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Working Paper

Regional and technological effects of cooperation behavior

Jena Economic Research Papers, No. 2008,014

Provided in Cooperation with:
Max Planck Institute of Economics

Suggested Citation: Cantner, Uwe; Meder, Andreas (2008) : Regional and technological effects of cooperation behavior, Jena Economic Research Papers, No. 2008,014, Friedrich Schiller University Jena and Max Planck Institute of Economics, Jena

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JENA ECONOMIC RESEARCH PAPERS



2008 – 014

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www.jenecon.de

ISSN 1864-7057

The JENA ECONOMIC RESEARCH PAPERS is a joint publication of the Friedrich Schiller University and the Max Planck Institute of Economics, Jena, Germany. For editorial correspondence please contact m.pasche@wiwi.uni-jena.de.

Impressum:

Friedrich Schiller University Jena
Carl-Zeiss-Str. 3
D-07743 Jena
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Regional and technological effects of cooperation behavior*

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February 25, 2008

Abstract

In this paper we investigate the determinants of cooperative innovation and put our main focus on the regional or spatial and on the technological or sectoral dimension. We suggest a method to disentangle these two factors and to extract differential regional effects. The latter can be used to identify and evaluate the strength of regional innovation systems. Applying this method to German patent data we find evidence that regional differences in the degree of cooperative innovation are not only due to the technological/sectoral composition of the region but also due to a specific regional effect.

JEL classification: O31, P25, Q55

Keywords: Cooperative innovation, regional innovation system, technological proximity, spatial proximity

*We thank the Volkswagen Foundation for funding the research project "2nd Order Innovation" and the German Science Foundation for funding the position of Andreas Meder within the RTG 1411 "The Economics of Innovative Change". We thank the participants of the DIME conference on "Network dynamics and the performance of local innovation systems" October 2007 in Jena for commenting an earlier draft.

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1 Introduction

Looking at how innovative activities are distributed over time, between regions and among actors delivers non-equal distributions. Industry life cycle approaches (e.g. Klepper 1996) take into account the time dimension, regional economics refers to the spatial dimensions and entrepreneurship research is devoted to particular innovative actors. Equivalent observations can be made with respect to cooperative innovation, which shows up when particular innovations are not performed by a single actor but a group of actors. For this Allen (1983) coined the notion of collective invention. And also here non-equal distributions of collective invention/innovation are observed with respect to time (e.g. Hagedoorn & Schakenraad 1992), to regions (e.g. Cantner & Graf 2006) and to actors. The focus of this paper is laid on cooperative innovation and the influence regional factors on the one hand and technological factors on the other have herein.

Why do actors engage in cooperative innovation? Generating innovations in terms of new products and processes is often closely connected to and dependent on knowledge bases outside the innovating firm (Powell 1990). To get access to these external knowledge sources, firms or actors engage in joint (formal and informal) research projects. Hence, those collaborations are not only a device to share costs and risk of development as mentioned in the approach of the "transaction cost theory" (Williamson 1985), but also to get access to external knowledge (Eisenhardt & Schoonhoven 1996, Mowery et al. 1998, Combs & Ketchen 1999, Das & Teng 2000). In this context a major issue is the way or the criteria by which firms select external knowledge sources. This choice seems to be dependent on (1) the relationship between an actor's or firm's internal and external knowledge and (2) the ease by which firms or actors can get access to external knowledge sources. Furthermore one may ask for whether actors in order to improve their innovative performance look for complements or for substitutes of their own knowledge (Caloghirou et al. 2004, Belderbos et al. 2006).

Answers to these questions are found in the literature on innovation systems (Edquist 1997). Such systems are to be seen as a device allowing the exchange of knowledge and cooperative innovation between a system's actors. Generally, firms and innovative actors are member of several of those innovation systems, starting from the level of national innovation systems, comprising several layers of technological or sectoral innovation systems, and finally integrating in regional and local innovation systems.

For an understanding of cooperative innovation of actors one obviously cannot rely on only the one or the other of those levels. In principle they all should be considered simultaneously. In this paper, however, we do not take into account the layer of national innovation systems as we are only concerned with panel data from Germany. Hence, we presume that all actors in Germany are equally affected by the German national innovation system.

Within the frame of this system we focus on technological and on regional systems. These two systems represent each a specific aspect of the easiness to access knowledge external to the firm, the former one on the basis of technological proximity and the latter one on the basis of geographical (or social) proximity. Investigating differential cooperative innovation of actors both of these views are relevant. Take first actors located in different regions and observe differences in

cooperative innovation. Obviously regional factors and hence spatial proximity play a role; but we cannot exclude that technological proximity and hence the technological or sectoral composition of the regions are negligible. Secondly, look at differences in cooperative innovation between technologies and sectors. Again, technological proximity and therefore technological and/or sectoral determinants have to be considered; but you also cannot neglect regional factors whenever we observe a spatial clustering of those technologies or sectors.

This paper is just on the relationship between both kinds of proximity explaining regional differences in cooperative innovation. Looking at cooperative innovation taking place in and between certain technologies and certain regions one may ask as to what degree do observed regional differences relate to the technological composition of a region and to what degree does a region itself have an influence? In the following we want to shed some light on this question and suggest a solution to identify the differential regional impact on regional differences in cooperative innovation. After a brief review of literature in section 2, in section 3 we suggest a methodology attempting to identify regional effects in cooperative innovation. Section 4 and 5 contain an application of this method to patent data for Germany between 1998-2003 allowing us to track cooperative innovation. Section 6 concludes.

2 Theoretical background

The focus of this paper is laid on regional differences in cooperative innovation and the influence regional factors on the one hand and technological factors on the other have herein. To understand the procedure in section 3 where we suggest to distinguish between regional and technological effects, we first will have a brief look at the literature on cooperative innovation and the related literature on innovation systems.

2.1 Cooperative innovation

The manifold literature on voluntary, collaborative projects in the field of research and development differentiate between three main motives for the engagement of individual firms in such projects. Beside the incentives to (i) reduce risk and sharing R&D costs (Deeds & Hill 1996, Baum et al. 2000) and (ii) to combine complementary assets in order to enhance to propensity of a successful development project (Teece 1986, Nooteboom 1999), (iii) the internalization of knowledge spillovers is another reason to engage in R&D collaboration (Griliches 1992).¹

An explanation why firms consider the internalization of knowledge spillovers useful is found in the concept of the resource-based-view of the firm (Penrose 1959, Wernerfelt 1984, Barney 1991). Here, the main incentive to engage in a research cooperation is to get access to productive resources, here mainly technological knowledge, of the partners (Das & Teng 2000, Sher & Yang

¹The positive impact of knowledge spillovers is a fundamental issue of recent approaches to growth theory (Krugman 1991) as well as to concepts of innovation systems (Lundvall 1992, Malerba & Orsenigo 1997). Both can be applied to the regional level leading to the concepts regional growth (Fritsch 2004a) and of a regional or local innovation system.

2005) with the aim to improve its own performance. The role of a firm's or actor's environment for this performance in general and on its innovative performance in particular is highlighted and discussed by the concept of innovation systems (Lundvall 1992).

2.2 The general concept of innovation systems

In the literature on technological and economic change the aspect of collective invention and collective innovation is taken up by the so-called systemic approach which meanwhile offers various levels of "systems". Generally systems are defined as a "*set or arrangement of things so related or connected as to form a unity or an organic whole*" (Webster Collegiate Dictionary).

According to Carlsson et al. (2002), a system is made up of *components*, *relationships* and *attributes*. A *component* is a operating unit of a system. This can be either a physical unit such as a firm and other actors or it can possess a more intangible nature as institutions in the form of legislative artifacts such as regulatory laws, traditions, and social norms. The systemic nature shows up whenever these components do not act in isolation but are related to and interact with each other. Hence, a development of *relationships* can be observed which, however, does not necessarily predict a specific action but it implements a reaction of components to an action by an other component. So each component depends on the properties and behavior of all other system members.

Therefore, a system cannot be divided into several subsystems that are independent of each other (Blanchard & Fabrycky 1990). According to Carlsson et al. (2002), the components of a system will react if another component is removed from the system. Both the components and the relationship between them constitute the *whole system*. The *attributes*, as described by Carlsson et al. (2002), define the characteristics of a system. The boundaries of a system (Edquist 2001) isolating the system from the rest of the world depend on the respective attributes of actors.

