Innovation cooperation in East and West Germany: A study on regional and technological impact

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Abstract: In this paper we investigate the impact of regional and technological innovation systems on innovation cooperation. We develop an indicator applicable to regions, which demonstrates the relative regional impact on innovation cooperation. Applying this method to German patent data, we find that regional differences in the degree of innovation cooperation do not only depend on the technology structure of a region but also on specific regional effects. High-tech oriented regions, whether east or west, are not automatically highly cooperative regions. East German regions have experienced a dynamic development of innovation cooperation since re-unification in 1990. Their cooperation intensity remains higher than in West German regions.

JEL classification: O31, P25, Q55

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1. INTRODUCTION

Innovations often take place collectively when different actors cooperate in order to create something new (Allen 1983). Over the last decades, innovation cooperation activities[i] have increased strongly as a real phenomenon (Hagedoorn 2002) and many empirical studies deal with their economic effects (Belderbos et al. 2004, Oerleman/Meeus 2000).

From the resource-based view of a firm, actors engage in cooperation to share the costs and risks of innovation activities and to get access to external knowledge (Mowery et al. 1998, Combs/Ketchen 1999, Das/Teng 2000). Literature in the field of innovation economics points to the importance of networks of innovators in this context (Pyka/Küppers 2002, Pyka 2007). These networks of innovators are subject to a systemic perspective on innovation processes.

The systemic perspective emphasizes knowledge interactions between different types of actors belonging to a system which in terms of borders can be nationally, technologically or regionally defined. The common feature is that cooperation takes place in a certain institutional setting. The differentiation between national, regional, and technological or sectoral systems is a theoretical construct suitable for studying certain phenomena within these frameworks. Empirical literature provides insights into the impact of national innovation systems on technological performance (Nelson 1993). Studies based on technological innovation systems typically refer to certain sectors or technologies (e.g. MacKelvey 1996, Miyazaki/Islam 2007), and there are many empirical analyses pertaining to regional innovation systems (e.g. Asheim/Isaksen 1997, Morgan 1999).

We will contribute to literature in innovation economics by going beyond the perspective of a single innovation system. Our theoretical perspective is that innovative actors are simultaneously exposed to several innovation systems at the national, technological and regional level. Any of these systems represents specific conditions for innovation cooperation. As outlined in more detail below, we will particularly focus on technological and regional innovation systems.

In the empirical study, we will analyse the development of innovation cooperation in East and West German regions (ROR) using patent data from the time period after re-unification. Analogous to the Federal Republic of Germany (FRG), innovation cooperation also existed in the German Democratic Republic (GDR). However in case of the GDR, it was subject to central planning (Meske 1993) and did not exist in a dynamic Schumpeterian sense of 'creative destruction'. Spontaneous innovation throughout space and technologies was not part of the socialist system (Kornai 1992, 292ff). While technological development was paid attention to from a strategic perspective (Meske 2004), regional development was of no particular concern in a system of central planning. Thus, the locations of technological activity were largely a result of planning even if historically grown technology centres also continued to exist during socialism. What followed after 1989 in East Germany was a tremendous restructuring process through privatisation, liquidation, start-up activity and the complete dissolution of the science system. During the 1990s, innovation was also subject to enormous changes (Brezinski/Fritsch 1995), and existing networks of production fell entirely apart (Albach 1993 and 1995).

With respect to innovation cooperation, existing research shows that since the late 1990s East German companies no longer fall behind their counterparts in the West, although the choice of partners differs (Fritsch 2003, Günther 2004). Large foreign and West-German-owned firms are integrated in innovation networks especially with respect to science organisations (Günther et al. 2008). These studies look at East and West Germany as a whole. Our objective is to go further by using a more extensive regional breakdown, namely 'planning regions', ROR (see section 4). We also find evidence for the importance of public funding for successful cooperation in technology-intensive East German regions (Schwartz et al. 2012). While these studies use survey data, which became available in the late 1990s, other empirical studies use patent data and analyse cooperative innovation in selected regions in East Germany. They show the importance of public science organisations for cooperative innovation in regional innovation systems (Graf 2011, Graf/Henning 2009). Others compare selected East and West German regions (Fritsch 2004, Fritsch/Graf 2011), emphasising the institutional conditions for regional innovative performance. Cantner/Graf (2006) analyse the emergence and determinants of cooperation within a successful East German local innovation system.

To date, no empirical study has been conducted which comprehensively investigates the emergence of innovation cooperation in East (and West) German regions after re-unification. 25 years later, this is an appealing research question since regional innovation systems had to be developed from scratch in the East, and the West mostly served as a benchmark. We assume a strong dynamic of cooperation due to exits and entries of actors (Fritsch 2004), re-orientation of remaining actors (Cantner/Graf 2006), and policy support (Schwartz et al. 2012). As a result of transition, technological activities in East Germany nowadays are very weak compared to West Germany, but the industrial structure and density also differ strongly (Kronthaler 2005, Hornych/Schwartz 2009).

The main contribution of this paper is to analyse the emergence of innovation cooperation since the beginning of transition, covering all of East (and West) Germany. For this purpose, this paper focuses on technological and regional aspects of innovation systems, making use of an indicator that shows whether regional factors have an impact on cooperation that is below or above average, controlling for the technological size and structure of a region. We introduce this indicator as an alternative to the simple share of regional cooperation events which ignores the technological dimension, and we make use of long time series data to also compare the cooperation dynamics in East and West Germany. Essentially, we find evidence for a continuously high cooperation activity and regional relevance in the East, as well as a much stronger dynamism compared to the West German regions.

In the following we will present the theoretical and methodological framework (section 2). Based on this, the indicator to measure innovation cooperation at a regional level will be developed (section 3). Section 4 presents the data base, followed by empirical results (section 5). Section 6 will discuss the results, limitations and further research.

2. THEORETICAL AND METHODOLOGICAL CONSIDERATIONS

In the literature on technological change, the aspect of collective innovation is taken up by the systemic approach, which distinguishes between different types of 'systems'. Both the elements and the relationships between them constitute the system as a whole. The attributes, as described by Carlsson et al. (2002), define the characteristics of a system. The boundaries of a system separate the system from the rest of the world.

These system considerations have been applied to innovation in the respective innovation system literature, considering innovation as an evolutionary process (Edquist 2004). Here innovations are stimulated by factors internal as well as external to actors (Doloreux & Parto 2005). 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).

Co-existing levels of innovation systems

Regarding systemic innovation we distinguish between national innovation systems (Freeman 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), and urban innovation systems (Fischer et al. 2001).

From an actor's perspective, 'membership' in various innovation systems is possible. A firm located in a certain region can belong to the regional system, one or several technological systems, one or several national innovation systems (multinational firm), etc. These different systems should be considered simultaneously. To accomplish this, we suggest an indicator in section 3 and use it in the empirical analysis of East and West German regions, which is the focus of our paper.

For the analysis of innovation cooperation in German regions, we assume the national innovation system affects all actors the same way. Although we are aware of differences in national innovation systems between countries, we apply this method as a tool for detecting differences between regions within one country. This way we can neglect the framework of a national innovation system and methodological problems that occur by comparing regions located in different countries. Furthermore, we 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 regional aspects, while technological and sectoral systems are related to the technological dimension.

Technological dimension

The concepts of technological innovation systems (Carlsson/Stankiewicz 1991, Carlsson et al. 2002) or sectoral innovation systems (Malerba et al. 1997) point to the fact that actors engaged in the same technology or sector are better able to understand each other and to cooperate. In both concepts, the boundary of the system is justified by the specificity of a sector or technology in terms of a common knowledge base. The idea behind this is that innovative and cooperative behaviour is driven by proximity in their knowledge bases. The concept of technological proximity is rather vague. It has at least three closely interrelated dimensions. First, there is the degree of common understanding in the sense of common or overlapping knowledge among actors. Second, understanding is not only related to the type of knowledge but also to the actor's 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 knowledge, which is never fully complete, determines knowledge spillovers and how cooperation works herein. This degree of appropriability differs among technologies (Doloreux/Parto 2005). Technological proximity defined this way can be used to describe innovation cooperation. Obviously, the higher (lower) the technological proximity the more likely the knowledge of actors is substitutive (complementary).

Regional dimension

The regional innovation system (RIS) approach derives from the acknowledgement that innovation is often a geographically bounded phenomenon (Asheim/Isaksen 2002, Cooke 1992). The importance of regional resources in stimulating innovative capabilities is a major issue for RIS. It emphasizes geographical proximity as a driving force of cooperation (Fritsch 2001) because of low transaction costs, easier exchange of tacit knowledge, and strengthening of trust. Several empirical studies, however, show that spatial proximity is not always a crucial factor for successful innovation cooperation (Beise/Stahl 1999, Petruzzelli 2011, Slavtchev 2013).

Recent literature on RIS often deals with certain regions and describes their development. In regional science, the existence of a RIS pinpoints innovation cooperation as a main factor of regional economic growth (Fritsch/Mueller 2004). In RIS the boundaries are given by the geographical term 'region'. Following Cooke (2001), a region is a meso-political unit above local governments and below nations, and often has a common culture and history.

Implications and assumption for the empirical study on East and West Germany

With respect to the subject of this paper, we take into consideration that actors are exposed to the regional innovation system, but simultaneously to technological innovation systems. In doing so, some particularities arise with respect to our subject. The development of cooperation in East and West German regions relates to completely different historical settings and starting conditions in the early 1990s. This needs to be considered when deriving a general working hypothesis out of the theoretical considerations outlined above.

As regards the technological dimension, actors in East and West German regions have been exposed to technological innovation systems very differently. While actors in the West built relations to technologically proximate actors in a market system over decades, East German actors had to get access to these networks after re-unification and establish market-oriented links from scratch in a very uncertain environment. This process was accompanied by many exits and entries of actors and heavy experimentation in all fields of corporate and scientific activity (Grupp/Hinze 1994, Bluhm 1999).

The regional dimension of innovation (cooperation) as discussed above stresses the geographical boundaries of a system, the spatial proximity of actors, and the distinct institutional setting of a region. After re-unification, East German regions, in contrast to the West, were newly defined administratively and suddenly given the chance to develop an independent institutional setting (Fritsch/Graf 2011). This process went back to square one and involved a substantial public innovation policy activity in favour of networks and cooperation (Koschatzky et al. 2001).

Considering the technological and regional aspects under conditions of economic transition, we assume that the heavy structural changes led to a strong dynamism in innovation cooperation in the East, especially throughout the 1990s, and we assume that newly emerging regional framework conditions impacted cooperation particularly in the Eastern part of Germany.

