables. As we will use different time delays in the regression models, the correlation matrix comprises correlation values without any time delay.

The hypotheses H1 are on the effects of the regional knowledge base on the regional effects of cooperative behavior. These regional effects are measured by the ratio between real and expected number of regional cooperations ($\ln(Ratio)$). With respect to hypothesis H1a the variable $\ln(App)$ indicating the amount of the regional knowledge base has to be positively correlated to the variable $\ln(Ratio)$ indicating regional effect of cooperation behavior. The same correlation is expected regarding hypothesis H1b between $\ln(Cos)$ and $\ln(Ratio)$ and between $\ln(KB)$ and $\ln(Ratio)$ according to hypothesis H1c. Surprisingly, there are significant correlations between all three pairs of variables, but instead of the expected positive coefficient they have negative ones. So in this correlation matrix we find hints according to the hypotheses 1. As the relation between $\ln(Ratio)$ and $\ln(App)$, with an other time structure, is used to test hypothesis 2, the same surprising significant negative coefficient occurs. Unexpected signs of the correlation coefficient suggest either that the time delays are of greater importance or that the assumptions we have made in our hypotheses 1 and 2 do not fit with our data base. Contrary to the first results, table 2 comprises results that contribute hypothesis 3, because the variables $\ln(App)$ and ΔGDP are as expected positively correlated.

4.2 Estimation results

After showing correlation values between our variables without any time delay, we use linear time series regression models in order to test the three hypotheses we stated above.

Table 2: Correlation matrix. pooled sample including time delays

	$\ln(Ratio)$	$\ln(KB)$	$\ln(Cos)$	$\ln(App)$	ΔGDP	$Size$	$PubRes$
$\ln(Ratio)$	1.000						
$\ln(KB)$	-0.110 0.061	1.000					
$\ln(Cos)$	-0.097 0.097	0.010 0.072	1.000				
$\ln(App)$	-0.151 0.010	0.690 0.020	0.012 0.836	1.000			
ΔGDP	-0.104 0.040	0.573 0.000	-0.022 0.707	0.675 0.000	1.000		
$Size$	0.032 0.535	0.492 0.000	0.067 0.258	0.533 0.000	0.222 0.000	1.000	
$PubRes$	-0.055 0.283	0.524 0.000	-0.099 0.091	0.642 0.000	0.371 0.000	0.668 0.000	1.000

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 system. Specifically, we want to know whether the relatedness or heterogeneity of the knowledge base affects the regional interaction structure. As we have shown in an analysis on firm level basis (Cantner & Meder 2007), an actor who is willing to cooperate has to offer valuable knowledge by himself to become an attractive research partner. Transferring this argument on the regional level, we assume that the incentive to engage within a regional network depends on the regional amount of knowledge. This assumption is contributed by suggestions of the learning economy approach where innovative activities like research cooperation are determined among other things by the cumulative base of knowledge (Lundvall 1992, Sharpe & 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 shown in equation 6, the regional interaction structure variable $\ln(Ratio)_t$ depends on the knowledge amount $\ln(App)_{t-1}$, its relatedness $\ln(Cos)_{t-1}$ and its regional knowledge base $\ln(KB)_{t-1}$ of the former time period.

In table 3 we use four robust fixed effect (FE) linear models to test for the hypotheses H1a, H1b and H1c. The first regression model includes all three control variables. None of them have a significant coefficient. According to this, the results do not contribute literature dealing with agglomeration effects like Acs et al. (2002), Sorenson et al. (2006) or Bettencourt et al. (2007). Furthermore we can not observe any differences between Eastern and Western Germany (GDP_t has no significant effect). Finally the variable $PubRes_t$ indicating the strength of the public research institutions within a region do not influences the regional interaction structure.