Applying this abstract definition to the field of innovation economics, one finds a strong systemic view of innovative activities and a respective literature on innovation systems considering innovation as an evolutionary and social process (Edquist 2004). Here innovations in terms of new processes and products are stimulated by factors internal as well as external (Doloreux & Parto 2005) to actors. The social aspect of these innovations refers to collective invention (Allen 1983) and in a systemic view to collective learning processes between independently acting system entities.

With respect to the motivation of individuals to engage in cooperative innovation the main purpose of innovation systems is the generation, diffusion and utilization of knowledge (Lundvall 1992). Thus, the key features of a system are different capabilities which are related to this main purpose. Carlsson et al. (2002) differentiate between selective, organizational, functional and learning capabilities. Furthermore, these features are related to the dimension in which systems are analyzed.

2.3 Co-existing levels of innovation systems

Levels of systemic innovation

Based on the constituting elements of a system one can distinguish several kinds or levels of analysis. The combination of several attributes makes up the respective level and for that the type of actors, their location, their kind of activity, the type of relationships are relevant. With respect to systemic innovation we distinguish analyses towards national innovation systems (Freedman et al. 1988, Lundvall 1992), technological systems (Carlsson & Stankiewicz 1991), sectoral innovation systems (Malerba & Orsenigo 1997), regional innovation systems (Cooke 1992), local innovation systems (Breschi & Lissoni 2001), urban innovation systems (Fischer et al. 2001) etc.

Taking the perspective of an individual actor, "membership" in various innovation systems is obvious. A firm located in a certain region may belong to the regional system, one or several technological or sectoral systems (multi-product firm), one or several national innovation systems (multinational firm) etc. This multiple membership constitutes in various activities related to cooperative innovation and, in turn, the firm's general attitude towards cooperative innovation is influenced and dependent on the very features of all the levels of innovation systems involved. Hence, they all have to be considered simultaneously. In doing so and in order to understand cooperative innovation and differences herein the respective effects have to be disentangled.

This process of disentanglement runs in two stages: First, in view of the relevant research questions one selects the level of analysis and systems to be considered. Second, on this basis one attempts to identify the effects accruing from the various system levels considered. However, as it turns out, rather generally one is only able to determine differential effects, that is effects above or below the average influence of a certain system. A method how to perform this is suggested in the next section.

For this paper which deals with cooperative innovation of German firms the disentanglement runs as follows: For the various feasible levels of analysis we do assume the national innovation system to affect all the firms the same way.² We then consider the regional dimension on the one hand and the technological dimension on the other as major determinants of cooperative innovation. In doing so, regional, local and urban innovation systems represent the regional aspects, whereas technological and sectoral systems are related to the technological dimension.

Technological proximity

The concepts of technological innovation systems (Carlsson & Stankiewicz 1995, Carlsson et al. 2002) or sectoral innovation systems (Malerba et al. 1997) point to the fact that actors engaged in the same technology or the same sector are more able to understand the others' technological knowledge than actors from different technologies or sectors. In both concepts the boundary of the innovation systems is justified by the specificity of a sector or the technology in terms of a certain

²We are aware of differences in the legal and fiscal frame and thus in the national innovation system between countries. However, we apply this method as a tool for testing differences between regions within one country so that we can neglect the framework of a national innovation system and methodological problems that occur by comparing regions located in different countries.

knowledge base and key interactions within this sector or technology system (Malerba et al. 1997). The main idea behind this concept is that innovative and cooperative behavior of actors is mainly driven by proximity in their individual knowledge bases.

The concept of technological proximity is a rather vague one. It has at least three, closely interrelated dimensions. First, there is the degree of common understanding in the sense of common or overlapping knowledge bases among the actors. Second, understanding is not only related to the type of the knowledge base but also to the respective actors level of knowledge and hence to the so-called technology gaps between actors. Third, so-called technological regimes characterizing a sector or a technology play a role. Here the degree of appropriability of know-how - which never is fully complete - determines the easiness by which of know-how spills over from one actor to another and how cooperation works herein. This degree of appropriability differs considerably among technologies (Doloreux & Parto 2005).

Technological proximity defined in this way can now be used to describe cooperative innovation. And here one may conclude if actors are engaged in the same technology or industry this proximity is rather close. Obviously, the higher (lower) the technological proximity the more likely the knowledge stocks of the actors are substitutive (complementary).

Spatial proximity

The regional innovation system approach (RIS) developed from the empirically based acknowledgement that innovation is a geographically bounded phenomenon (Asheim & Isaksen 2002, Cooke et al. 1997). The discovery of the importance of the regional scale and of regional resources in stimulating the innovative capabilities of firms is the major issue of this approach (Asheim & Isaksen 2002). The concept of a local or regional innovation system (RIS) (Cooke et al. 1997) emphasizes interactive research and development activities on a face-to-face basis and, thus, low geographical proximity as a main driving force of cooperative innovation. The concept of geographical proximity comprises several dimensions such as low transaction costs compared to long distance interaction, advantages of face-to face interaction in exchanging tacit knowledge, and the importance of social relationships especially with respect to trust.

Recent literature on RIS often deals with certain regions and describes their development in a rather narrative way. In regional science approaches the existence of a RIS is appreciated by pinpointing cooperative innovation to constitute a main ingredient to explain regional economic growth (Fritsch 2004b). It is close spatial and social proximity that promotes and eases the exchange of knowledge and information and thus contributes to collective learning and creation of knowledge.

With respect to system boundaries in 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 an easy task and one more than often relies on political or administrative boundaries.

Based on these brief characterization of the regional and technological dimension of innovation

systems, we conclude that within the broad concept of innovation systems there exist several independent streams focusing on different attributes of actors and, thus, dealing with different kind of innovation systems. We argue that a main shortcoming of the innovation system concept, beside methodological issues (deeply discussed in Carlsson et al. 2002), is the co-existence of different types of innovation systems at the same place and at the same time. Empirical studies dealing with one of type of system usually ignore the presence of other levels and types of innovation systems.

In answering our research question whether there are differences in cooperation behavior among regions, we want to take into account that effects from the technological dimension are also prevalent. In doing so identifying differences between regions with regard to the number of cooperative innovations or even the share of cooperation agreements in all applications is not a sufficient measure for the differential strength of the respective regional innovation systems. A simple reason for this is that a region with a high tendency to cooperate consists of establishments, mainly firms, that show characteristics of sectors or technologies that are more likely to engage in co-application or in R&D cooperation (Fritsch 2003). Hence, in the next section we suggest a method able to distinguish between regional effects of cooperation behavior and the effects accruing to the technological dimension.

3 Concept of Ratio value

Based on the theoretical background introduced in the last section, in the following we suggest a method allowing to identify (differential) regional effects on cooperative innovation. Our methodology is based on the assumption that regional and technological innovation systems are the two most important types of innovation systems innovative agents are engaged in. A further assumption is that regional and technological effects are independent of each other so that they can be isolated.

3.1 General Methodology

Our analysis requires several types of information about innovations: (1) the actor(s) involved in generating an innovation, (2) the region(s) those actors are located in, and (3) the technology field(s) an innovation belongs to. With (1) we cover the issue of cooperative vs. non-cooperative innovations, with (2) we take into account the regional dimension, and with (3) we have at hand information about the technological dimension. For these three categories we introduce a formal representation.

First, we take into account n innovations indexed by $i \in N = \{1, \dots, n\}$. The technological space within which innovations are created is f with different technologies index $j \in F = \{1, \dots, f\}$. Here it is entirely possible that an innovation $i \in N$ is related to more than one technology $j \in F$. The spatial dimension of innovative activities is represented by the regions r indexed by $k \in R = \{1, \dots, r\}$. Here it is also possible that the R&D activities for innovation i have taken place in more than one region $k \in R$. This is the case whenever innovation i is the result of a cooperation between actors located in different regions. However, we will observe a spatial distri-

bution of innovation i also in the case where the innovative actors belong to different branches of the same firm which are located in different regions. To distinguish between both possibilities we take into account information on whether an innovation i has been developed in cooperation or not.