We do not derive a theoretical model or specific test hypotheses here, but we use the theoretical considerations to build an indicator on innovation cooperation that refers to the aforementioned considerations. We use the technological dimension as a starting point for the methodological approach (section 3), since the above mentioned literature discusses substantial transition-induced technological losses and restructurings in the East German regions, which represent an obstacle for catching-up development (Meske 1993, Kronthaler 2005, Hornych/Schwartz 2009). Further, the technological dimension allows a clear-cut and reliable operationalisation strategy (section 4). In the following, we will describe the methodological approach.

3. THE INDICATOR: RELATIVE REGIONAL IMPACT (RRI)

In order to empirically investigate our hypothesis, we will go beyond a simple comparison of the regional share of innovation cooperation. The mere share of regional co-innovations would ignore the technological size and structure of a region. Based on the theoretical considerations above, our indicator will control for the technological dimension and measures the remaining regional impact on innovation cooperation.

As developed in section 2, the indicator is based on the assumption that regional and technological innovation systems are the two most important systems in which actors of a particular region are involved, distancing ourselves from the national innovation system. Furthermore, the indicator is based on the assumption that regional and technological factors affect collaboration independently. In other words, we assume that the embeddedness of an actor in the regional system is additive to the embeddedness in the technological system. However, in reality factors interact and lead to complex collaboration structures. In this respect, the index is an analytical tool based on the conception that factors can be looked at separately.

The methodological approach requires information about an actor's (1) innovation, (2) location, and (3) technology field. Innovations can be observed using information (1) whether they are cooperative or non-cooperative; with (2) and (3) the regional and technological dimension are taken into account. Cooperative innovations are defined as joint innovation activities of at least two different actors. An actor is a firm, a science organization, or an individual person (see section 4).

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, in which innovations are created, consists of f different technologies indexed by $j \in F = \{1, \dots, f\}$. 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. We also observe a spatial distribution of innovation i when the innovative actors belong to different branches of the same firm which are located in different regions. To distinguish between both possibilities we take information into account regarding 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 **A**. **A** is a $n \times f$ matrix with a typical element:

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

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

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

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

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

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

The technological dimension of cooperative innovation

To start with, we identify the propensity to cooperate for each technology. Since innovations are often related to several technologies, we need to know to which degree an innovation i is related to each technology f. Hence, for each innovation i we determine weights with respect to each technology. For this purpose, we row-standardize matrix **A** which contains un-weighted values, as described in the previous section. This operation leads to a $n \times f$ matrix $\mathbf{A}^w$ containing the weights by which each technology j contributes to innovation i with a typical element:

$$(4) \qquad a_{ij}^w = \frac{a_{ij}}{\sum_{h=1}^{f} a_{ih}}$$

The sum of the elements of row i in matrix $\mathbf{A}^w$ is necessarily equal to one; all technologies related to innovation i enter with the same weight.

In order to distinguish between innovative and cooperative activities among technologies, a $n \times n$ diagonal matrix $\mathbf{\Gamma}$ with the elements of vector $\boldsymbol{\gamma}$ on the main diagonal is multiplied by matrix $\mathbf{A}^w$. 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:

$$(5) \qquad a_{ij}^{wc} = \sum_{d=1}^{n} \gamma_{id} a_{dj}^{w}$$

which is equal to a_{ij}^{w} if γ_i= 1 and 0 otherwise.

Matrices $\mathbf{A}^w$ and $\mathbf{A}^{wc}$ are used to determine the average cooperation behaviour for each technology. To achieve this, we sum up the elements of each column (technology) in $\mathbf{A}^w$ and $\mathbf{A}^{wc}$. In the former case we get an account of the weighted number of innovations related to technology j; in the latter case we get an account 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 for all the technologies are included in vector $\mathbf{p}^c$.[ii] It is a vector of length f with a typical element:

$$(6) \qquad p_j^c = \frac{\sum_{i=1}^{n} a_{ij}^{wc}}{\sum_{i=1}^{n} a_{ij}^{w}}$$

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

The regional dimension of cooperative innovation

In a second step, we focus on the regional distribution of innovation in general and 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 unweighted relationships. Its row-standardization delivers the $n \times r$ matrix B^w with a typical element:

$$(7) \qquad b_{ik}^{w} = \frac{b_{ik}}{\sum_{l=1}^{r} b_{il}}$$

that contains the weights by which each region contributes to an innovation i.

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

$$(8) \qquad b_{ik}^{wc} = \sum_{m=1}^{r} \gamma_{im} b_{mk}^{w}$$

which is 0 for γ_i=0.

Matrix $\mathbf{B}^{wc}$ contains information about the regional distribution of cooperative innovation independent of whether the cooperation takes place within the region or between regions.

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 the cooperative innovation of the previous section which also contains the average regional effect. We start by computing the number of innovations of technology j in region k. The $r \times f$ matrix $\mathbf{C}^w$ – with r rows (regions) and f columns (technology fields) – contains information about the number of innovations that have been developed in technology j by actors from region k, i.e. it is simply a matrix which combines technologies and regions. $\mathbf{C}^w$ is computed by:

$$(9) \qquad \mathbf{C}^w = \mathbf{B}^{w\prime} \cdot \mathbf{A}^w$$

$\mathbf{B}^{w\prime}$ is the transposed matrix $\mathbf{B}^w$. $\mathbf{C}^w$ contains c_{kj}^{w} as a typical element, which stands for a number of innovations in every region allowing for a specific technology and is used to create an indicator that we call the 'expected number 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 ($\mathbf{C}^w$) for cooperative innovation p_j^c of those technologies which are used in region k. Vector $\mathbf{e}^c$ contains the expected number of all cooperative innovations in all regions k. It is a vector of length r received by multiplying a matrix of all innovations assigned to respective regions and technologies ($\mathbf{C}^w$) by a vector of propensity to cooperate in accordance with a technological field ($\mathbf{p}^c$) with a typical element:

$$(10) \quad e_k^c = \sum_{j=1}^{f} c_{kj}^w \cdot p_j^c$$

Observed and expected value of regional cooperative innovation

If cooperative innovations within a region were solely affected by technological determinants (and an average regional effect), the observed number of cooperative innovations has to be identical to the expected number. Thereby we imply that there are no differing regional effects on cooperative innovation. In order to test for this in a final step, for each region r the ratio between the observed and the expected cooperative innovations is determined. To ensure this, we compute the column sum of elements of matrix $\mathbf{B}^{wc}$, which leads to the 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 called "relative regional impact" (RRI) are contained by vector $\mathbf{v}$. It is a vector of length r with the typical element:

$$(11) \quad \mathbf{v}_k = \frac{\sum_{i=1}^{n} b_{ik}^{wc}}{e_k^c}$$

This ratio accommodates values between 0 and infinite. With a ratio value of 1 the number of cooperative innovations observed in a region is equal to the expected number. A ratio different from 1 indicates that factors other than technological ones impact the cooperation performance, and we ascribe them to the regional innovation system as such. If a region, for example, exhibits an RRI value of 2.0, this region's number of cooperative innovations is twice as high as one could expect regarding the region's technological size and structure (technological innovation system). This higher innovation cooperation activity is regarded here as an expression of a well-functioning and stimulating regional innovation system. For example, the regional innovation system may be characterized by a good infrastructure for inventors, a creative milieu or favourable policy tools. The other way around, an RRI value of 0.5 means that this region's number of cooperative innovations is only half of what one could expect given the technological size and structure of the region. According to our theoretical framework, we ascribe this low RRI value to deficiencies of the regional innovation system.

Additionally, the indicator is independent of the size of a region in terms of the number of cooperative innovations observed. Hence, agglomeration effects or the strength of a regional innovation system that we want to measure cannot simply be attributed to the size of the region, but have to do with an above-average propensity to cooperate. Here, one may alternatively think of the cooperation per innovation ratio as being enough (the share of regional co-innovations over all innovations). While this would be a suitable proxy for the cooperation intensity of a region over all, this ratio would not take into account the differences of cooperative innovation and it would not be related to the specific technologies a region hosts. Since East German regions experienced heavy technological restructuring and losses in the past, we explicitly pay attention to structural differences using the RRI index instead of pure regional co-innovation share. Furthermore, the RRI index includes a standardization with respect to statistical significance, i.e. values of 1.0 signalling an average cooperation activity. Due to these advantages, we suggest the RRI indicator as a means to measure the strength of a regional innovation system and to track its performance over time. To illustrate, we provide an example calculation in Appendix 1.

Equivalent to the procedure above, we can restrict the analysis to cooperative innovation taking place only within the region. For this purpose, a diagonal $n \times n$ matrix $\tilde{\Gamma}$ which now has elements of vector $\tilde{\boldsymbol{\gamma}}$ (γ_i =1 if innovation is developed by multiple actors from the same region and 0 otherwise) is multiplied by matrix $\mathbf{A}^w$. The result is a matrix $\widetilde{\mathbf{A}}^{wc}$ comprising only the technology weights of cooperative innovations which have taken place within regions. Using matrices $\mathbf{A}^w$ and $\widetilde{\mathbf{A}}^{wc}$, we can then compute the propensity of cooperative innovation represented by vector $\widetilde{\mathbf{p}}^c$, which does not only comprise the technological effects but also the average intra-regional effect.

Calculated analogously, matrix $\widetilde{\mathbf{B}}^{wc}$ contains information on cooperative innovations internal to the region. Using matrix $\widetilde{\mathbf{B}}^{wc}$ and vector $\widetilde{\mathbf{p}}^c$ one achieves a vector $\tilde{\mathrm{v}}$ which contains the ratio of realized intra-regional cooperation to the expected one. The interpretation is equivalent to the above one. The difference is that in the above we identify regional effects on cooperative innovation in general, whereas here we look at regional effects on intra-regional cooperation.

4. DATA

We use patent data to apply the suggested indicator. Although there has been some discussion on the limitations of patents for measuring innovation (e.g., Pavitt 1985, Lall 2003, and Aiginger/Falk 2005) and support of the criticism through empirical evidence (e.g. Aiginger/ Falk 2005), patent data has also been frequently recommended as a proxy for innovative activity (e.g. Archibugi 1992, Dachs/Pyka 2010, Nagaoka/ Motohashi/ Goto 2010, Nesta/Patel 2013 etc.). Moreover, with respect to our research question, patent data is the only data source that allows for the investigation of innovation cooperation over a period going back to the early 1990s.

