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by

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How General Conditions Affect Regional Innovation Systems – The Case of the Two Germanys¹

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Abstract

We compare two leading regional innovation systems (RIS) in East Germany with two RIS in West Germany of about the same size and internal settlement structure. Our analyses show that differences in the performance between the regions cannot easily be related to the structural properties of the respective innovation networks because divergent general economic conditions in the two parts of the country as well as the integration of regions into their neighboring spatial environment play a rather dominant role. Overall, our analysis clearly shows that an analysis of RIS should account for the general economic conditions as well as for the position of a region in its spatial environment. Focusing just on the respective region is not enough.

Keywords: Regional innovation systems, national innovation systems, innovator networks, gatekeeper; social network analysis

JEL Classification: O31; Z13; R11

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1. The effect of general conditions on Regional Innovation Systems

There can be little doubt that the national innovation system (NIS) has a considerable effect on regional innovation systems (RIS) that it comprises. However, the strength and the nature of such effects of a NIS on the respective RIS have remained largely unexplored. A main reason for this research deficit is that attempts to compare regions of different countries or long-term studies within countries that could answer the respective questions suffer from missing data or from available data being hardly comparable. The case of East and West Germany provides an excellent opportunity for such an analysis because after unification of the two Germanys in the year 1990, the legal framework and the formal institutions of West Germany have been transferred and implemented in the East. Hence, to study differences between East and West Germany may be regarded as an international comparison within one country.

General conditions between East and West Germany differ for two main reasons. First, for more than forty years, East Germany had been under a socialist regime characterized by a substantially different institutional framework, different macro-economic conditions, and in particular a rather different organization of innovation processes compared to the West (see section 2 for details). This “natural experiment” has left substantial imprints on the East German RIS. Second, beginning in the year 1990, East Germany was subject to a turbulent transformation process towards a market economic system (Brezinski and Fritsch, 1995) that created an environment for innovation activities quite distinct from the one prevailing in the West (Fritsch, 2004; Kronthaler, 2005). Hence, we should expect to find considerable effects of the different general conditions on the performance of RIS in both parts of the country.

For our comparative study, we have selected two of the leading RIS of East Germany, Dresden and Jena, and two well-performing RIS in West Germany, which have a comparable size and settlement structure, Aachen and Karlsruhe. In particular, we use patent statistics to construct networks of innovators in the four regions under study (Cantner and Graf, 2006; Graf and

Henning, 2009). Our analysis shows striking differences between the two East German and the corresponding West German RIS which clearly indicate different modes of innovation that may be traced back to the different historical developments in the regions during the more than forty years under different regimes. A striking difference pertains to the level of cooperation in the two parts of the country. The East German RIS show relatively low levels of innovation performance but considerably higher levels of R&D cooperation than their more efficient West German counterparts, which is in contrast to what would be predicted on the basis of the systems of innovation approach (Cooke, 1998; Asheim and Gertler, 2006). This may indicate an effect of the general economic conditions as well as differences in the organization of innovation activities in the two parts of the country. Another factor that could contribute to the explanation of this phenomenon is that the two East German RIS (Dresden and Jena) under inspection are spatially isolated 'hot spots' in the East German landscape while the two West German RIS (Aachen and Karlsruhe) are to a much higher degree embedded in their relatively prosperous regional neighborhood. This suggests that the performance of RIS depends to a considerable degree on their wider spatial environment. Altogether, we find that the general conditions have a rather strong effect on the performance of RIS that should neither be neglected in empirical analyses nor in the design of respective policy measures.

In the remainder we first introduce the regional innovation systems approach (section 2). Section 3 gives a brief overview of the historical background and innovation performance in East Germany compared to the western part of the country in general and section 4 provides information on characteristics and the performance of the four case-study regions. The comparative analysis of the four regions is reported in section 5. Section 6 gives information about the development of the regions in the subsequent period. Section 7 concludes.

2. Literature: Regional Innovation Systems and the network perspective

The systemic view of innovation processes (e.g., Lundvall, 1992; Nelson, 1993; Edquist, 1997) emphasizes the importance of a division of innovative labor and of knowledge transfer between innovative actors. Since knowledge flows tend to be regionally bounded (Jaffe et al., 1993) and because the preconditions for innovation activities may differ substantially between regions, the RIS approach particularly stresses the role of geography (Cooke, 1998; Asheim and Gertler, 2006). The main argument for the spatial dependence of knowledge flows is that knowledge has tacit components which can only be transferred via personal relationships that may be facilitated by geographical proximity (Boschma, 2005; Breschi and Lissoni, 2009). Building on these ideas, the RIS approach highlights the importance of embeddedness of regional interaction within an environment of specific actors and institutions that may considerably affect the regional innovation process and the innovation performance of a region as a whole.

The literature discusses quite a number of region-specific factors that may determine the performance of RIS such as location with regard to other regions, the size of a region and its settlement structure, the qualification of the regional workforce, the endowment with universities and other public research organizations, the innovative milieu, regional industry specialization (clustering) (Fritsch and Slavtchev, 2010), etc. (see Fritsch and Slavtchev, 2008, for an overview). According to the systemic view, the innovation performance of an RIS may be particularly shaped by the level and the structure of regional interaction as well as the relationships to external actors that may indicate the openness of a region (Graf, 2010). In a nutshell, the systemic view may be boiled down to the hypothesis that the level and the quality of division of innovative labor has an important positive effect on the level and the success of innovation activities and, therefore, on the performance of RIS. One may, therefore, expect that tightly knit regional networks and integration of local actors into global knowledge flows constitute an excellent precondition for the effectiveness of RIS.