The relationship between innovations, technological field, spatial distribution and cooperative innovation are formalized as follows. The assignment of all innovations n to the technological fields f is summarized in matrix \mathbf{A} . \mathbf{A} is a $n \times f$ matrix with a typical element:

$$a_{ij} = \begin{cases} 1 & \text{if innovation } i \text{ is related to technology } j \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

The spatial distribution of innovations N is represented by the matrix \mathbf{B} . \mathbf{B} is a $n \times r$ matrix with a typical element:

$$b_{ik} = \begin{cases} 1 & \text{if innovation } i \text{ has been developed by actors located in region } k \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

A spatial distribution of an innovation i occurs whenever different research groups cooperated in a R&D project resulting in innovation i . Whether these research groups work for different economic actors (e.g. firms or universities) is indicated in vector γ . γ is a vector of length n with a typical element:

$$\gamma_i = \begin{cases} 1 & \text{if innovation } i \text{ has been developed by more than one actor} \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

In addition and as a variant to general cooperative innovation we suggest a vector $\tilde{\gamma}$ which contains information about cooperative innovation taking place within a region. This vector is again of length n with a typical element:

$$\tilde{\gamma}_i = \begin{cases} 1 & \text{if innovation } i \text{ has been developed by more than one actor,} \\ & \text{all located in the same region} \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

Given this information we propose a method able to identify regional effects on cooperative behavior by separating technological effects. Hence, the first step is to account for the technological effects.

The technological dimension of cooperative innovation

Our first step focusses on the technological dimension of innovation. The aim is to indicate the propensity of cooperative innovation for each of the technologies. Since innovations regularly are related to several technologies we need to know to what degree an innovation i is related to each of the f technologies. Hence, for each innovation i we determine weights with respect to each of the f technologies.

Matrix \mathbf{A} which contains the unweighed values is the starting point. Dividing each element $a_{i,j}$ of row i by the sum of all elements $\sum_{h=1}^f a_{i,h}$ just leads to the weights required. Matrix \mathbf{A}^w contains these weights. It is a $n \times f$ matrix with a typical element:

$$a_{ij}^w = \frac{a_{ij}}{\sum_{h=1}^f a_{ih}} \quad (5)$$

The sum of the elements of row i in matrix \mathbf{A}^w is equal to one. We here assume that all technologies related to innovation i show the same weight.

In order to distinguish between innovative and cooperative activities among technologies, each row i of matrix \mathbf{A}^w is multiplied with the corresponding value γ_i of vector γ . The result is a matrix \mathbf{A}^{wc} comprising only the technology weights of cooperative innovations. \mathbf{A}^{wc} is a $n \times f$ matrix with a typical element:

$$a_{ij}^{wc} = \begin{cases} \frac{a_{ij}^w \times \gamma_i}{\sum_{h=1}^f a_{ih}^w \times \gamma_i} & \text{if } \gamma_i = 1 \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

Matrices \mathbf{A}^w and \mathbf{A}^{wc} are now used to determine average cooperation behavior for each technology. For that we sum up the elements of each column (technology field) in \mathbf{A}^w and \mathbf{A}^{wc} . In the former case we get an account of the number of innovations related to technology j , in the latter case of the number of related cooperative innovations in that technology. The ratio of both magnitudes indicates the propensity of cooperative innovation in technology j . The ratios of all the technologies are included in vector \mathbf{p}^c .³ It is a vector of length f with a typical element:

$$p_j^c = \frac{\sum_{i=1}^n a_{ij}^{wc}}{\sum_{i=1}^n a_{ij}^w} \quad (7)$$

At this point, however, one has to be careful in interpreting this ratio as a purely technological effect. Since the cooperative innovations considered are affected by both technological as well as regional effects the ratio computed contains the specific technology based propensity to cooperate as well as an average influence of regional effects.

Equivalently to the procedure above we can restrict the analysis to cooperative innovation taking place only within the region. For that each row i of matrix \mathbf{A}^w is multiplied with the corresponding value $\tilde{\gamma}_i$ of vector $\tilde{\gamma}$. The result is a matrix $\tilde{\mathbf{A}}^{wc}$ comprising only the technology weights of cooperative innovations which have taken place within regions. Using now matrices \mathbf{A}^w and $\tilde{\mathbf{A}}^{wc}$ we can compute the propensity of cooperative innovation represented by vector $\tilde{\mathbf{p}}^c$ which does not only comprise the technological effects but also the average intra-regional effect.

The regional dimension of cooperative innovation

In a second step we focus on the regional distribution of innovation in general and of cooperative innovation in particular. Equivalent to the procedure above, we determine the weights by which an innovation i is related to regions $k \in R$ where the actors innovating i are located. Matrix \mathbf{B} contains the unweighed relationships. Dividing each element of row i by the sum of all elements of row i delivers the respective weights; here to each region related to innovation i the same weight is assigned. Matrix \mathbf{B}^w contains the results. It is a $n \times r$ matrix with a typical element:

³We assume that there is at least one innovation in each technology. Therefore, we do not distinguish several cases in equation 7

$$b_{ik}^w = \frac{b_{ik}}{\sum_{l=1}^r b_{il}} \quad (8)$$

Multiplying each element b_{ik}^w of matrix \mathbf{B} by the element γ_i of vector γ leads to the spatial distribution of the cooperative innovations. The resulting matrix is \mathbf{B}^{wc} . It is a $n \times r$ matrix with a typical element:

$$b_{ik}^{wc} = \begin{cases} \frac{b_{ik}^w \times \gamma_i}{\sum_{l=1}^r b_{il}^w \times \gamma_i} & \text{if } \gamma_i = 1 \\ 0 & \text{otherwise} \end{cases} \quad (9)$$

Matrix \mathbf{B}^{wc} contains information about the regional distribution of cooperative innovation independent of whether the cooperation is within the region or between different regions. Using $\tilde{\gamma}$ instead of γ leads to a matrix $\tilde{\mathbf{B}}^{wc}$ which contains information on cooperative innovations internal to the region.

The expected value of regional cooperative innovation

In a third step, we compute an indicator stating the expected number of cooperative innovations in a region k . For this index we take into account the technology specific propensity for cooperative innovation of the previous section which contains also the average regional effect. We start by computing the number of innovations of technology j in region k . The respective numbers are stated in a matrix \mathbf{C} with r rows (regions) and f columns (technology fields).

This $r \times f$ matrix \mathbf{C}^w contains information about the number of innovations that have been developed in technology j by actors from region k . \mathbf{C}^w is computed by:

$$\mathbf{C}^w = \mathbf{B}^{w'} \mathbf{A}^w \quad (10)$$

$\mathbf{B}^{w'}$ is the transposed matrix \mathbf{B}^w . \mathbf{C}^w is used to create an indicator of what we call the "expected value of cooperative innovation" (e_k^c) of region k . It indicates how many cooperative innovations are to be expected in region k taking into account the technology specific propensities for cooperative innovation p_j^c . Vector \mathbf{e}^c contains the expected cooperation values for all regions k . It is a vector of length r with a typical element:

$$e_k^c = \sum_{j=1}^f c_{kj}^w \times p_j^c \quad (11)$$

Real and expected value of regional cooperative innovation

Were cooperative innovations within a region solely affected by technological determinants (and an average regional effect) - implying that there are no differential regional effects on cooperative innovation - the observed number of cooperative innovations has to be identical to the expected number. In order to test for this, in a final step, for each region r the ratio between observed and the expected cooperative innovations is determined. For that we compute the column sum of elements of matrix \mathbf{B}^{wc} . This just leads to number of all cooperative innovations observed in each region. For each region we take this sum and divide it by the respective expected number of cooperative innovations e_k^c . The region specific ratios are contained by vector \mathbf{v} . It is a vector of length r with the typical element:

$$v_k = \frac{\sum_{i=1}^n b_{ik}^{wc}}{e_k^c} \quad (12)$$

This ratio takes values between 0 and infinite. At a ratio of 1 the number cooperative innovations observed in a region is just equal to the expected number. A ratio different from 1 indicates that there exists a differential regional effect above or below the average regional effect. Regional cooperative innovation above (below) the average is indicated by a positive (negative) ratio.

Using instead of \mathbf{B}^{wc} the matrix $\tilde{\mathbf{B}}^{wc}$ one achieves at a vector $\tilde{\mathbf{v}}$ which contains the ratio of realized intra-regional cooperations to the expected ones. The interpretation is equivalent to the one above. The difference is that above we identify regional effects on cooperative innovation in general whereas here we look at regional effects on intra-regional cooperation.