The data source is the REGPAT database of the OECD (Maraut et al. 2008) which includes applications at the European Patent Office (EPO) and Patent Cooperation Treaty (PCT). Data from the German Patent Office (DPMA) could have served as an alternative with a higher number of cases; however, it shows many missing values about the location, which is essential for our study. We compared both data sources for the technological structure and find that they have a very similar structure in terms of distribution among technological fields. Thus, we decided to use REGPAT data which provides sufficient information on the location of actors for the years 1993 to 2010.

To distinguish patent applications by technology, we rely on the information about international patent classification (IPC). Since the IPC is very detailed, we reduce the number of technology classes to 44 categories according to Schmoch et al. (2003). A full list of technology classes used for the current study can be found in Appendix 3. If a patent application lists more than one technology, we use fractional counts with equal weight per technology.

According to the regional dimension, each patent application must be assigned to a region. The patent document allows for two modes of assignment: the address of the applicant or the inventor. The first one has the weakness that actors applying for a patent often state the headquarter address. This can lead to an overestimation of inventive activity in regions with many headquarters. These regions are strongly present in West Germany, while many subsidiaries in East Germany are located. Thus, in this study we use the address(es) of the inventors to assign a patent application to a region. If there are patent applications with more than one inventor, we assign it with the same weight to all regions.

To define a region, we use the concept of planning regions (ROR) which are determined by the Federal Institute for Research on Building, Urban Affairs, and Spatial Development in Germany, taking into account commuter data. The size of the planning regions is between the level of NUTS 2 and NUTS 3. Germany is divided into 96 planning regions considering an administrative and functional approach, since the concept accounts for regional labour mobility by commuting activities. A full list of regions can be found in Appendix 4.

Patent data can easily be used to detect innovation cooperation. In this paper, a patent application with at least two different applicants is regarded as a cooperative innovation activity. Since we have no information about the creative share of each applicant we consider their contribution as equal. Furthermore, we consider cooperative innovation between partners within and across regions, since we want to account for cooperation activity in general instead of just intra-regional cooperation.

Our analysis is based on data for the years 1993 to 2010. In order to eliminate a high patent variation over time, we form sub-periods of three years (see Appendix 2). Since the number of patent applications in general and cooperative patent applications in particular was very small in East German regions before 1993, we cannot include earlier time periods.

In general, the number of patent applications increased over time. Only for 2008-2010 does the data show a decline presumably related to the economic crisis. The number of cooperative patent applications follows a similar pattern, whereby the share of cooperative patent applications is clearly higher in East than in the West Germany.

5. INNOVATION COOPERATION IN EAST AND WEST GERMAN REGIONS

In the following, we will first only refer to the technological dimension of cooperation investigating the differences in patenting behaviour across technologies, including a comparison between East and West Germany. Following this, we will refer to the regional dimension of cooperation in order to scrutinize regional differences at the level of planning regions, again comparing East and West Germany. Then we will combine the technological and regional dimension calculating and comparing the RRI index.[iii]

Technological dimension of innovation cooperation

First, we look at the differences in patenting and cooperation between technologies over time. Appendix 5 shows the number of patent applications for each technology and time period *t*. Differences in patent activity are obvious, with most patent applications in technology class 42 (motor vehicles) in all periods, except for 1993 till 1995. Other important technology classes are basic chemicals (class 10), pharmaceuticals (class 13), energy machinery (class 21), special purpose machinery (class 25) and signal transmission, telecommunication (class 35), all with similar growth rates and representing the top technologies over all periods.

Appendix 6 presents information about the number of patent applications, co-applications, and the propensity to cooperate, including the Gini coefficients (Gini 1921) as a measure for the inequality of distribution. We observe an inequality between technologies concerning patent applications and co-applications with Gini coefficients mostly above 0.5 in East and West Germany without major changes over time.[iv] Although the findings about the differences between technologies are not particularly surprising, they support our methodical approach which controls for the technological structure of a planning region (ROR).

If we look at the cooperation propensity (share of co-applications over total applications), we recognize that this share is much higher in East than in West Germany. It declines and converges over time but remains stronger in the East (8.4% versus 4.5% in 2008-2010). Furthermore, in the early 1990s, cooperation in the East is much more strongly concentrated on certain technological fields (high Gini coefficient) as compared to the West, but it converges over time with a Gini coefficient 0.284 in East and 0.278 in West Germany.

The different cooperation propensities contain the respective technological dimension but also the average regional effect on cooperation, which is the same for all technologies in a given region. This is due to the fact that for the observed co-applications we cannot extract the sheer technological effects. More precisely, for each technology this propensity contains the technology specific effect and the average regional effect pertaining to those regions in which the respective technology is located.

Regional dimension of innovation cooperation

Appendix 7 shows how the total number of patents is distributed over the 96 planning regions. Overall, we observe visible differences among regions. There are two outstanding regions, Stuttgart (ROR 810) and Munich (ROR 910), with the highest number of patent applications in each period. Both regions are high-tech oriented, and Munich is also an important location of large universities and public science institutes, including the Fraunhofer and the Max-Planck headquarters.

Appendix 8 presents data about patent applications and co-applications in East and West Germany, including information about the inequality of distribution among regions (Gini coefficient). As in the case of technology fields, the Gini coefficient lies at about 0.5 for both patent applications and co-applications with a tendency of being a bit lower in East than in West Germany. We do not observe strong changes over time.

Thus, in addition to technology related effects on patenting and co-patenting, there are regional effects to be considered in the empirical analysis. As in the case of differences in co-application at the technological level, the observed differences in innovation cooperation on the regional scale include regional effects and the average effect of those technologies contained in the respective region. The next step is to extract the technological effects when looking at regional innovation cooperation.

Differing regional effects on cooperative innovation

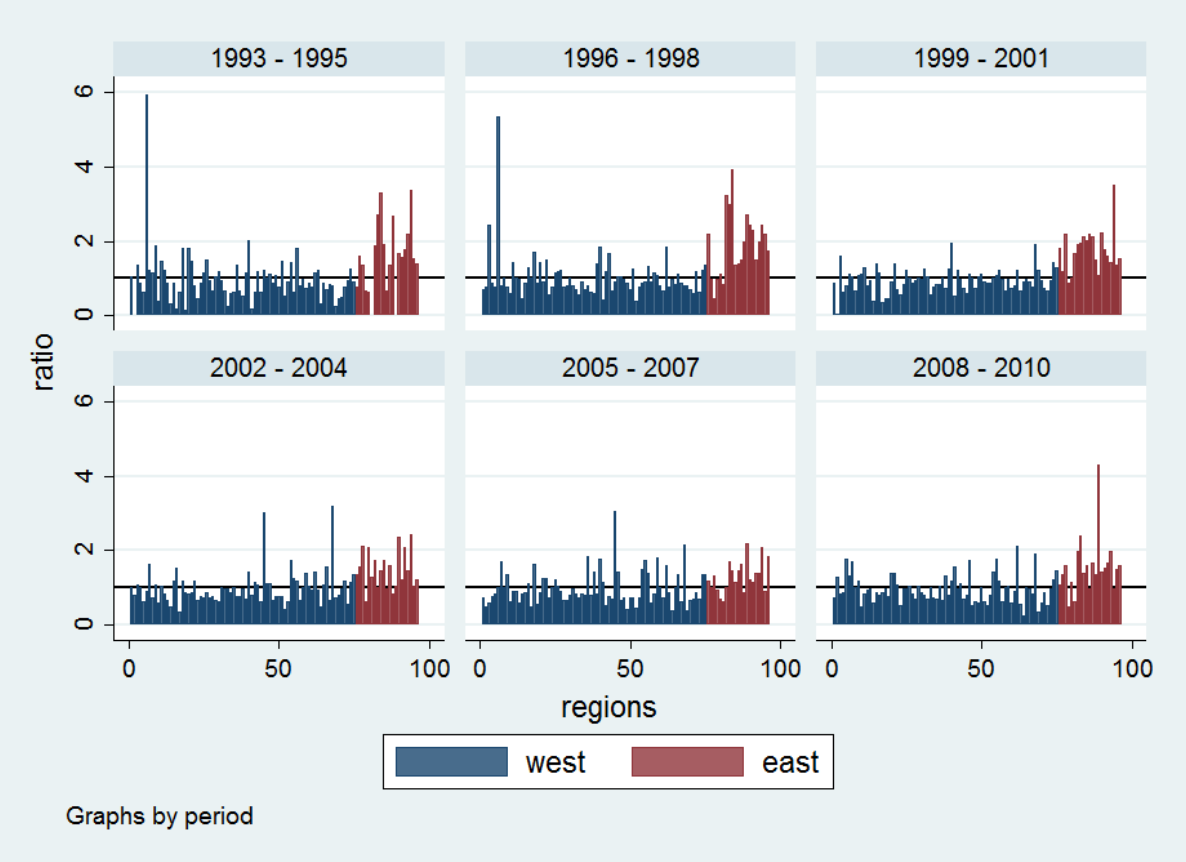
In the final step, we use the RRI index, comparing the observed number of co-applications of a region with the expected number of co-applications. Following section 3, the ratio between observed and expected co-applications per region, which can be balanced or can be above or below 1.0, indicates an "average status" of a region or an impact of the regional innovation system that advantages or disadvantages innovation cooperation (RRI values higher/lower 1.0).

The RRI index is illustrated for all planning regions in figure 3. The indices differ between regions, which means that there are differing regional effects on innovation cooperation.

Interestingly, as shown in figure 3, the RRI index is clearly higher in East than in West German regions, especially in the early period of transition and throughout the 1990s, whereas it converges later on.[v] This result might be an expression of the tremendous restructuring processes in the East German industry and science system. We do not only observe high levels of innovation cooperation but also a strong dynamic of its development within the East German regions. RRI values fluctuate much stronger in East than in West German regions. Throughout the time periods, the variance of the RRI index of an East German region is on average 0,393 while it is 0,177 for a West German region.

The mean RRI values for each region are presented in Appendix 14 including the information on whether an RRI value is significantly higher or lower than one. We run a t test which compares the mean RRI value per region over the six time periods with the hypothetical value of one. In the majority of cases we find statistical significance (see Appendix 14).

FIGURE 3: RRI index of East and West German planning regions (ROR)[vi].