The second regression model refers to hypothesis H1a. The coefficient of the variable indi-

Table 3: Estimation results of hypotheses 1

	M1a		M1b		M1c		M1d	
	FE model	linear	FE model	linear	FE model	linear	FE model	linear
	$\ln(Ratio)_t$		$\ln(Ratio)_t$		$\ln(Ratio)_t$		$\ln(Ratio)_t$	
$\ln(App)_{t-1}$			0,349 (2,33)*					
$\ln(Cos)_{t-1}$					0,656 (1,43)			
$\ln(KB)_{t-1}$							0,382 (2,81)**	
$Size_t$	-0,409 (-1,07)		-0,514 (-0,54)		-0,928 (-1,05)		-0,469 (-0,5)	
GDP_t	-6,433 (-1,17)		-10,391 (-0,45)		-20,888 (-0,95)		-9,695 (-0,42)	
$PubRes_t$	0,164 (1,78)		0,279 (1,83)		0,167 (1,13)		0,298 (1,96)	
$Intercept$	4,319 (0,81)		2,957 (0,23)		10,34 (0,86)		1,715 (0,13)	
Observations	364		272		273		272	
Number of ROR	91		91		91		91	
R-squared	0,01		0,04		0,02		0,05	
Robust t statistics in parentheses								
* significant at 5%; ** significant at 1%								

cating the available regional knowledge $\ln(App)_{t-1}$ within a region has a significant positive influence - on a 5% level - on the regional interaction structure. So we can not reject hypothesis H1a for our sample. Our finding is in a line with the results in other empirical RIS studies like Fritsch & Franke (2004) or Asheim & Gertler (2004) and theoretical statements made by the learning economy (e.g. Lundvall 2004, 2006). But there are also suggestions that such using count patent data as regional knowledge base is a too rough measure and therefore not appropriate (Jaffe 1986, Griliches 1990). We try to find a more convenient measure of the regional knowledge base with including the relatedness of the regional knowledge base.

So the main focus of this paper is on the hypotheses H1b and H1c. The findings are embodied in the coefficients of $\ln(Cos)_{t-1}$ in regression model M1c and of $\ln(KB)_{t-1}$ in model M1d. The time lagged term $\ln(Cos)_{t-1}$ has no significant value which implies that we have to reject hypothesis H1b for our sample. The relatedness of knowledge measured with the Cosine index has no significant influence on the regional interaction structure, although the coefficient is positive as expected. We get the same results if we take the pure number of regional cooperations as dependent variable. The variable which combines both dimensions of knowledge to what we called regional knowledge base $\ln(KB)_{t-1}$ has in model M1d a strong (1% level) significant influence on the regional effects of cooperation behavior. So we can not reject hypothesis H1c for our sample. This finding is in a line with empirical results on firm level like Mowery et al. (1998), Sorenson et al. (2005) or Cantner & Meder (2007).

After proving the validity of hypotheses H1a, H1b and H1c, we are interested in how regional effects of cooperation behavior affect the innovative success. This relation is the core assumption of the RIS approach. It is generally conceded that the innovative performance of regions is improved when actors recognize potential benefits of interactive learning processes

(Doloreux & Parto 2005, p.148). Regarding this general assumption, we use in table 4 again FE linear models.

Table 4: Estimation results of hypothesis 2

	M2a	M2b	M2c
	FE linear model	FE linear model	FE linear model
	$\ln(App)_t$	$\ln(App)_t$	$\ln(App)_t$
$\ln(Ratio)_{t-1}$	0,367 (4,06)**	0,367 (4,07)**	0,256 (3,56)**
$Size_t$		-0,436 (-5,28)**	-6,214 (-7,46)**
GDP_t			-150,245 (-6,99)**
$PubRes_t$			-0,000 (-1,34)
<i>Intercept</i>	5,136 (305,85)**	11,023 (9,91)**	92,930 (8,03)**
Observations	290	290	290
Number of ROR	97	97	97
R-squared	0,11	0,12	0,48

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

The coefficient of $\ln(Ratio)_{t-1}$ has a significant positive value in all three models presented in table 4. This finding fosters the assumption made in hypothesis H2 that an increase of the regional effects of cooperation behavior leads to an increase of the regional innovative success. As this relationship is the core element of the RIS approach, our finding is in line with empirical studies on firm level (Kleinknecht & Reijnen 1992, Miotti & Sachwald 2003, Belderbos et al. 2004) as well as findings on regional level (Sternberg 2000, Bettencourt et al. 2007). Contrary to the results of table 3, the control variables have a significant influences on the innovative success. The size influences the innovative success negatively. This results is surprisingly as there exists a body of literature dealing with advantages of agglomerations. The variable GDP_t indicating the gap between Eastern and Western Germany has a significant negative influence. This influence is caused in a great influence of this variable on the between R-squared value which indicates structural differences between Eastern and Western Germany, because if we include only regions in East Germany the GDP variable becomes insignificant. This implies that the significance occurs because this variable distinguishes two groups of regions within the data sample. This finding supports the results of Fritsch (2004). Finally, an increasing number of students within a region has no effect on the innovative success. We can imagine that this is due to the long run effects of basic research.