Using this ratio to determine differential regional effects of cooperative innovation has two advantages. First, it is independent of the data base. Below we will use patent data to test whether these regional effects on cooperative innovation exist; but this method can be applied to any other data base on innovation activities which includes information about technology, spatial distribution and cooperation. This data for example can be based on firm survey data.

Second, this indicator is independent of the size of a region as measured by the number of cooperative innovations observed in that region. Hence, agglomeration effects or the strength of a regional innovation system we want to measure cannot be attributed simply to the size of the region but have to do with above average propensity to cooperate. Here, one alternatively may think of the ratio cooperation per innovation doing the job. However, this ratio is not able to take into account the differences of cooperative innovation related to the specific technologies a regions hosts. Taking into account the pure intra-regional dimension may deliver additional information on the regional innovation system. Because of these advantages, we suggest our ratios to be used for indicating the strength/weakness of a regional innovation system and to track its performance over time.

3.2 Method application

Before we start to apply the method to real data we want to exemplify it with the help of a simple example. We consider three innovations, hence $i = \{1, 2, 3\}$ and $n = 3$. These innovations are related to two technologies (TF1 and TF2), so that $j = \{1, 2\}$ and $f = 2$. The inventors are located in two different regions (R1 and R2), $k = \{1, 2\}$ and $r = 2$). Two of those three innovations are generated by two actors and are identified as cooperative innovation. We do not consider the case of intra-regional cooperation but the more general case. The data are as follows:

Table 1: Example - data

Innovation	Techn. field	Region	Cooperative innovation
Innovation 1	TF1	R1 and R2	coop
Innovation 2	TF1 and TF2	R1 and R2	no coop
Innovation 3	TF2	R2	coop

With respect to this example matrix \mathbf{A} is a 3×2 -matrix:

$$\mathbf{A} = \begin{pmatrix} 1 & 0 \\ 1 & 1 \\ 0 & 1 \end{pmatrix}$$

Matrix \mathbf{B} is a 3×2 matrix:

$$\mathbf{B} = \begin{pmatrix} 1 & 1 \\ 1 & 1 \\ 0 & 1 \end{pmatrix}$$

Vector γ indicating whether innovation i is cooperatively generated contains the following elements:

$$\gamma = \begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}$$

With these data, first the activities among the technological space are analyzed. The absolute values in matrix \mathbf{A} are weighted by the number of technologies j innovation i is related to. The outcome is matrix \mathbf{A}^w :

$$\mathbf{A}^w = \begin{pmatrix} 1 & 0 \\ 0.5 & 0.5 \\ 0 & 1 \end{pmatrix}$$

Proceeding the same way for cooperative innovations ($\gamma_i = 1$) leads to the matrix \mathbf{A}^{wc} :

$$\mathbf{A}^{wc} = \begin{pmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{pmatrix}$$

The two matrixes set up contain information about the relationship between all innovations on the one hand and cooperative innovations on the other hand to the two technology fields. Both matrices are used to compute the propensity for cooperative innovation in each of the two technologies. The result is contained in vector \mathbf{p}^c :

$$\mathbf{p}^c = \begin{pmatrix} 0.66 \\ 0.66 \end{pmatrix}$$

Here for both technologies we get the same propensity to cooperate of 0.66.

In a second step, the regional dimension of innovation and cooperative innovation is considered. Proceeding analogously to the technological dimension we obtain \mathbf{B}^w for the regional distribution of all innovations and \mathbf{B}^{wc} for the cooperative innovations:

$$\mathbf{B}^w = \begin{pmatrix} 0.5 & 0.5 \\ 0.5 & 0.5 \\ 0 & 1 \end{pmatrix}$$

$$\mathbf{B}^{wc} = \begin{pmatrix} 0.5 & 0.5 \\ 0 & 0 \\ 0 & 1 \end{pmatrix}$$

The third step sets into relation the technological and the spatial dimension using all innovations. The result of multiplying the transpose of matrix $\mathbf{B}^{w'}$ and \mathbf{A}^w is shown in matrix \mathbf{C}^w which has the dimension 2×2 (2 regions and 2 technologies):

$$\mathbf{C}^w = \begin{pmatrix} 0.75 & 0.25 \\ 0.75 & 1.25 \end{pmatrix}$$

The expected share of cooperative innovations for each region is computed by multiplying matrix \mathbf{C}^w with the vector of the cooperation propensity \mathbf{p}^c . The result is a vector \mathbf{e}^c which has a length of 2 according to the number of regions:

$$\mathbf{e}^c = \begin{pmatrix} 0.66 \\ 1.33 \end{pmatrix}$$

According to the technological classification of all innovations in region 1 and 2, the expected cooperation value in region 1 is twice (1.33) the value for region 2 (0.66). Finally, the observed number of cooperative innovations for each region k , indicated through matrix \mathbf{B}^{wc} , is related to these values. The final result are the ratio values \mathbf{v} for each region.

$$\mathbf{v} = \begin{pmatrix} 0.75 \\ 1.25 \end{pmatrix}$$

In our example in the first region the observed cooperative innovations are less than one could expect (0.75) according to its patent application behavior among all technologies, whereas in the second region observed cooperative innovations exceed their expected value (1.25). Within our theoretical context this suggests that for region 1 there is a regional effect working fostering cooperative innovation above the average; in region 2, contrariwise, factors seem to be present not fostering or even preventing cooperative innovation.

4 Data base

The methodology introduced to identify differential regional effects of cooperation behavior will now be applied to a specific source of information about innovations, patent data. The sample contains data about patent applications for Germany between 1998 and 2003. This information is taken from the "Deutsche Patentblatt" publication which includes data from the German patent office as well as data from the European patent office (EPO).

Technological dimension in patent data

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

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

Regional dimension in patent data

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

Just like a patent may be filed for several technology fields, there may be more than one region the inventors of a patent are located. We accordingly assign the patent activity to all regions where the inventors come from. And to each region addressed the same weight will be assigned.

For the spatial grid we use the concept of "Raumordnungsregionen" developed by the "Deutsches Bundesamt für Bauwesen und Raumplanung". Due to this concept Germany is divided into 97 regions with the objective of including all - or at least as much as possible - labor mobility within one region. Therefore, we assume that the residence and workplace address of an inventor lies within the same Raumordnungsregion. Based on this regional grid the set of regions in our study amounts to $r = 97$.

Cooperative patents

Patent data can also be used to account for cooperative innovation. Cooperative innovation is

understood here as any innovation where more than one actor has been involved in the generation of innovative knowledge. This cooperation can be formal or informal, it can be explicitly stated or implicitly assumed.

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

There, however, exists an additional source of the occurrence of cooperative innovation, scientist mobility. Consider the case where inventor Z works for firm X during the whole period of time and is listed on a first patent I; a second patent II is the result of a R&D cooperation between X and Y, where, however, only Y has filed for this patent and where inventor Z has been involved. Since in general all the inventors are listed on the patent application, we find Z as inventor on both patents. By this, even without a co-application for patent II we can assume that there has been knowledge exchange between X and Y by the mean of inventor Z. This is labelled cooperation by scientist mobility.

Accounting for the empirical relevance of this case, in a firm survey done in 2006 (Cantner et al. 2008) only every fourth patent being the result of an R&D cooperation has been applied by both cooperation partners. A caveat of this indicator is that knowledge flows by scientist mobility link only in one direction. For these two reasons we decided to further analyze cooperative innovation only on the basis of the first mode of interaction, co-application.

In applying our approach to the German patent data by the way of 43 technological classes and the 97 regions we refrain from treating intra-regional cooperative patents. This decision is based on the fact that the 43/97 assignment does not allow us to observe a sufficient number of intra-regional cooperative innovations. Hence, when we refer to regional effects on cooperative innovation than it is the regional effect on being cooperative in general, that is independent of whether the cooperation partners are inside or outside the own region.

Descriptive data

Our analysis is based on patent data for the period between 1998 and 2003. These data are available on an annual basis. Some descriptive statistics as given by table 2 characterize our data base.