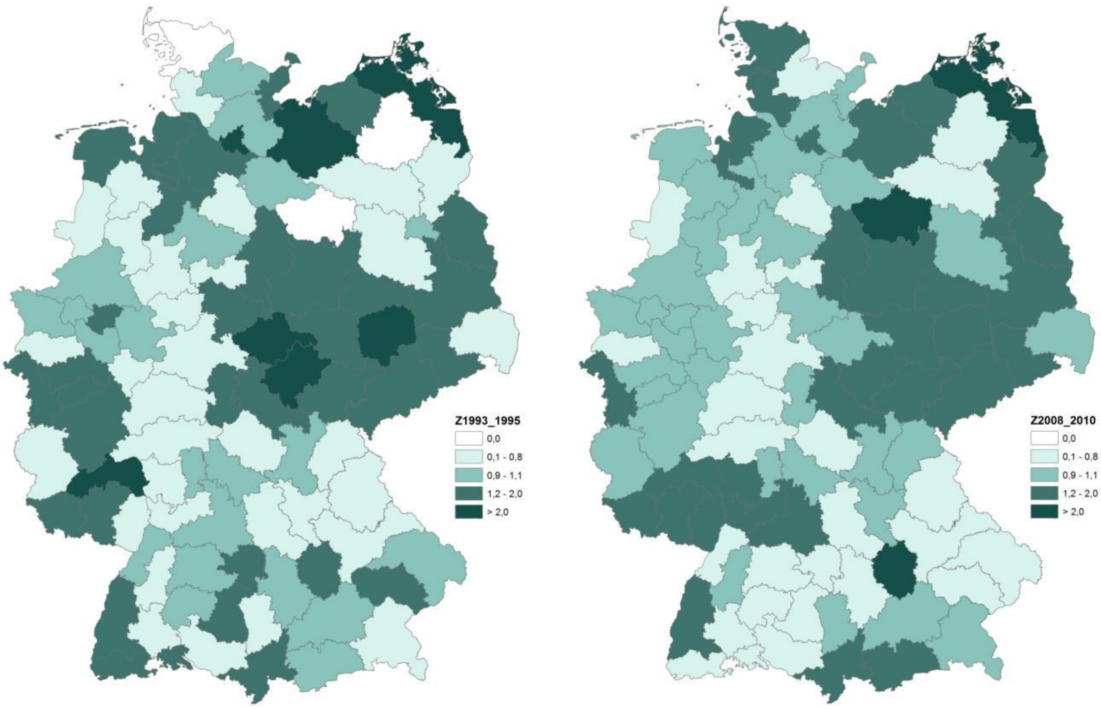


Source: REGPAT database, own calculation. Note: RRI = Relative regional impact

Although some West German regions show very high RRI values in certain time periods with values above five, the average RRI value of East German regions remains higher in every time period. The (in)equality of distribution of the RRI values (Gini coefficient) does not differ substantially between East and West Germany (see Appendix 10).

Finally, Figure 4 below shows a map of the 96 planning regions for the first and last time period. (For maps for the other time periods see Appendix 12) White spots mean that there was no cooperation at all. A darker color indicates a higher RRI value. The maps visualize relatively high RRI values in East Germany.[vii] Moreover, regions with a very high innovative activity in terms of number of patent applications, e.g. Munich and Stuttgart, do not necessarily exhibit a high RRI index. It lies between 0.88 and 1.02 in Munich and in Stuttgart between 0.91 and 0.78. In general, there is no correlation between the technological size of a region and a region's RRI value (see Appendix 13).

FIGURE 4: RRI values for East and West German regions 1993-1995 and 2008-2010.



Source: REGPAT database, own calculation.

The results show that East German regions – although weakened technologically and industrially through the transition process – have a stronger cooperation intensity than West German regions throughout the 1990s. Furthermore, the RRI value as an expression of the relative regional impact on cooperation shows that regional framework conditions in many East German regions have a stronger meaning for cooperation as compared to West German regions.

A robustness check confirms our results. Using a more aggregated technology classification (main technology classes according to IPC) leads to RRI values that are very close to the main findings. When we use applicant information as a basis for the regionalization of patents we observe a higher level of RRI values overall, but with East German regions exhibiting higher values than West German regions.[viii] Moreover, the higher dynamics of cooperation (variance of RRI) as well as higher median values of RRI in the East can be confirmed in the robustness check (see Appendix 15).

Our results are in line with earlier studies (Fritsch 2003, Günther 2004) and patent data for selected East and West German regions (Cantner/Graf 2006). The assumption of "disrupted networks" put forward in earlier literature on production systems (Albach 1993 and 1995) cannot be confirmed. This latter point is rather surprising. It is most probably related to the specific situation of research units in the early stage of transition. These units lost their cooperation partners but had to quickly find new actors to collaborate with under conditions of severe survival pressure.

At first glance, the results are favourable for East German regions since they express a higher innovation cooperation activity (RRI values) as compared to West German regions. However, this must be considered in light of the real structural situation in the two regional parts of Germany. East Germany is characterized by a weak industrial base with many small and medium firms and not many headquarters, while West Germany shows many large companies and headquarters. Actors in East Germany may try to generate economies of scale through cooperation. Whether this will at the end be enough to compensate for the lack of large firms and headquarters is, however, not clear.

6. DISCUSSION AND CONCLUSION

Normally, empirical studies on innovation cooperation deal with either the technological or the regional dimension of innovation. Our contribution is an approach that accounts for the simultaneous participation of actors in technological and regional innovation systems. This progress has been made at the expense of some analytical assumptions that must be discussed when using the indicator. A major assumption is that technological and regional factors are independent of each other, which in reality does not apply. In this sense, the indicator is an analytical approach that expresses a regional impact below or above average. It can, however, not fully be disentangled from technological (and maybe even further) dimensions. Apart from this, by using patent data, we include only those innovation cooperation events that produce patents. In reality, the knowledge base and its stimulus for cooperation can be much broader.

Still, the index controlling for the technological dimension is of high importance for the subject of this paper, since the Eastern part of Germany is strongly characterized by transition-related technological weaknesses. We contribute to the literature through a comprehensive investigation of the emergence of innovation cooperation since re-unification, including all German regions (ROR) instead of studying selected or single regions, which has been done frequently so far (e.g. Cantner/Graf 2006, Fritsch 2004, Fritsch/Graf 2011, Graf/Henning 2009, Schwartz et al. 2012) or just East and West Germany as a whole (e.g. Günther 2004, Fritsch 2003, Günther et al. 2008).

Furthermore, we show that the dynamic of innovation cooperation within East German regions is much higher, expressed through a strong variation of RRI values in East German regions. This is most probably an expression of the tremendous restructuring and reorientation processes due to the sudden system change. Industry and science organizations experienced ownership changes, liquidations, restructuring etc. Under these circumstances, private persons might have found it attractive to (co-)patent, especially in the early periods of transition in order to secure their intellectual property in times of heavy uncertainty. Furthermore, Graf & Henning (2009) state that many firms in East Germany are young. If they fail, the patent rights are part of the insolvency volume, which motivates inventors in East Germany to apply as a private person. The structure of applicants as an explanatory factor of differences in cooperation calls for further research considering actors' patenting behaviour. Another limitation of our analysis is the fact that we cannot use the RRI values presented here to make clear-cut statements about the strength or weakness of the respective regional innovation system. This is because our calculations relate to innovation cooperation in general instead of intra-regional cooperation in particular. Furthermore, one must discuss the cooperation intensity in light of the general structural conditions of a region under consideration.

Thus, further research could deal with an evaluation oriented assessment of regional innovation systems and would then use the RRI indicator on an intra-regional basis. Considering the high importance of cooperation in innovation policy (Muldur et al. 2006), another important field for further research is the question as to whether and to what degree innovation cooperation (high RRI values) contributes positively to regional economic performance. This is of particular interest for post-transition regions where the problem of network failure or misalignment has been discussed (Varblane et al. 2007; von Tunzelmann 2004). It means that linkages in production and innovation systems might exist, but in an unfavourable or ineffective manner without a positive impact on economic development (von Tunzelmann et al. 2010). With respect to East Germany and new EU member states where innovation policy strongly rests on the support of regional science-industry cooperation, the subject offers much scope for further analyses also taking a European perspective.

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APPENDIX 1: Illustration of the RRI indicator

The RRI indicator can be illustrated on the following example calculation.

Basic data for the example:

Innovation	**Technology field**	**Region**	**Cooperation innovation**
Innovation 1	TF1	R1 and R2	Coop
Innovation 2	TF1 and TF2	R1 and R2	No coop
Innovation 3	TF2	R2	Coop

Note: TF = technology field, R = region

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), hence $k = \{1;\ 2\}$ 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. With respect to this example, matrix **A** is a 3×2-matrix:

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

Matrix **B** is a 3×2 matrix:

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

Vector $\boldsymbol{\gamma}$ indicating whether innovation i is cooperatively generated contains the following elements:

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

With these data, first the technological dimension is analyzed. The absolute values in matrix **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 matrices 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 by dividing each column sum of $\mathbf{A}^{wc}$ by the respective column sum of $\mathbf{A}^w$. The results are contained in vector $\mathbf{p}^c$:

$$\mathbf{p}^c = \begin{pmatrix} 0.67 \\ 0.67 \end{pmatrix}$$

Here, for both technologies, we get the same propensity to cooperate (0.67).

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

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

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 $\mathbf{C}^{w}$ by 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:

$$\mathbf{e}^{c} = \begin{pmatrix} 0.67 \\ 1.33 \end{pmatrix}$$

According to the technological classification of all innovations in region R1 and R2, the expected cooperation value in region 1 is twice (1.33) the value of region 2 (0.67). Finally, the observed number of cooperative innovations for each region k, indicated through matrix $\mathbf{B}^{wc}$, is related to these values; for region 1 this is 0.5 and for region 2 we get 1.5. The final result are RRI values included in $\mathbf{v}$:

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

In our example in region 1, the observed cooperative innovations are less than one could expect (0.5/0.67=0.75) according to its patent application behaviour among all technologies, whereas in region 2 observed cooperative innovations exceed their expected value (1.5/1.33=1.25). Within our theoretical context this suggests that for region 2 there is a working regional effect fostering cooperative innovation above the average; in region 1, by contrast, factors seem to be present that are not fostering or even preventing cooperative innovation.