The literature on regional innovation systems provides substantial descriptions and analyses of relationships between innovation, learning and the economic performance of particular regions (Cooke 2001, Doloreux & Parto 2005). We want to round down our analysis of the regional development with testing our hypothesis H3, the impact of the innovative success on the economic development. As the Eastern Germany is still in a catching up process, we have to take into account effects determining regional growth. As we have used the GDP per capita as an indicator of the structural differences in Germany, we include these effects in the time series regression through estimating the impact of patent application on economic success using a Arellano-Bond linear, linear, dynamic panel-data estimation. This model allows past realizations of the dependent variable to affect its current level. Arellano & Bond (1991) derive

a generalized method-of-moments estimator using lagged levels of the dependent variable and the predetermined variables and differences of the strictly exogenous variables. The dependent variable now represents the regional GDP growth and, as mentioned before, if there is a catch up process in Eastern Germany, we expect a negative sign of the coefficient for the lagged GDP per capita (GDP_{t-1}). A significant positive influence of the lagged variable $\Delta \ln(App)_{t-1}$ indicating the innovative success would contribute our hypothesis 3.

Table 5: Estimation results of hypothesis 3

	M3a	M3b	M3c
	Arellano-Bond	Arellano-Bond	Arellano-Bond
	ΔGDP_t	ΔGDP_t	ΔGDP_t
GDP_{t-1}	0,717 (25,43)**	0,713 (25,81)**	0,712 (25,58)**
$\Delta \ln(App)_{t-1}$	372 (3,82)**	389 (3,61)**	406 (3,55)**
$\Delta Size_t$		327,98 (4,67)**	331,839 (4,94)**
$\Delta PubRes_t$		-21,262 (-0,11)	-22,098 (-0,11)
$\Delta \ln(KB)_{t-1}$			-54,217 (-0,60)
Intercept	69,94 (4,05)**	74,916 (2,98)**	73,011 (2,95)**
Observations	194	182	182
Number of ROR	97	91	91
Robust z statistics in parentheses			
* significant at 5%; ** significant at 1%			

As there is the coefficient of the endogenous absolute variable in all three regression models of table 5, we can not observe any catch up process in Germany. With respect to hypothesis H3, the influence of $\Delta \ln(App)_{t-1}$ on the economic development (ΔGDP_t) is significant. Therefore, we can not reject hypothesis 3. So the relationship between innovative success and economic development implied in the conceptual work by Cooke (2001), can be found in our data base.

5 Conclusion 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 regional interaction structure. Following 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 we state in three hypotheses:

1. For regional cooperative activities in terms of regional co-application, we find evidences for a positive influence of the amount of knowledge base present within the region. Contrary, the relatedness of the knowledge base measured with the Cosine index does not affect the interaction structure significantly. But the combination of both measures, the regional knowledge base, explains the regional effects of cooperation behavior better than each single dimension. These results contribute theoretical explorations of the

learning economy approach (Lundvall 2004, 2006) and the resource-based view of the firm (Combs & Ketchen 1999, Das & Teng 2000) as well as empirical findings on firm level (Mowery et al. 1998, Sorenson et al. 2005, Cantner & Meder 2007).

2. The systemness of a certain region affects her innovative success positively. We find evidences for the positive influences of an increasing interaction structure in terms of co-application on the patent application amount. The findings show that the innovative performance of a region depends on the systemic linkages between its actors. This contributes the importance of the systemness, the core element of the RIS approach.
3. Concerning the influence of the innovative output on the economic development, we find a positive relationship. The economic effects assumed in the conceptional framework of RIS can maybe even better be identified in a more long-run setting.