First, the number of patent applications increased slightly over time and shows an abrupt cutback in 2002 related to the burst at the worldwide stock markets. Second, the number of cooperative patents followed a similar development. Third, a slightly declining propensity of co-

Table 2: Description of the data base

Abbr.	Description	Database					
T	time series	1998	1999	2000	2001	2002	2003
N	number of patent applications	$N_1 = 28151$	$N_2 = 31736$	$N_3 = 34206$	$N_4 = 33842$	$N_5 = 17045$	$N_6 = 24254$
C	No. of co-applications	$C_1 = 1459$	$C_2 = 1584$	$C_3 = 1684$	$C_4 = 1625$	$C_5 = 765$	$C_6 = 910$
	Propensity of co-applications	5,18%	4,99%	4,92%	4,8%	4,49%	3,75%
I	number of technological fields	43	43	43	43	43	43
R	number of regions observed	97	97	97	97	97	97

operative patenting can be observed over time. Fourth, in each year at least one patent has been assigned to each of the 43 technological fields spanning our technological space (I). Fifth, in each year at least one inventor is assigned also to each of the 97 regions of our spatial space (R).

To smoothen variations over time, our approach is applied to moving periods with one year overlap. We use a moving 3-year average, leading to 4 subperiods t . To ease notation we label each of these subperiods by the middle of the respective three years, hence, 1999, 2000, 2001, and 2002.

5 Results for Cooperative Innovation in Germany

5.1 Technological dimension of cooperative innovation

This section looks at the differences in patenting behavior between technologies and focusses on co-applications and their development over time. We consider each of the four subperiods.

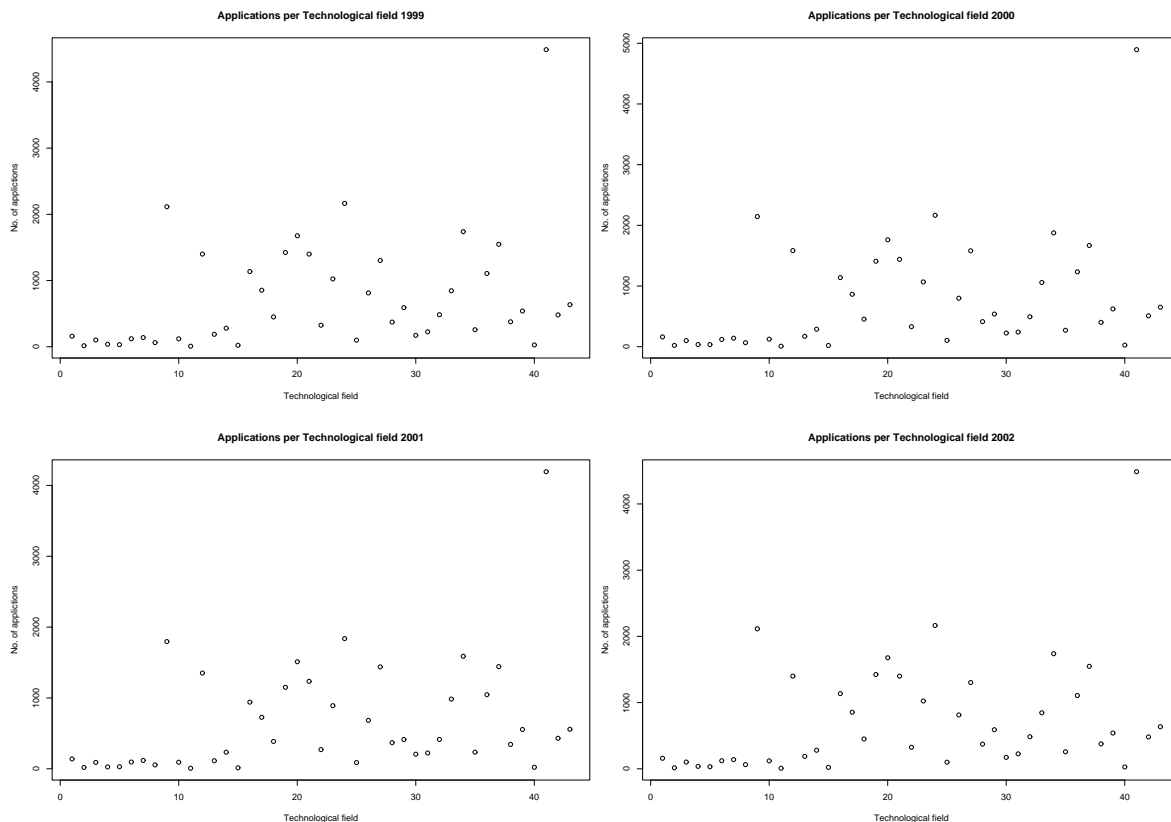
Figure 1 shows the number of patent applications for each technology class ($F = 43$) for each period t . In each period most of patents have been filed for in technology class 43 (motor vehicles). The technology with the fewest number of patent applications in each period is class 12 (paints and varnishes). Hence, there obviously exists an unequal distribution of patenting activity among technologies.

To have a closer look at those differences we refer to Gini coefficients ⁴. For that table 3 states the number of both the total patent applications and the total number of co-applications. For both we computed the Gini coefficient with respect to the 43 technology classes. Since the data is normalized in this procedure, the coefficients between the two different variables can be compared.

We first observe that the inequality between technologies concerning patent applications is always above 0.55 and considerably constant over time. Hence, the number of patent applications is not equally distributed between the observed technologies. Tracking the Gini coefficients over

⁴The Gini coefficient developed by Gini (1921) is a measure of inequality of a distribution. It is defined as a ratio with values between 0 and 1: the numerator is the area between the Lorenz curve of the distribution and the uniform (perfect) distribution line; the denominator is the area under the uniform distribution line.

Figure 1: Amount and development of patent applications



time indicates that the inequality is not changing much. Obviously this does not tell us anything about the development in each of the technology classes. However, the visual inspection of figure 1 shows some persistent pattern herein.

Although these finding seems to be somehow trivial they are of importance for our understanding of regional innovative performance. For this we refer to Griliches who shows that the relationship between patent applications and R&D is close to be proportional for all industries (Griliches 1990, p.1702). We conclude from this that differences in number of patents in each class is an indication for differences in the innovative activities and in the innovative performance among those classes. Hence, the distribution of patent applications mirrors the distribution of innovative activities in the technology classes. For our research question this implies that the level of regional innovative activities and performance depends among others on the respective regional composition in terms of industries or technologies.

We secondly find the Gini coefficient for co-applications being slightly lower than the one for patent application. Its value is always above 0.53 and also remains rather constant over time. The same interpretation applies here: the degree of regional cooperative innovation is dependent of the regions type and composition of industries and technologies.

This result easily can be related to literature on R&D cooperation. Respective empirical stud-

Table 3: Application and Co-application distribution regarding technological fields

		Period 1	Period 2	Period 3	Period 4
		1999	2000	2001	2002
Applications	no. of	31364	33261	28364	25047
	Gini coefficient	0.557	0.560	0.562	0.568
Co-applications	no. of	1563	1619	1358	1100
	Gini coefficient	0.534	0.532	0.532	0.539
Co-appl. Prob.	mean	0.061	0.059	0.053	0.048
	median	0.053	0.053	0.052	0.048
	min	0.015	0.015	0.000	0.000
	max	0.129	0.135	0.106	0.095
	Gini coefficient	0.238	0.242	0.218	0.231

ies often deal either with firm characteristics influencing cooperation behavior (Miotti & Sachwald 2003, Belderbos et al. 2004) or concentrate on the impact of cooperations on firm performance (Oerleman & Meeus 2000, Lööf et al. 2001, Thornhill 2006). In this context of certain interest are organizational practices affecting firms' performance for which one often observes a slow diffusion of best practices due to difficulties in imitating complex organizational capabilities (Teece 1986). Applying this to the organizational device "to cooperate" may already explain sustained performance differences of firms within and between industries. And extending the argument one may discuss differences between certain technologies (characterizing industries). The empirical evidence on this issue, however, is rather scarce.