APPENDIX 2: Descriptive statistics of the data base

Time period	Number of patent applications			Number of cooperative patent applications			Cooperative patent applications (%)		
	Total	**East**	**West**	**Total**	**East**	**West**	**Total**	**East**	**West**
1993 – 1995	39406.55	1106.14	38300.41	2107.90	103.30	2004.59	5.35	9.34	5.23
1996 – 1998	56646.39	2000.86	54645.53	2850.53	188.33	2662.20	5.03	9.41	4.87
1999 – 2001	72077.29	3228.74	68848.55	3463.81	301.45	3162.36	4.81	9.34	4.59
2002 – 2004	76214.36	3664.58	72549.78	3557.92	269.62	3288.30	4.67	7.36	4.53
2005 – 2007	86072.62	4659.10	81413.52	4130.94	300.43	3830.51	4.80	6.45	4.71
2008 – 2010	76962.24	4524.73	72437.51	3614.43	348.72	3265.71	4.70	7.71	4.51

Source: REGPAT database, own calculation.

APPENDIX 3: List of technology classes used in the study.

Class No.	Class description
1	Food, beverages
2	Tobacco products
3	Textiles
4	Wearing apparel
5	Leather articles
6	Wood products
7	Paper
8	Publishing
9	Petroleum products, nuclear fuel
10	Basic chemical
11	Pesticides, agro-chemical products
12	Paints, varnishes
13	Pharmaceuticals
14	Soaps, detergents, toilet preparations
15	Other chemicals
16	Man-made fibres
17	Rubber and plastics products
18	Non-metallic mineral products
19	Basic metals
20	Fabricated metal products
21	Energy machinery
22	Non-specific purpose machinery
23	Agricultural and forestry machinery
24	Machine-tools
25	Special purpose machinery
26	Weapons and ammunition
27	Domestic appliances
28	Office machinery and computers
29	Electric motors, generators, transformers
30	Electric distribution, control, wire, cable
31	Accumulators, battery
32	Lighting equipment
33	Other electrical equipment
34	Electronic components
35	Signal transmission, telecommunications
36	Television and radio receivers, audiovisual electronics
37	Medical equipment
38	Measuring instruments
39	Industrial process control equipment
40	Optical instruments
41	Watches, clocks

42	Motor vehicles
43	Other transport equipment
44	Furniture, consumer goods

Source: Own presentation based on Schmoch et al. (2003)

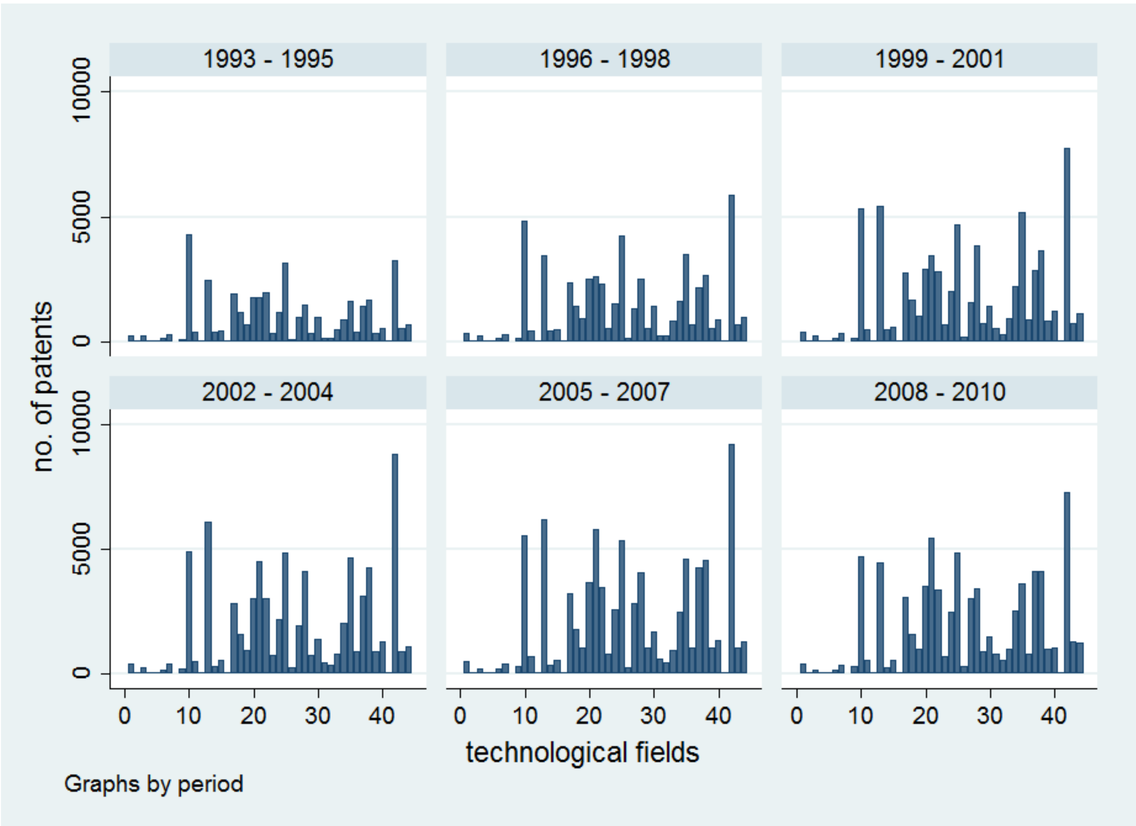
APPENDIX 4: List of regions used in the study.

ROR No.	Name of ROR
101	Schleswig-Holstein Mitte
102	Schleswig-Holstein Nord
103	Schleswig-Holstein Ost
104	Schleswig-Holstein Süd
105	Schleswig-Holstein Süd-West
201	Hamburg
301	Braunschweig
302	Bremen-Umland
303	Bremerhaven
304	Emsland
305	Göttingen
306	Hamburg-Umland-Süd
307	Hannover
308	Hildesheim
309	Lüneburg
310	Oldenburg
311	Osnabrück
312	Ost-Friesland
313	Südheide
401	Bremen
501	Aachen
502	Arnsberg
503	Bielefeld
504	Bochum/Hagen
505	Bonn
506	Dortmund
507	Duisburg/Essen
508	Düsseldorf
509	Emscher-Lippe
510	Köln
511	Münster
512	Paderborn
513	Siegen
601	Mittelhessen
602	Nordhessen
603	Osthessen

604	Rhein-Main
605	Starkenburg
701	Mittelrhein-Westerwald
702	Rheinhessen-Nahe
703	Rheinpfalz
704	Trier
705	Westpfalz
801	Bodensee-Oberschwaben
802	Donau-Iller (BW)
803	Franken
804	Hochrhein-Bodensee
805	Mittlerer Oberrhein
806	Neckar-Alb
807	Nordschwarzwald
808	Ostwürttemberg
809	Schwarzwald-Baar-Heuberg
810	Stuttgart
811	Südlicher Oberrhein
812	Unterer Neckar
901	Allgäu
902	Augsburg
903	Bayerischer Untermain
904	Donau-Iller (BY)
905	Donau-Wald
906	Industrieregion Mittelfranken
907	Ingolstadt
908	Landshut
909	Main-Rhön
910	München
911	Oberfranken-Ost
912	Oberfranken-West
913	Oberland
914	Oberpfalz-Nord
915	Regensburg
916	Südostoberbayern
917	Westmittelfranken
918	Würzburg
1001	Saar
1101	Berlin
1201	Havelland-Fläming
1202	Lausitz-Spreewald
1203	Oderland-Spree
1204	Prignitz-Oberhavel
1205	Uckermark-Barnim

1301	Mecklenburgische Seenplatte
1302	Mittleres Mecklenburg/Rostock
1303	Vorpommern
1304	Westmecklenburg
1401	Oberes Elbtal/Osterzgebirge
1402	Oberlausitz-Niederschlesien
1403	Südsachsen
1404	Westsachsen
1501	Altmark
1502	Anhalt-Bitterfeld-Wittenberg
1503	Halle/S.
1504	Magdeburg
1601	Mittelthüringen
1602	Nordthüringen
1603	Ostthüringen
1604	Südthüringen

APPENDIX 5: Number of patent applications by technology fields.



Source: REGPAT database, own calculation.

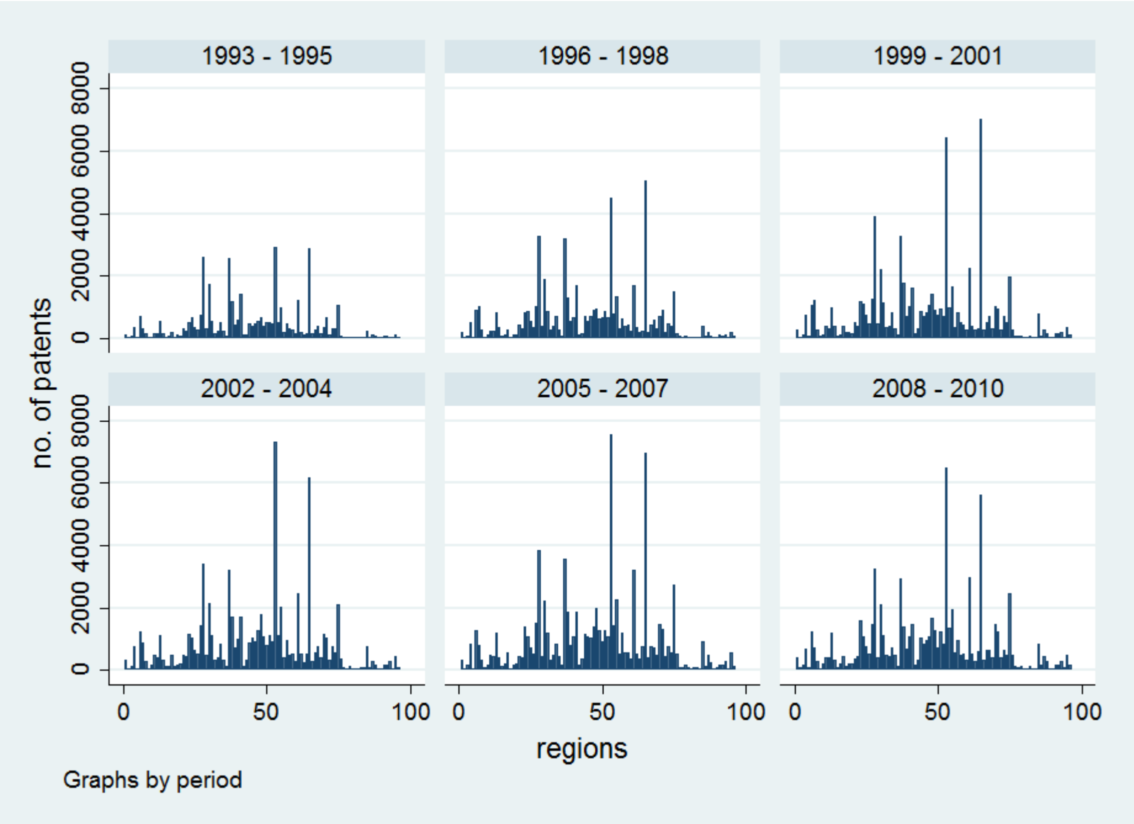
APPENDIX 6: Patent application and co-application distribution by technological fields