As we are mainly interested in explaining regional interaction with the knowledge base available within a region, we combine theoretical and empirical results of firm level analysis with the RIS approach. As knowledge is factor affecting the competitiveness of firms and regions, we have to take into account the nature of knowledge and its development more seriously. With this German wide analysis we are going a unusual way of RIS analysis. As recent literature emphasizes the importance of institutions and regional specificities, factors which we have totally neglected in this analysis, it 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 (see for example Sternberg 2000, Doloreux & Parto 2005, Asheim & Gertler 2004, Sharpe & Martinez-Fernandez 2006). We attempt to find evidence on a more abstract and general level. Of course, doing so we can not include many information that might explain the regional interaction structure in certain regions, as do results stemming from case studies.

Nevertheless, in further analytical steps we want to take into account several regional specificizes. Beside these methodological improvements, there are several features of the RIS approach we do not mentioned in this paper. The importance of connections above regional level may be the topic in the next step of analysis.

A Ratio

A.1 Interaction structure according technological fields

In this subsection the method to analyze the development of the introduced patenting and co-application behavior in Germany with respect to the technological fields listed indicating the different technologies in the German economy.

The 43×4 matrix $TFApp_{it}$ contains values of applications with at least one German inventor in each of the 43 technological fields $i \in I$. In order to avoid peaks because of external effects in certain years, the moving 3 year average values are used. As the patenting behavior is observed over six years, there are information available for 4 time periods t , starting in 1999.

$$TFApp_{it} = \sum_{n=1}^N \frac{1}{a} PA_{it} \quad (9)$$

$$i \in I; t \in T \quad (10)$$

The number of overall patents N in a respective time period t is distributed over all technological fields I . The term $\frac{1}{a}$ indicates value of the patent in a field in which it is filed for. Here, a is the number of field this patent is filed for.

Example:

In our example the three patents are distributed as reported in table A.1. Patent A and Patent C have an a -value of one because both are filed for in one technological field. Patent B has an a -value of 2 because both technological fields are named on the application.

Table 6: $TFAppI$ - example

Techn. field	Application Distribution
TF1	1.5
TF2	1.5

After allocating the patent applications with regard to their technological fields, the co-applications are distributed in the same way. Again, to avoid shortcomings through introducing single-year-peaks, I use 3 year - moving average values to measure co-application behavior. Therefore, the matrix $TFCoap_{it}$ has again a 43x4 dimension.

$$TFCoap_{it} = \sum_{n=1}^N \frac{1}{a} Coap_{it} \quad (11)$$

$$i \in I; t \in T \quad (12)$$

Example:

On patent A and C are more than 1 actor named as an applicant. As both are classified in different technological fields, there is 1 co-application in table A.1 for each field. The sum of the distributed co-application behavior corresponds with the overall number of applications.

Table 7: $TFCoap$ - example

Techn. field	Co-application Distribution
TF1	1
TF2	1

Finally, the application and co-application behavior determine a co-application probability for a certain technology in a certain point in time. The 43x4 matrix $P(Coap)_{it}$ include these values.

$$P(Coap)_{it} = \frac{TFCoap_{it}}{TFApp_{it}}, i \in TF; t \in T \quad (13)$$

Example:

As both co-applications are filed for in different technological fields, the co-application probability regarding certain technologies is equal in our example. The probability of a patent filed for by more than one applicant is 66.66% in both fields.

Table 8: $P(Coap)$ - example

Techn. field	Co-application probability
TF1	0.666
TF2	0.666

A.2 Interaction structure according regions

After allocating the patent (co-)applications over all technological fields, the same (co-)applications are distributed in space according the inventor addresses named on the patent document. We use regional boundaries that have been established by the Bundesamt für Bauwesen- und Raumordnung who divided Germany into 97 Raumordnungsregion (ROR_j). These regions are in the following steps the spatial units that are observed.