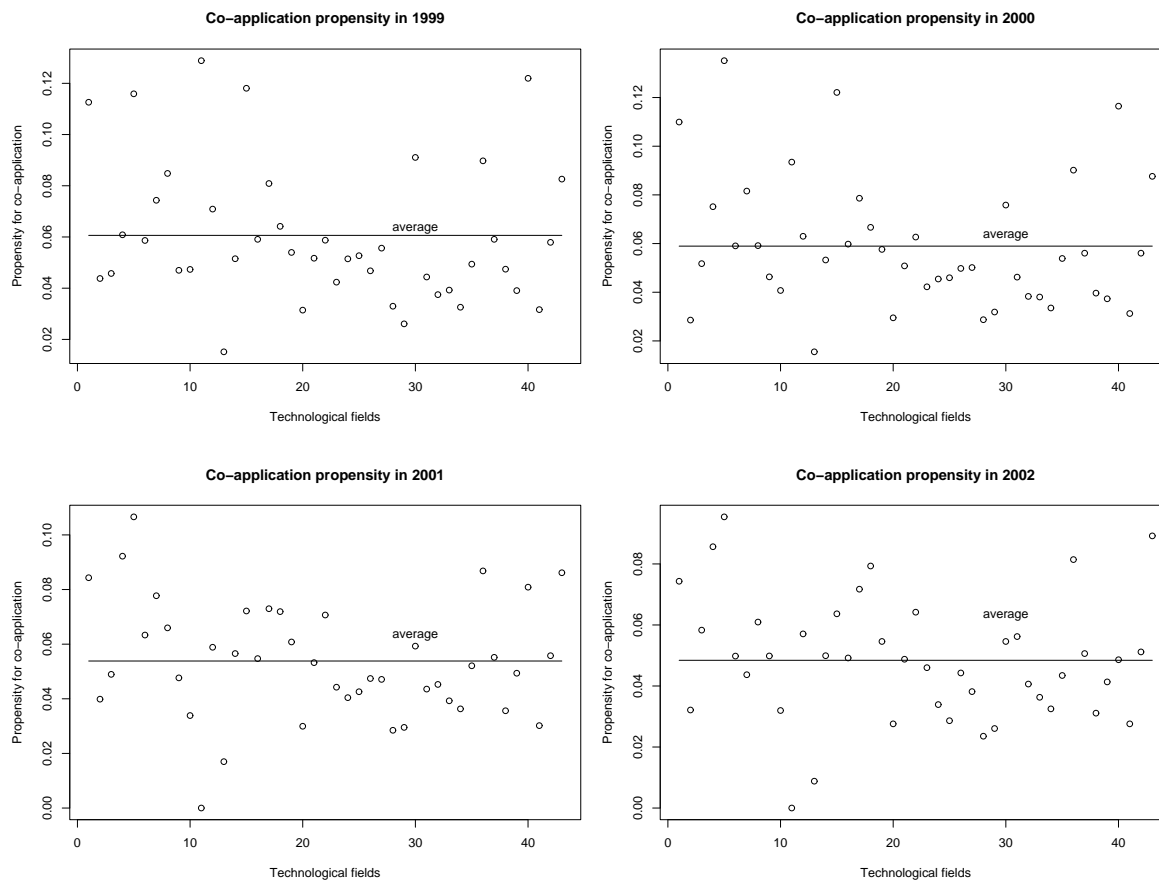
Both the development and the distribution of this co-application propensity are shown in figure 2. The mean value of the co-application propensity declines from 6.1% in 1999 to 4.8% in 2002. In other words the number of co-applications decreases more than the number of applications. The inequality between the 43 technological fields remains rather stable. However, its level is much lower in comparison to the Gini coefficients shown for applications and co-applications.

Obviously, there are differences between technology fields in terms of the propensity to co-apply. The lowest value is in the first two periods slightly above zero (1.5%) and 0 for the last two periods, while the maximum value is about 13% in the first two periods and about 10% in the third and fourth one. Interpreting these propensities one has to take into account that they contain the respective technological or sectoral dimension but also the (for all the technologies the same) average regional effect on cooperative innovation.⁵ This is due to the fact that for the observed co-applications we cannot extract the sheer technological effects.

On the basis of the observed differences in co-application propensity between technologies or sectors the question is whether this already can explain regional differences in cooperative inno-

⁵More precisely, for each technology this propensity contains the technology specific effect and the average regional effect pertaining to those regions the respective technology is "located" in. However, due to the broad definition of the 43 technology classes we observe each technology at least once in each of the 97 regions.

Figure 2: Distribution and development of the Propensity for co-application



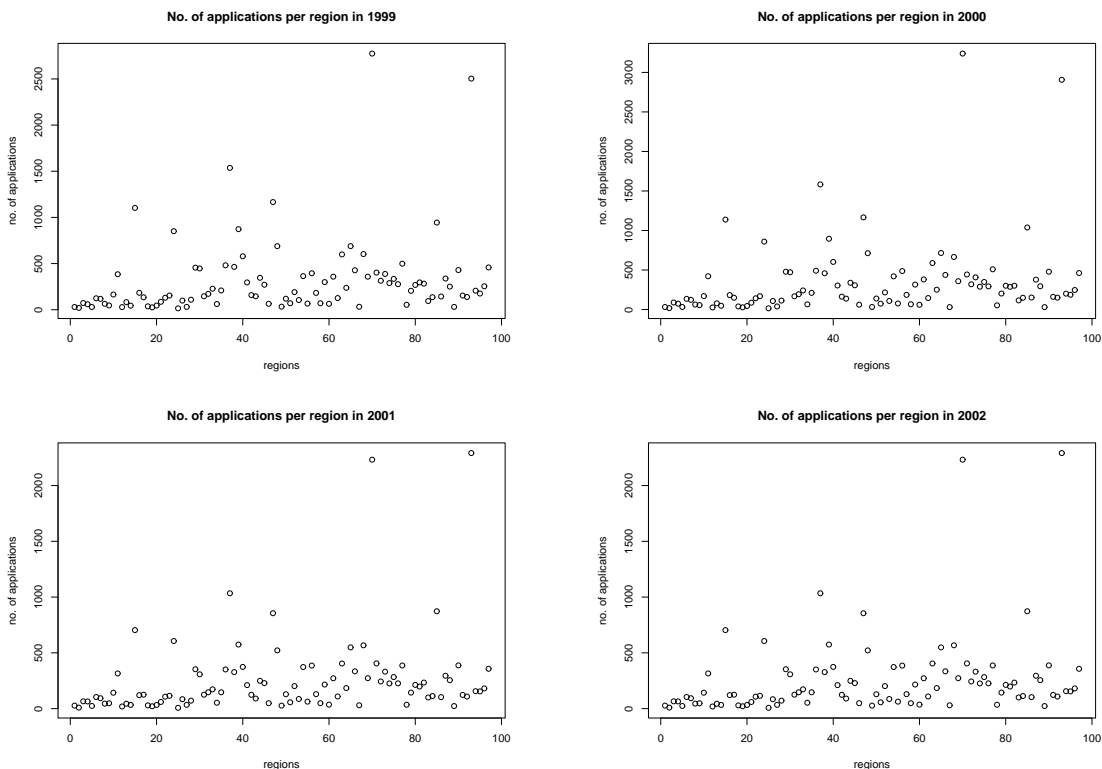
vation in the following sense: Consider two regions differing in their composition of technologies or industries. Take into account the observed sectoral or technological differences in cooperative innovation. If one of the regions consists of more cooperative sectors and the other region of rather non-cooperative sectors, then regional differences can be readily explained by regional composition of industries and their respective propensity to co-apply. Then an additional regional factor is not working.

5.2 Regional innovative and cooperative behavior

Having shown that there exist differences in cooperative patenting among technologies, differences in regional cooperation behavior are analyzed now. In a first step we observe regional differences in patent application. Figure 3 shows how the overall number of patents is distributed over all 97 regions.

There are two outstanding regions, Stuttgart (ROR 72) and Munich (ROR 93) with the highest number of patent applications. While this can be attributed to automobile industry in the former case, in the latter it is due to public research institutes such as Fraunhofer or Max-Planck whose

Figure 3: number of regional applications and its development



headquarters are located in Munich.

Equivalently to table 3, the regional distribution of patent applications and co-applications is shown in table 4. The Gini coefficient of about 0.54 for the regional distribution indicates a regional inequality similar to the one among technology fields (about 0.56). This level remains roughly constant over all four periods. Accordingly, in addition to technology related effects on patenting there are regional effects to be considered.

Table 4: Regional distribution of patent applications and co-applications

		period 1	period 2	period 3	period 4
		1999	2000	2001	2002
Applications	no. of	31364	33261	28364	25047
	Gini coefficient	0.547	0.551	0.545	0.545
	for regional distr.				
Co-applications	no. of	1563	1619	1358	1100
	Gini coefficient	0.493	0.491	0.501	0.482
	for regional distr.				