	East Germany							
Period	Patent applications		Co-application		Cooperation propensity			
	Number	Gini coeff. techn. fields	Number	Gini coeff. techn. fields	Min	Max	Mean	Gini coeff. techn. fields
1993 - 1995	1106	.538	103	.484	.022	.923	.144	.481
1996 - 1998	2001	.555	188	.506	.015	.758	.125	.400
1999 - 2001	3229	.578	301	.577	.016	.344	.114	.308
2002 - 2004	3665	.566	270	.522	.013	.552	.098	.431
2005 - 2007	4659	.538	300	.503	.021	.211	.067	.270
2008 - 2010	4525	.551	349	.563	.018	.306	.084	.284
	West Germany							
Period	Patent applications		Co-application		Cooperation propensity			
	Number	Gini coeff. techn. fields	Number	Gini coeff. techn. fields	Min	Max	Mean	Gini coeff. techn. fields
1993 – 1995	38300	.546	2005	.517	.007	.123	.054	.258
1996 – 1998	54646	.550	2662	.544	.014	.105	.050	.197
1999 – 2001	68849	.561	3162	.562	.024	.114	.050	.220
2002 – 2004	72550	.567	3288	.621	.013	.145	.047	.290
2005 – 2007	81414	.556	3831	.606	.015	.132	.048	.312

2008 – 2010	72438	.539	3266	.587	.017	.133	.045	.278

Source: REGPAT database, own calculation.

APPENDIX 7: Number of patent applications by planning regions (ROR).



Source: REGPAT database, own calculation.

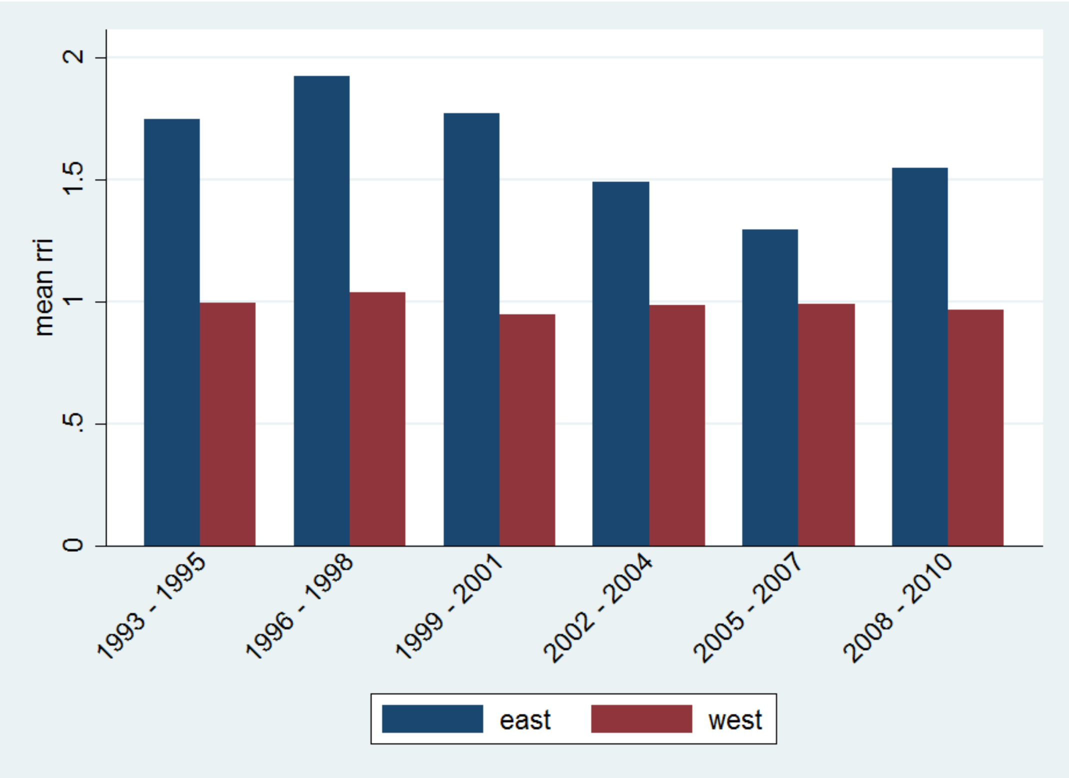
APPENDIX 8: Patent application and co-application distribution by planning regions (ROR)

Period	**East Germany**				**West Germany**			
	Patent applications		Co-applications		Patent applications		Co-applications	
	Number	Gini coeff. ROR	Number	Gini coeff. ROR	Number	Gini coeff. ROR	Number	Gini coeff. ROR
1993 - 1995	1106	.495	103	.483	38300	.528	2005	.574
1996 - 1998	2001	.471	188	.475	54646	.519	2662	.533
1999 - 2001	3229	.496	301	.503	68849	.518	3162	.537
2002 - 2004	3665	.478	270	.478	72550	.501	3288	.536

2005 - 2007	4659	.472	300	.460	81414	.500	3831	.548
2008 - 2010	4525	.452	349	.490	72438	.484	3266	.534

Source: REGPAT database, own calculation.

APPENDIX 9: "Convergence" of RRI values in East and West over time



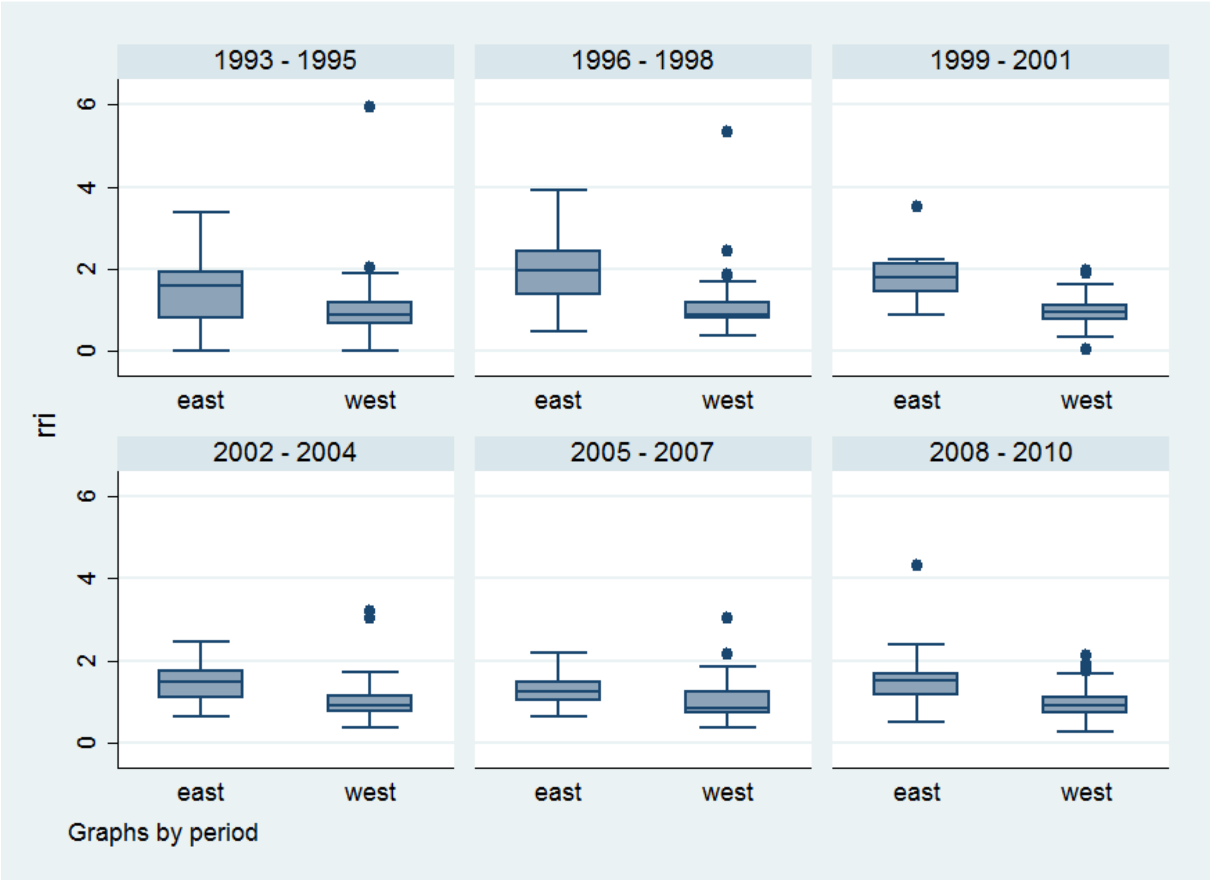
Source: REGPAT database, own calculation.