First, the patent applications classified into technological fields ($TFApp_{it}$) are allocated to the regions where the inventors coming from. The factor b_j contains the number of regions the inventors on a patent n are located in. Following this, the term $\frac{1}{b_j}$ indicates the counting value of a recent patent within a certain region. Therefore, the matrix $ROR - App_{jit}$, with the dimensions $i * j * t$, contains all patents n of period t associated to their technological fields i and regions j .

$$ROR - App_{jit} = \sum_{n=1}^N \frac{1}{b_j} TFApp_{it} \quad (14)$$

$$i \in I; t \in T \quad (15)$$

Example:

The matrix $ROR - App_{jit}$ in the recent example has a 2x2x1 dimension, as there are 2 regions and technological fields in a static example ($t \in [1]$). Table A.2 displays the values of $ROR - App_{jit}$ for our example.

Table 9: $ROR - App$ - example

Techn. field	Region	
	ROR I.	ROR II.
TF1	0.75	0.75
TF2	0.25	1.25

This regional and technological distribution enables us to indicate the "expected cooperation" amount in a certain region. To be aware of the technological cooperation probability $P(Coap)_{it}$, the matrix $ROR - App_{jit}$ can be used to indicate the mentioned number of regional cooperation activities $E(Coap)_{jt}$.

$$E(Coap)_{jt} = \sum_{i=1}^I ROR - App_{jit} * P(Coap)_{it} \quad (16)$$

Example:

In the example the value of $E(Coap)_{jt}$ is 0.66 in the first region and 1.33 in the second. The sum of each row in table A.2 accords to the $TFCoap$ values shown in table A.1

Table 10: $E(Coap)$ - example

Techn. field	Region	
	ROR I.	ROR II.
TF1	0.5	0.5
TF2	0.16	0.84
$E(Coap)_{jt}$	0.66	1.33

In the following step the realized number of cooperation $ROR - Coap_{jt}$ in terms of co-applications is composed of the matrix $TFCoap_{it}$ with respect to the inventor addresses.

$$ROR - Coap_{jt} = \sum_{n=1}^N \frac{1}{b_j} TFCoap_{it} \quad (17)$$

$$i \in I; t \in T \quad (18)$$

Example:

The patents A and C have been identified as co-applications. After their allocation following the technological fields listed on the patent document, both patents are additionally distributed over both regions.

Table 11: $ROR - Coap$ - example

Techn. field	Region	
	ROR I.	ROR II.
TF1	0.5	0.5
TF2	0.0	1
$ROR - Coap_{jt}$	0.5	1.5

Finally, we divide the realized no. of cooperations through the expected value to indicate the "pure regional" interaction ratio. The value composed of the first divided by the latter amount takes a value above 1 if the number of co-applications is above the expected average value and below 1 otherwise. So if the actors of a certain region are more likely to cooperate than we would expected the value is greater than one. If there exist "pure regional effects" in cooperation behavior, the vector of values of all regions has to be significant different from one.

$$Ratio_{jt} = \frac{ROR - Coap_{jt}}{E(Coap)_{jt}} \quad (19)$$

Example:

In our example one the amount of regional interactions in region ROR II. is above the expected amount (value 1.125). Consequently, the value of region ROR I. is below 1. After testing whether these value differ significantly from 1, one can conclude that the differences in the regional interaction structure are not only due to the different technological endowment, but there is also a "pure regional" effect.

B Cosine matrix (1999)