Looking in a second step at co-applications they regionally are obviously more equally distributed than applications. The Gini coefficient is somewhat lower at about 0.49 and rather stable

over time. This observation suggests that for explaining cooperative innovation effects related to technological classes addressed are more discriminatory than effects related to the regions the innovators are located in.

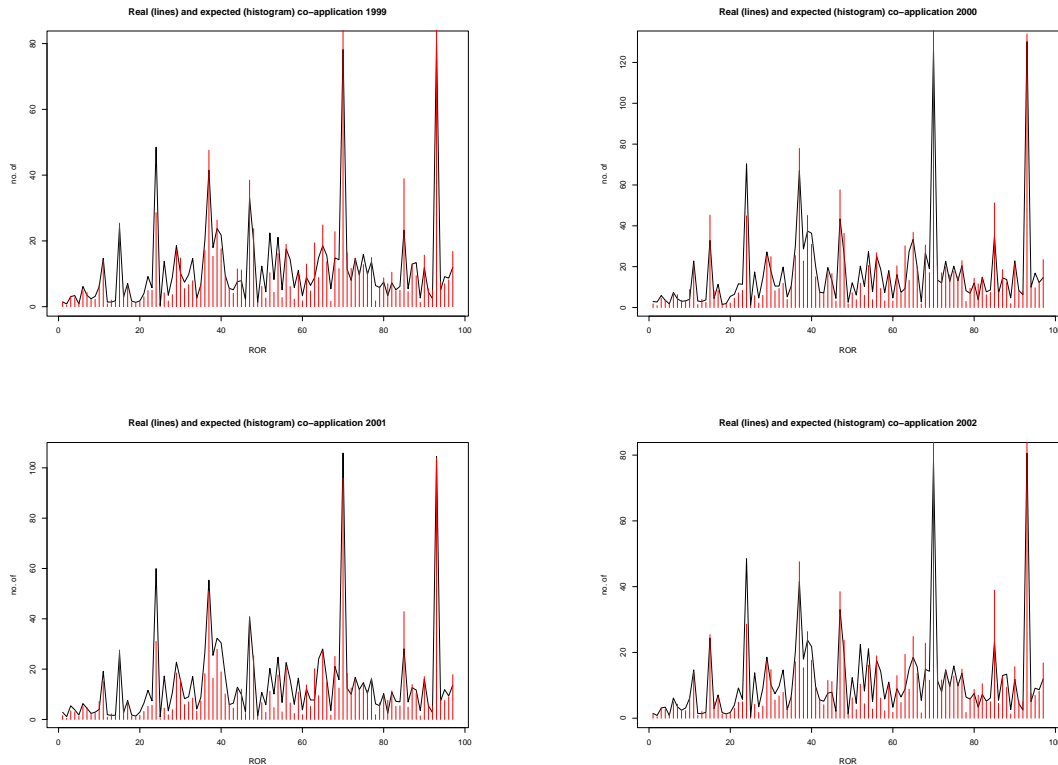
Equivalent to the technological differences in co-application, the observed differences in cooperative innovation on the regional scale comprise both regional effects and the average effect of those technologies contained in the respective regional composition of industries or technologies. The next step now is to extract the technological effects. This is done by applying the technology or sector oriented propensity to co-apply.

5.3 Differential regional effects on cooperative innovation

In this final step we separate the technology specific effect and the average regional effect on cooperative innovation in order to get an index for the differential regional effect. For this we use the expected regional number of co-applications computed on the basis of the industry or technology composition of a region and relate it to the observed number of co-applications.

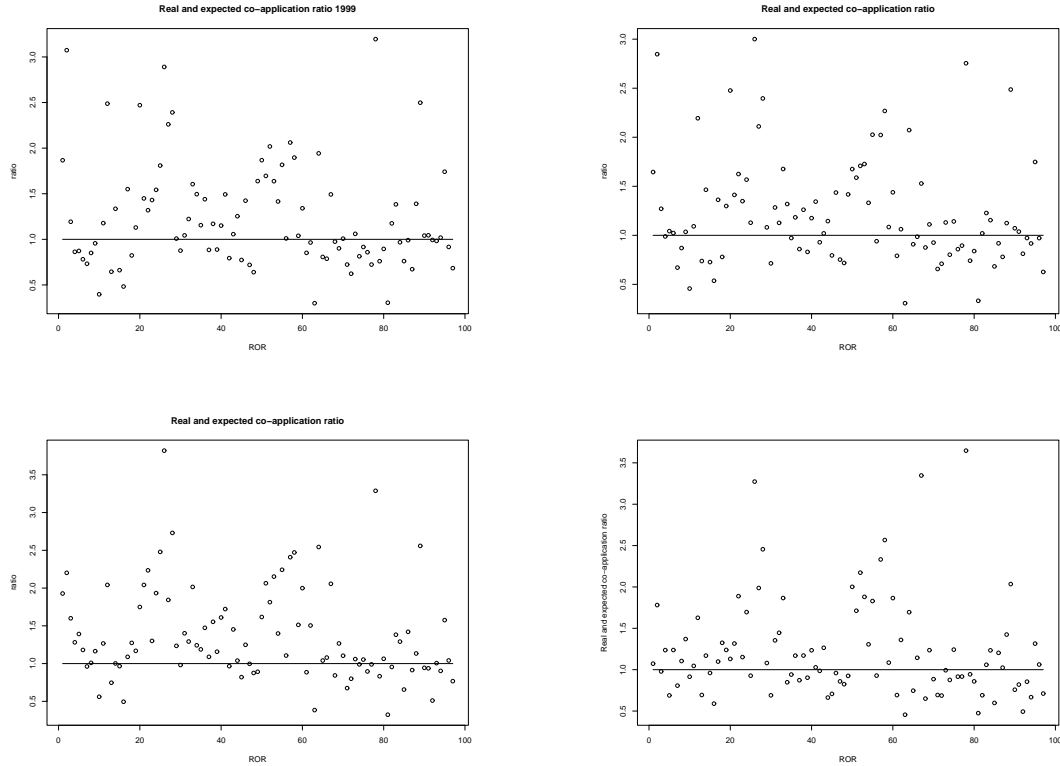
Figure 4 shows for the 4 periods analyzed and for all 97 ROR the *observed* co-applications (black line) as well as the *expected* number of co-application (bars).

Figure 4: Real and expected regional co-applications



We observe first that the expected number of co-applications for each region differs from the observed one. However, comparing regional differences in the absolute numbers leads to a size dependent bias. Therefore a relative account is required. Following equation 11, the ratio between observed and expected regional interaction just renders this as it looks at cooperative innovation above or below average. This ratio is shown for each of the 97 regions and for each of the 4 sub-periods in figure 5.

Figure 5: Ratio of expected and real regional co-applications



A ratio value of 1.0 means that the level of regional cooperative innovation is as high as the realized one and thus that cooperative innovation in this regions is average. Ratios below and above one indicate a level of cooperative innovation below and above average. Looking at the ratios the disparity between the regions is considerably high.

This observed disparity of the ratio values among the regions indicates that there are regional effects on cooperative innovation. Since we here focus on cooperative innovation in general and not on the restricted case of only intra-regional relations, the regional effects detected for ratio values above respectively below 1 can neither be interpreted as the existence or lack nor as the strength or weakness of a regional innovation system in the respective region. For that to hold, a closer inspection of the cooperative arrangements and an additional analysis of intra-regional cooperative innovation are required. Hence, the differential regional effects we computed work on the region-specific attitude of actors to engage cooperative innovation independent of whether the cooperation partners belongs to the same region or not.

Having shown visually that there are differences of regional effects of cooperation behavior, we want to show that the distribution of ratio values is significant different from 1. If the calculated values do not differ significantly from this value, this would imply that to explain regional differences in cooperative innovation one has to refer only to the regional composition of technology classes. Therefore, the distribution of all ratio values has to be tested. First, we apply a Shapiro-Wilk test to test for normal distribution. Table 5 shows that the ratio values in all four periods are not normally distributed. Referring on this result, we use Kolmogorov-Smirnov equality-of-distributions test in order to calculate whether the ratio values differ significantly from a normal distribution with an expected value of 1. In table 5 the corresponding corrected p-values are presented. For all four periods we found p-values below a critical 1% level which implies a refusal of the null hypothesis that the distribution of the ratio values have a mean value of 1. We can conclude from these results that the ratio values have are non-normal distribution with a higher variance than a normal distributed variable and a mean value which differs significantly from 1.