APPENDIX 10: RRI distribution by planning regions (ROR)

	East Germany				West Germany			
Period	**Min**	**Max**	**Mean**	**Gini coeff. ROR**	**Min**	**Max**	**Mean**	**Gini coeff. ROR**
1993 - 1995	0.000	3.383	1.745	0.254	0.000	5.925	0.996	0.295
1996 - 1998	0.473	3.924	1.921	0.246	0.391	5.340	1.038	0.230
1999 - 2001	0.895	3.525	1.768	0.166	0.058	1.962	0.946	0.180
2002 - 2004	0.645	2.444	1.490	0.188	0.358	3.188	0.988	0.211
2005 - 2007	0.643	2.172	1.294	0.178	0.369	3.036	0.989	0.236
2008 - 2010	0.488	4.296	1.549	0.227	0.256	2.128	0.965	0.207

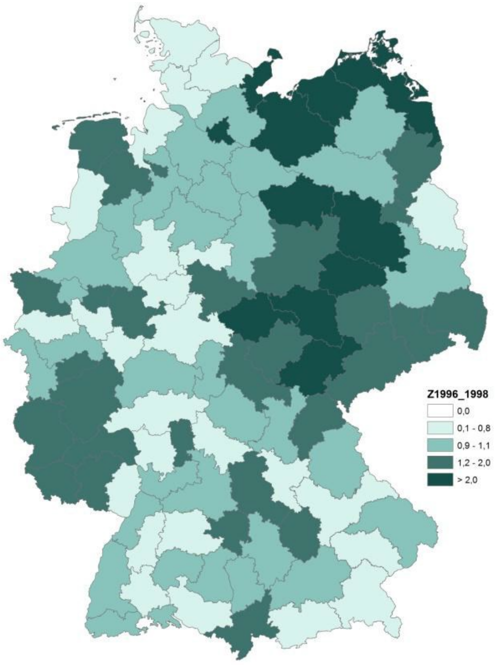
Source: REGPAT database, own calculation

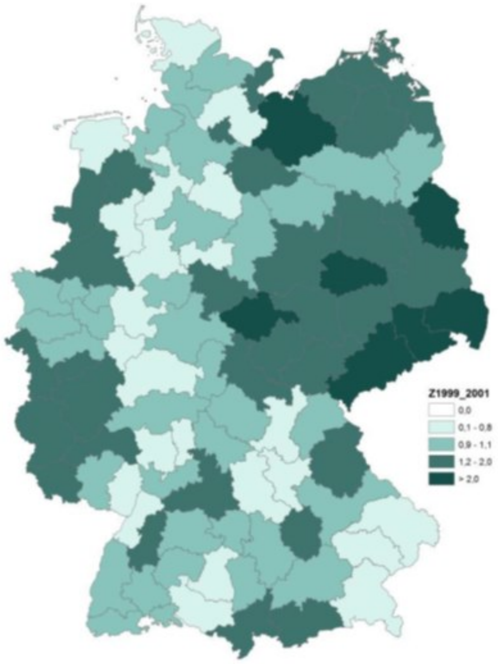
APPENDIX 11: RRI values in East and West Germany (alternative illustration)

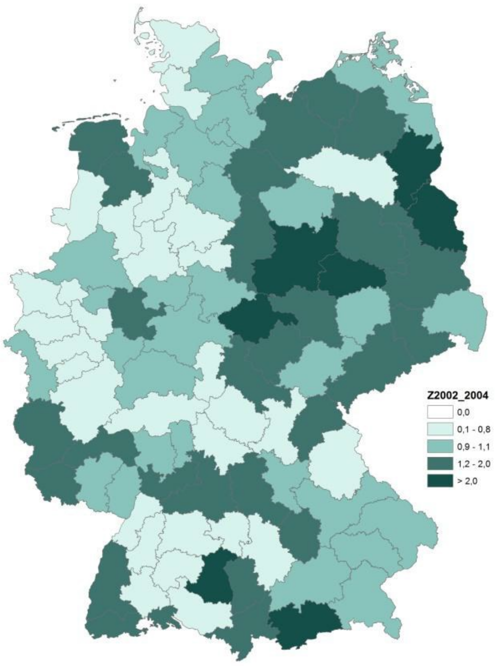


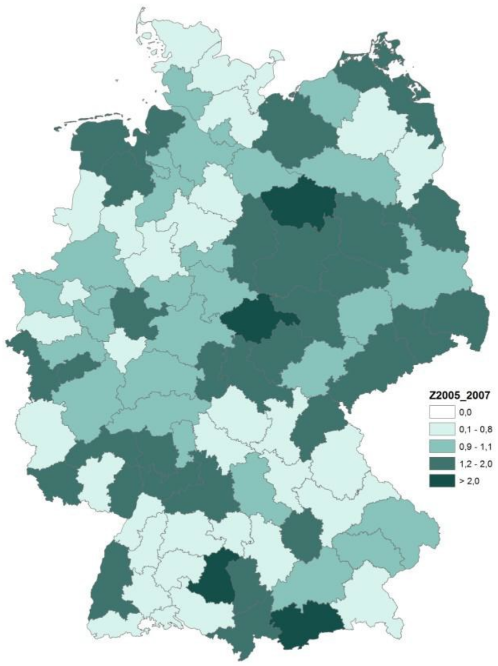
Source: REGPAT database, own calculation

APPENDIX 12: RRI index for German regions 1996-1998, 1999-2001, 2002-2004, 2005-2007



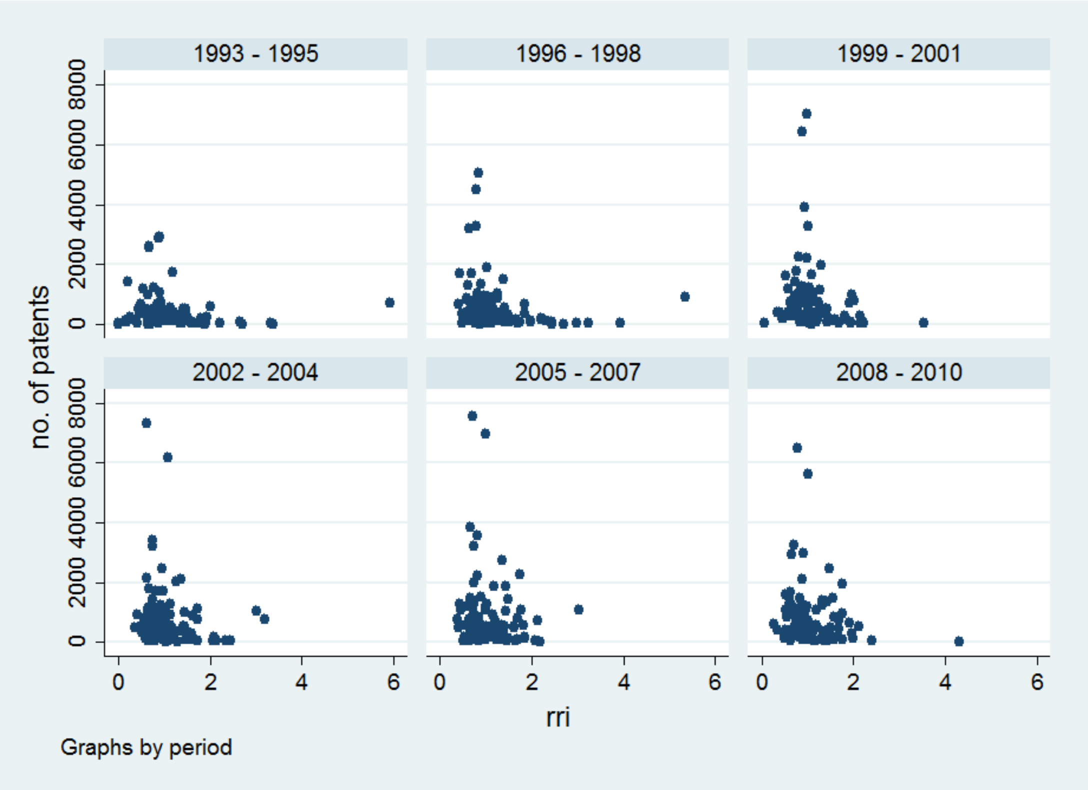






Source: REGPAT database, own calculation

APPENDIX 13: Correlation between size of a region (number of patents) and RRI value



Source: REGPAT database, own calculation

APPENDIX 14: Mean RRI values per region

ROR No.	Name of ROR	RRI mean	ROR No.	Name of ROR	RRI mean
101	Schleswig-Holstein Mitte	0.855132*	806	Neckar-Alb	0.802653
102	Schleswig-Holstein Nord	0.571462*	807	Nordschwarzwald	0.856301*
103	Schleswig-Holstein Ost	1.321696	808	Ostwürttemberg	0.957694
104	Schleswig-Holstein Süd	0.839078**	809	Schwarzwald-Baar-Heuberg	0.532515***
105	Schlesw.-Holst. Süd-West	0.915747	810	Stuttgart	0.783649***
201	Hamburg	2.604984	811	Südlicher Oberrhein	1.328857**
301	Braunschweig	1.350171*	812	Unterer Neckar	1.233678
302	Bremen-Umland	0.932881	901	Allgäu	1.36054**
303	Bremerhaven	1.227942	902	Augsburg	0.766855**
304	Emsland	0.640486**	903	Bayerischer Untermain	0.950162
305	Göttingen	1.162545	904	Donau-Iller (BY)	1.188654
306	Hamburg-Umland-Süd	0.956977	905	Donau-Wald	0.851096*
307	Hannover	0.836005*	906	Industrieregion Mittelfranken	0.805384***
308	Hildesheim	0.51862***	907	Ingolstadt	1.563962**
309	Lüneburg	1.014126	908	Landshut	0.83426
310	Oldenburg	1.004051	909	Main-Rhön	0.561636**
311	Osnabrück	0.619538**	910	München	0.967602
312	Ost-Friesland	1.294971	911	Oberfranken-Ost	1.108736
313	Südheide	0.616825**	912	Oberfranken-West	0.772919***
401	Bremen	1.203486	913	Oberland	1.792386*
501	Aachen	1.211074*	914	Oberpfalz-Nord	0.624156*
502	Arnsberg	1.085688	915	Regensburg	0.689716***
503	Bielefeld	0.588893***	916	Südostoberbayern	0.722694**
504	Bochum/Hagen	0.871837**	917	Westmittelfranken	0.871374
505	Bonn	1.068262	918	Würzburg	0.794786***
506	Dortmund	1.106714	1001	Saar	1.271693**

507	Duisburg/Essen	0.922335	1101	Berlin	1.292613
508	Düsseldorf	0.753224***	1201	Havelland-Fläming	1.391142
509	Emscher-Lippe	0.873854	1202	Lausitz-Spreewald	1.286372*
510	Köln	0.916339	1203	Oderland-Spree	1.508711
511	Münster	0.976888	1204	Prignitz-Oberhavel	0.773352**
512	Paderborn	0.823752**	1205	Uckermark-Barnim	1.122908
513	Siegen	0.692223**	1301	Mecklenburgische Seenplatte	0.845751
601	Mittelhessen	0.794817***	1302	Mittleres Mecklenburg/Rostock	1.960988**
602	Nordhessen	0.791704**	1303	Vorpommern	2.120242**
603	Osthessen	1.114883	1304	Westmecklenburg	2.2778**
604	Rhein-Main	0.758093***	1401	Oberes Elbtal/Osterzgebirge	1.626803***
605	Starkenburg	0.937197	1402	Oberlausitz-Niederschlesien	1.284393
701	Mittelrhein-Westerwald	1.031349	1403	Südsachsen	1.642726***
702	Rheinhessen-Nahe	1.699505***	1404	Westsachsen	1.531486
703	Rheinpfalz	0.784849	1501	Altmark	1.881157
704	Trier	0.946807	1502	Anhalt-Bitterfeld-Wittenberg	1.886235***
705	Westpfalz	1.137205	1503	Halle/S.	1.59391**
801	Bodensee-Oberschwaben	0.677096***	1504	Magdeburg	1.677484***
802	Donau-Iller (BW)	1.598939	1601	Mittelthüringen	1.739575***
803	Franken	1.250257*	1602	Nordthüringen	2.476837**
804	Hochrhein-Bodensee	0.925859	1603	Ostthüringen	1.42644*
805	Mittlerer Oberrhein	0.764825***	1604	Südthüringen	1.553665***