TF	1	2	3	4	5	6	7	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
1		0,034	0,041	0,012	0,000	0,000	0,009	0,017	0,202	0,052	0,000	0,233	0,030	0,013	0,000	0,026	0,004	0,003	0,007	0,004	0,024	0,028	0,000	0,044	
2			0,054	0,000	0,000	0,000	0,000	0,000	0,025	0,000	0,000	0,009	0,000	0,000	0,010	0,019	0,000	0,006	0,000	0,000	0,016	0,010	0,007	0,043	
3				0,168	0,021	0,065	0,065	0,000	0,230	0,011	0,000	0,014	0,037	0,045	0,064	0,070	0,115	0,011	0,016	0,014	0,011	0,008	0,017	0,072	
4					0,179	0,000	0,034	0,026	0,060	0,000	0,000	0,000	0,000	0,028	0,029	0,010	0,012	0,005	0,045	0,000	0,006	0,000	0,003	0,038	
5						0,000	0,000	0,000	0,019	0,000	0,000	0,000	0,000	0,000	0,000	0,018	0,006	0,008	0,017	0,000	0,003	0,010	0,000	0,011	
6							0,042	0,000	0,065	0,000	0,011	0,000	0,000	0,018	0,000	0,040	0,143	0,026	0,077	0,019	0,041	0,017	0,056	0,030	
7								0,000	0,122	0,000	0,010	0,005	0,013	0,023	0,009	0,046	0,046	0,000	0,033	0,004	0,010	0,000	0,019	0,095	
9									0,196	0,000	0,000	0,019	0,003	0,053	0,000	0,002	0,004	0,006	0,016	0,004	0,028	0,019	0,004	0,012	
10										0,112	0,000	0,347	0,088	0,251	0,096	0,279	0,186	0,068	0,053	0,025	0,169	0,040	0,026	0,114	
11											0,038	0,319	0,039	0,008	0,014	0,001	0,002	0,003	0,003	0,000	0,007	0,020	0,000	0,008	
12												0,014	0,000	0,000	0,000	0,000	0,044	0,000	0,000	0,000	0,000	0,000	0,000	0,004	
13													0,148	0,050	0,013	0,019	0,015	0,010	0,012	0,001	0,045	0,087	0,004	0,037	
14														0,071	0,000	0,020	0,004	0,000	0,014	0,000	0,020	0,004	0,012	0,065	
15															0,004	0,081	0,122	0,044	0,056	0,000	0,035	0,006	0,023	0,092	
16																0,041	0,222	0,000	0,010	0,000	0,022	0,006	0,000	0,093	
17																	0,221	0,118	0,148	0,109	0,088	0,015	0,087	0,119	
18																		0,170	0,273	0,036	0,068	0,035	0,080	0,111	
19																			0,104	0,063	0,104	0,029	0,087	0,087	
20																			0,104	0,182	0,080	0,032	0,233	0,064	
21																					0,083	0,028	0,233	0,064	
22																					0,083	0,028	0,233	0,064	
23																					0,059	0,028	0,233	0,064	
24																						0,059	0,027	0,173	
25																									