Table 5: Tests on differences between real and expected co-application amount

		period 1	period 2	period 3	period 4
ratio	minimum	0.300	0.308	0.323	0.456
	maximum	3.195	3.000	3.820	3.647
	std. dev.	0.583	0.546	0.619	0.599
Shapiro-Wilk-test					
	$Prob > chi^2$	0.000	0.000	0.000	0.000
Kolmogorov-Smirnov test		0.000	0.000	0.000	0.000

Hence, our visual impression on the existence of differential regional effects on cooperative innovation are substantiated by the statistical tests in table 5. Consequently, for our sample regional differences in cooperative innovation are not only affected by the composition of regional technology base (technology classes) but also significantly by specific regional effects.

Looking more specifically at the results we find the lowest ratio degree over all periods except the third for the city of Trier in Rhineland-Palatinate with 0.299 to 0.456. The technologies located in that region call for a much higher number of co-applications than realized. The highest ratios of the first and the fourth period are found for Hochrhein-Bodensee in Baden-Wuerttemberg (3.195 and 3.647); in the second and third period the region of Uckermark-Barnim in Brandenburg shows the highest ratios (3.000 and 3.820).

A different visual representation is chosen in appendix A where we show a map of Germany with 97 regions. The regions are colored in accordance to their respective ratio. A darker color indicates a higher ratio value for this region. Two observations are interesting. First, those regions which are assigned as most innovative in terms of total patent applications, especially those in the southern part of Germany, show a considerably low ratio. Hence, here the level of cooperative innovation is lower than expected. Secondly, by and large all regions in Eastern Germany show a

higher level of cooperative innovation than expected.

These differences in the cooperative innovation between East German actors in comparison to actors located in the Western part has been discussed already in Cantner & Graf (2003) and Graf (2006). There a significant higher level of cooperative patenting has been found for the regional innovations systems of Jena and Dresden (two East regions) and the systems of Heidelberg and Ulm (two West regions). To find an explanation for this one may refer to other empirical work related to comparison between the eastern and the western part of Germany such as Brixy & Grotz (2004) or Fritsch (2004a). Looking at the firm level such work concludes that differences of the performance between newly founded firms in both parts of Germany that these differences are due to *"the region-specific stock of knowledge capital and knowledge spillovers, as well as other locational conditions, such as density of economic activity, the industry mix, and the characteristics of the regional innovation system."* (Fritsch 2004a, p.540). It would be interesting to dig deeper into those relationships and to ask for influence of regional innovation systems, to discuss the necessity and efficiency of cooperative innovation, and to look at the role of knowledge bases, human capital and actors' structure.

However, one reservation has to be made. One obviously may in this context question whether the higher ratio value in East German regions can really be attributed to a higher intensity of co-application and therefore cooperative innovation. One may argue that this may also have to do with a different attitude towards applying for patents. With respect to the latter one could think of a higher propensity for "private applications" in East Germany. Graf & Henning (2006) suggest that many firms in the respective regions are young. If these start-ups fail the patent rights are a part of the insolvency. In order to prevent this the inventors in Eastern Germany might tend to list themselves as applicants. Consequently, although those inventors belong to the same firm and the same region we have to consider them as co-applying since they are listed with different private addresses. This case seems to be more frequent in Eastern Germany with the consequence of a higher number of co-applications.

To substantiate this a more in-depth investigation along the lines briefly mentioned above is required and left over for future work. For this we consider the characteristics of the regional innovation systems as most interesting to be analyzed.

6 Conclusion

This paper suggests a method to disentangle regional and technological effects on cooperative innovation. The importance of both effects are maintained by approaches on the sectoral and on the regional innovation system. Generally, studies on cooperative innovation deal only with one of the both concepts although actors engaged in cooperative innovation can be considered to be member of both types of systems. The difference between both concepts lies in the definition of the boundaries of a system, i.e. how they define the set of system members in contrast to the rest of the world. Authors like Carlsson & Stankiewicz (1995) or Malerba & Orsenigo (1997) stress the technological proximity within technological or sectoral systems that furthers cooperation. The

regional innovation system approach (Cooke 1992) looks at spatial proximity and face-to-face contacts which ease the exchange especially of tacit knowledge.

We show how to distinguish between both effects and how to disentangle them in empirical work. For this we introduce the ratio value which relates the expected degree of cooperative innovation of a region to the observed one. Applying this method to patent data for Germany between 1998-2003 we identify regional differences in cooperative innovation for Germany which can not be explained by technological determinants and the technological or sectoral composition of a region.

Having identified differential regional effects on cooperative innovation are necessarily has to go on with an analysis of the intra-regional cooperative innovations - which we left out as explained above. This will be the next step we will pursue.

Furthermore a deeper analysis of where those differences come from is required. We expect the regional knowledge base according to several dimensions to have a major impact. This will be a second focus of future work.

Related to this another avenue of future research follows from the implicit assumption in this paper that the propensity to cooperate in each technology is exogenously given. Other work on cooperative innovation such as Hagedoorn & Schakenraad (1992) shows, however, that cooperative innovation shows a certain time pattern. Hence, an issue here is to concentrate on regularities of cooperative innovation among technologies with respect to the age of the technology or the age of the sector. Insights from technological life cycle studies can be used to explain why there are differences in the cooperation propensity among certain technologies. For this to work out, a data base comprising information about a longer time period is required. This will be the third focus of our future research.

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Jena Economic Research Papers 2008-014

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A Ratio of the number of expected and realized regional cooperations

Figure 6: Exp.-real co-application ratio in 1999

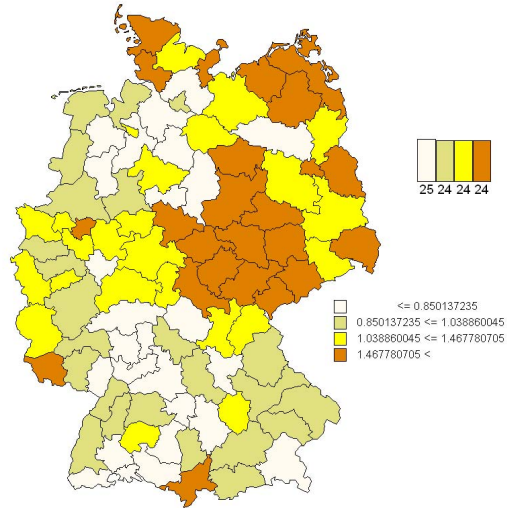


Figure 7: Exp.-real co-application ratio in 2000

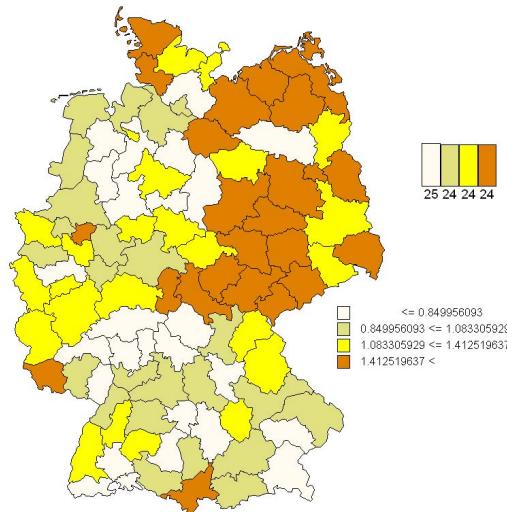


Figure 8: Exp.-real co-application ratio in 2001

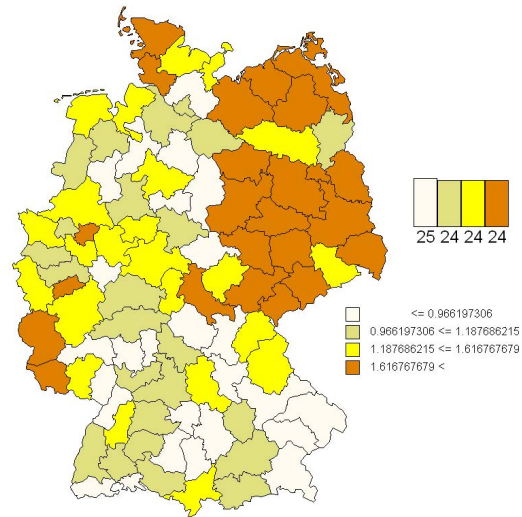


Figure 9: Exp.-real co-application ratio in 2002