Source: REGPAT database, own calculation

Note: Significance level of *** - 99%, ** - 95% or * - 90% (t test)

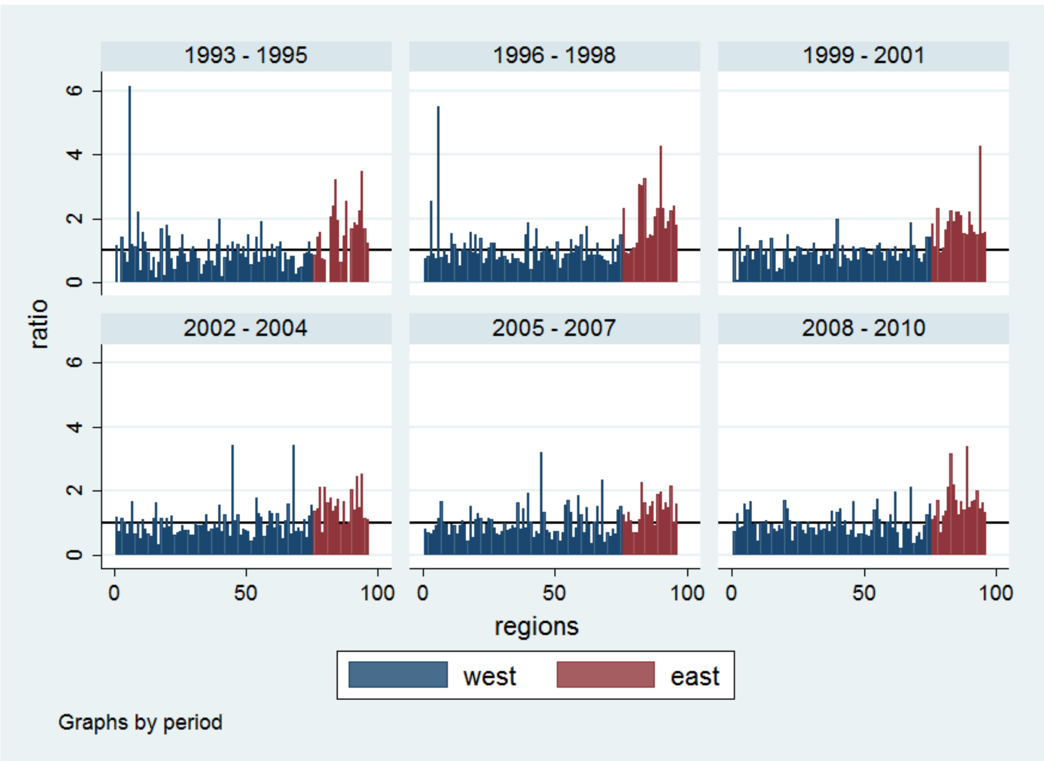
APPENDIX 15: Robustness check

Findings using 8 IPC main technology classes

a) Descriptive statistics

Time period	Number of patent applications			Number of cooperative patent applications			Cooperative patent applications (%)		
	Total	**East**	**West**	**Total**	**East**	**West**	**Total**	**East**	**West**
1993 – 1995	39689.01	1160.47	38528.54	2154.47	108.39	2046.09	5.43	9.34	5.31
1996 – 1998	57310.17	2080.83	55229.34	2932.05	199.71	2732.34	5.12	9.60	4.95
1999 – 2001	73240.40	3363.81	69876.59	3579.32	311.97	3267.35	4.89	9.27	4.68
2002 – 2004	77721.84	3817.98	73903.85	3708.11	286.02	3422.10	4.77	7.49	4.63
2005 – 2007	88228.70	4864.60	83364.09	4291.19	323.81	3967.38	4.86	6.66	4.76
2008 – 2010	78943.91	4704.53	74239.38	3789.51	368.39	3421.12	4.80	7.83	4.61

b) RRI values of East and West German regions over time



RRI variance East: 0.349 RRI variance West: 0.187

c) RRI values in East and West German regions

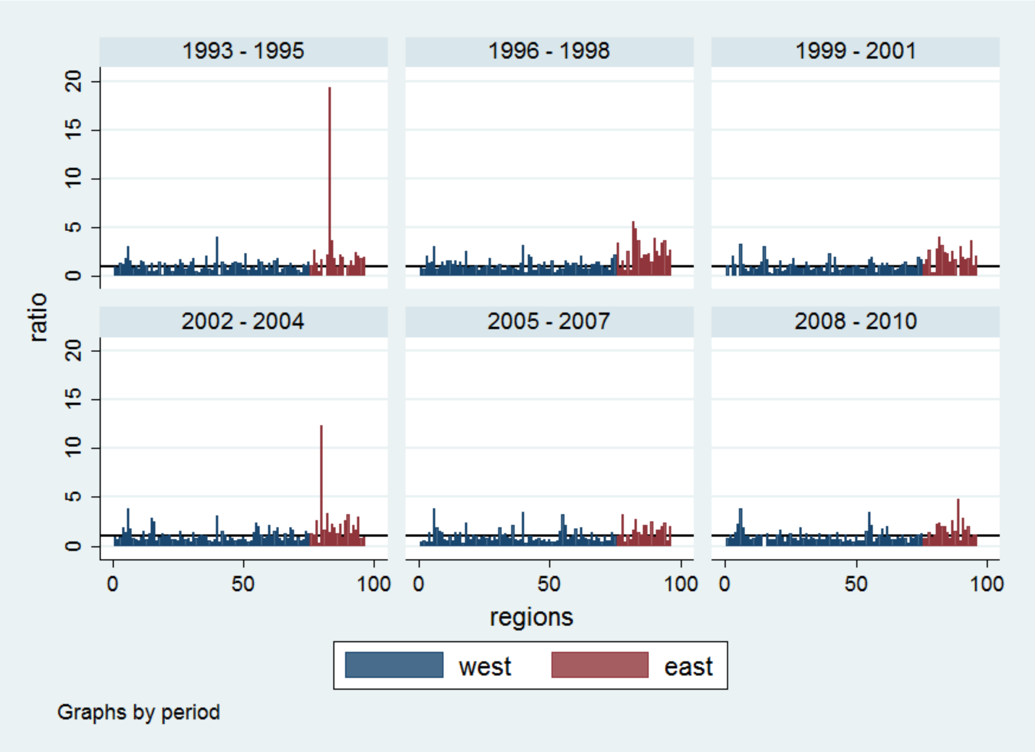
	East Germany			**West Germany**		
Period	Min	Max	Mean	Min	Max	Mean
1993 - 1995	0.000	3.467	1.767	0.000	6.157	1.016
1996 - 1998	0.882	4.265	2.008	0.424	5.505	1.058
1999 - 2001	0.938	4.274	1.859	0.062	1.975	0.954
2002 - 2004	0.712	2.545	1.555	0.333	3.426	1.005
2005 - 2007	0.683	2.274	1.409	0.376	3.213	0.994
2008 - 2010	0.688	3.505	1.690	0.227	2.124	0.970

Findings using applicants as a basis for regionalization

a) Descriptive statistics

Time period	**Number of patent applications**			**Number of cooperative patent applications**			**Cooperative patent applications (%)**		
	Total	East	West	Total	East	West	Total	East	West
1993 – 1995	39036.09	870.20	38165.89	2018.09	85.20	1932.89	5.17	9.79	5.06
1996 – 1998	56087.62	1468.66	54618.96	2892.62	187.66	2704.96	5.16	12.78	4.95
1999 – 2001	71903.33	2153.19	69750.13	3816.33	239.19	3577.13	5.31	11.11	5.13
2002 – 2004	75605.94	2425.53	73180.41	3960.94	224.53	3736.41	5.24	9.26	5.11
2005 – 2007	85209.27	2862.86	82346.41	4829.26	252.86	4576.41	5.67	8.83	5.56
2008 – 2010	76613.34	3076.30	73537.05	4205.34	289.30	3916.04	5.49	9.40	5.33

b) RRI values of East and West German regions over time



RRI variance East: 3,758 RRI variance West: 0,175

c) RRI values in East and West German regions

	East Germany			West Germany		
Period	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
1993 - 1995	0.000	19.348	2.720	0.137	3.980	1.121
1996 - 1998	0.634	5.582	2.563	0.338	3.213	1.188
1999 - 2001	0.000	4.007	2.103	0.000	3.279	1.099
2002 - 2004	0.365	12.354	2.312	0.406	3.826	1.130
2005 - 2007	0.378	3.190	1.597	0.313	3.794	1.055
2008 - 2010	0.595	4.807	1.682	0.000	3.813	1.054

i In our paper we are not talking about innovation networks, but deliberate cooperation, since there are substantial differences between these two concepts (for a discussion s. e.g. Günther 2004).

[ii] We assume that there is at least one innovation in each technology. Therefore, we do not distinguish several cases in equation 6.

[iii] In principle, we have two levels of empirical analysis, first of all planning regions (ROR) and second, East and West Germany, each consisting of a particular number of planning regions which can be compared to each other.

[iv] Since the data is normalized in this procedure, the coefficients between the two different variables can be compared.

[v] For an illustration see Appendix 9. In West Germany, the RRI value does not change much over time. In East Germany, an initially much higher value (close to 2) drops particularly between 1996 and 2007, and is close to 1.5 in 2008-2010 (see also Appendix 10).

[vi] For an alternative illustration (box plots), see Appendix 9.

[vii] The continuously high RRI values in the structurally weak North Eastern region (Vorpommern-Greifswald) are based on low numbers of patent applications and co-applications and should not be overestimated.

[viii] When using applicants for regionalisation, the total number of patents decreases in the East, which is a well-known finding from the above mentioned literature. However, the number of co-patents does not decrease as strongly as patents leading to a higher share of co-patents, which in turn contributes to the observed higher level of RRI values.