TF	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
1	0,000	0,039	0,000	0,001	0,000	0,000	0,002	0,001	0,001	0,000	0,000	0,020	0,005	0,002	0,001	0,000	0,001	0,000	0,004
2	0,000	0,005	0,000	0,000	0,000	0,000	0,013	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,004	0,000	0,000
3	0,012	0,029	0,001	0,000	0,000	0,000	0,000	0,008	0,000	0,003	0,000	0,014	0,001	0,000	0,002	0,000	0,010	0,002	0,006
4	0,039	0,026	0,002	0,000	0,003	0,000	0,004	0,015	0,002	0,010	0,008	0,041	0,004	0,001	0,008	0,000	0,004	0,013	0,034
5	0,000	0,008	0,004	0,000	0,000	0,000	0,000	0,004	0,000	0,000	0,000	0,028	0,000	0,003	0,002	0,000	0,001	0,015	0,015
6	0,000	0,014	0,003	0,002	0,000	0,000	0,007	0,000	0,000	0,002	0,000	0,001	0,009	0,002	0,001	0,000	0,001	0,001	0,016
7	0,000	0,015	0,100	0,000	0,002	0,015	0,003	0,009	0,009	0,013	0,000	0,001	0,004	0,002	0,030	0,000	0,003	0,000	0,014
8	0,005	0,003	0,042	0,002	0,002	0,003	0,005	0,043	0,002	0,011	0,005	0,015	0,074	0,016	0,006	0,000	0,012	0,005	0,005
9	0,004	0,026	0,069	0,003	0,003	0,110	0,008	0,009	0,067	0,005	0,001	0,063	0,035	0,006	0,046	0,001	0,025	0,008	0,010
10	0,000	0,000	0,003	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,024	0,003	0,003	0,002	0,000	0,000	0,000	0,006
11	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,012	0,000	0,000	0,000	0,000	0,000	0,000	0,000
12	0,000	0,017	0,056	0,000	0,000	0,008	0,000	0,001	0,019	0,000	0,000	0,215	0,135	0,001	0,037	0,000	0,000	0,000	0,003
13	0,000	0,018	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,019	0,000	0,000	0,002	0,000	0,003	0,000	0,002
14	0,143	0,009	0,024	0,000	0,012	0,003	0,000	0,006	0,007	0,007	0,011	0,028	0,006	0,000	0,030	0,000	0,007	0,007	0,009
15	0,000	0,002	0,000	0,000	0,000	0,004	0,000	0,000	0,006	0,000	0,000	0,014	0,002	0,000	0,003	0,000	0,000	0,018	0,000
16	0,005	0,084	0,027	0,028	0,088	0,007	0,019	0,019	0,023	0,023	0,003	0,047	0,032	0,026	0,032	0,005	0,082	0,021	0,040
17	0,029	0,055	0,024	0,006	0,006	0,017	0,029	0,031	0,052	0,014	0,001	0,023	0,007	0,003	0,032	0,000	0,029	0,023	0,015
18	0,006	0,025	0,013	0,021	0,060	0,012	0,015	0,017	0,092	0,022	0,001	0,013	0,019	0,005	0,022	0,000	0,021	0,011	0,019
19	0,002	0,086	0,052	0,054	0,046	0,012	0,036	0,032	0,041	0,034	0,003	0,041	0,027	0,028	0,022	0,003	0,128	0,042	0,066
20	0,004	0,049	0,013	0,175	0,025	0,005	0,008	0,017	0,034	0,013	0,003	0,022	0,037	0,023	0,009	0,000	0,319	0,065	0,018
21	0,012	0,162	0,061	0,027	0,013	0,066	0,014	0,031	0,030	0,020	0,005	0,066	0,054	0,032	0,003	0,004	0,129	0,043	0,023
22	0,015	0,012	0,017	0,002	0,002	0,000	0,009	0,017	0,004	0,009	0,000	0,033	0,025	0,009	0,003	0,000	0,064	0,010	0,021
23	0,000	0,022	0,037	0,051	0,043	0,004	0,001	0,013	0,071	0,036	0,003	0,039	0,067	0,044	0,025	0,000	0,059	0,021	0,010
24	0,021	0,110	0,132	0,055	0,013	0,006	0,001	0,027	0,094	0,026	0,027	0,100	0,091	0,034	0,046	0,002	0,054	0,037	0,033
25	0,000	0,000	0,017	0,004	0,011	0,000	0,004	0,018	0,000	0,017	0,006	0,005	0,022	0,004	0,016	0,000	0,050	0,030	0,009
26	0,066	0,066	0,043	0,043	0,052	0,010	0,179	0,062	0,052	0,033	0,004	0,041	0,047	0,050	0,049	0,017	0,067	0,016	0,108
27			0,023	0,023	0,055	0,003	0,015	0,156	0,068	0,347	0,148	0,065	0,112	0,109	0,135	0,024	0,053	0,008	0,034
28					0,083	0,014	0,014	0,136	0,092	0,044	0,007	0,012	0,033	0,053	0,004	0,003	0,108	0,021	0,005
29					0,020	0,020	0,064	0,064	0,059	0,186	0,008	0,008	0,047	0,024	0,022	0,006	0,076	0,005	0,006
30							0,006	0,024	0,054	0,055	0,004	0,003	0,046	0,006	0,000	0,000	0,039	0,004	0,000
31								0,028	0,087	0,024	0,015	0,021	0,012	0,005	0,096	0,005	0,078	0,016	0,047
32									0,045	0,024	0,075	0,037	0,129	0,088	0,031	0,012	0,129	0,037	0,012
33										0,141	0,033	0,053	0,141	0,039	0,084	0,003	0,064	0,012	0,005
34										0,176	0,033	0,045	0,167	0,197	0,080	0,066	0,109	0,015	0,033
35											0,265	0,069	0,167	0,197	0,162	0,007	0,037	0,005	0,027
36												0,069	0,252	0,060	0,101	0,025	0,024	0,027	0,144
37														0,213	0,121	0,032	0,251	0,046	0,145
38															0,121	0,032	0,208	0,024	0,019
39															0,024	0,011	0,208	0,024	0,019
40															0,041	0,011	0,113	0,036	0,090
41																	0,015	0,000	0,056
42																	0,269	0,000	0,147
43																		0,000	0,203

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