While there exist quite a number of empirical analyses on region-specific determinants of RIS performance, the effect of more general conditions has been left more or less completely unexplored. As a consequence, we know nearly nothing about the relative importance of such general framework conditions for the performance of RIS and their role for the effectiveness of region-specific determinants.² For example, what is the effect of specific institutional settings on the different modes of knowledge transfer from universities and from other public research organizations into the private sector? How does general prosperity affect the performance of RIS as compared to decline or to a high level of turbulence as could be found in East Germany during the 1990s?

In the present study, we compare a number of key characteristics of systemic innovation processes between four case-study regions. In particular, we focus on the relations between innovative actors (firms, public research institutions, and individuals), the resulting regional innovation networks as well as on the links to actors external to the respective region. This information allows us to assess the systemic properties of the four RIS and to derive expectations about their relative performance. Contrasting these results with the factual level of regional innovation activity and its development leads to conclusions about the relative importance of RIS-specific characteristics and general conditions.

3. Historical background: The two German innovation systems

Until the year 1945, the end of World War II, the national framework conditions in what is today's Germany had been identical. Right after the end of the war, the winning nations, France, Great Britain, Russia and the USA, divided the country into four zones, each of them governed by one of these nations. While the occupation zones of France, Great Britain and the USA formed the *Federal Republic of Germany* (FRG), West Germany, in the year 1949, the Russian zone became at about the same time the *German*

² A number of studies have investigated the effect of different characteristics of national innovation systems on their performance (Hall and Soskice, 2001; Dosi, Llerena and Labini, 2006) but have largely ignored regional conditions below the level of the nation state.

Democratic Republic (GDR), commonly referred to as East Germany. The FRG, West Germany, was set up as a capitalistic market economy which soon experienced vigorous economic recovery. In contrast, the GDR, East Germany, became a socialist-type centrally planned economy with its innovation system built much according to the Russian example.

Accordingly, the East German innovation system was characterized by a close orientation towards the linear model of the innovation process and pronounced attempts of bureaucratic steering (Fritsch and Werker, 1999; Hanson and Pavitt, 1987).

It is well known that socialist-type centrally planned economies and their innovation systems have performed rather badly (Radosevic, 1999). Hence, the East German economy had suffered enormous economic problems. One of these problems was the exodus of people fleeing to the FRG. The East German government reacted to this loss of human capital by constructing a border regime in 1961, the 'Wall', that more or less completely separated East Germany from the West and made any uncontrolled transfer of people, goods, and resources almost impossible. In the course of these developments, innovation activities in East Germany were largely cut off from those in the West. The East German government only rarely allowed Eastern scientists to travel into the West and to communicate with Western colleagues. Innovation in the East was also hampered by embargo lists of goods (e.g., modern machinery, software) that the Western block did not allow to be sent to the East (Kogut and Zander, 2000). Failure to meet western standards as well as integration into the Eastern Bloc led to a concentration of exports to other socialist countries. The fall of the Iron Curtain and German unification, particularly the introduction of a currency union with West Germany, disrupted the East German economy from their East European markets and put it under enormous competitive pressure from Western competitors (see Brenzinski and Fritsch, 1995, for a detailed assessment). Together with the necessity to fundamentally transform the political-administrative system, the East German economy experienced a

fundamental economic crisis that is still clearly noticeable twenty years later (Fritsch, 2004).

4. Regional innovation systems compared: Dresden and Jena versus Aachen and Karlsruhe

4.1 Selection of case-study regions

Dresden and Jena are the two East German regions that have been able to perform relatively well under the challenges of the East German innovation system described above. At the turn of the millennium, ten years after the initiation of the transformation process, they were the two East German lighthouses of innovation in terms of the level of innovation activity as well as with regard to the efficiency of their innovation systems (Fritsch and Slavtchev, 2008). However, despite their leading role within the East German economy they were still considerably behind the West German level. For our analysis we matched Dresden and Jena with two comparable regions in the West of the country with relatively high efficiency of their RIS. The matching West German regions had to be comparable to Dresden and Jena with regard to their size and their settlement structure.³ They also had to have a research university as well as a number of other public research organizations. According to these criteria, we chose Aachen and Karlsruhe for the comparison.

All four case-study regions are defined as German planning regions ("Raumordnungsregionen"). In order to represent functional entities, planning regions normally comprise several NUTS3 level districts, namely a core city and its surrounding area. Planning regions tend to be somewhat larger than labor market regions or travel-to-work areas. We consider planning regions to be more suitable for an analysis of RIS than districts for two reasons. First, a single district, particularly a core city, is probably too small to include the most important parts of innovation-related local interaction. The second

³ Comparability with regard to size and settlement structure implied that the two West German RIS with the highest levels of innovation efficiency, Munich and Stuttgart, were not selected because they are much larger than the two East German regions.

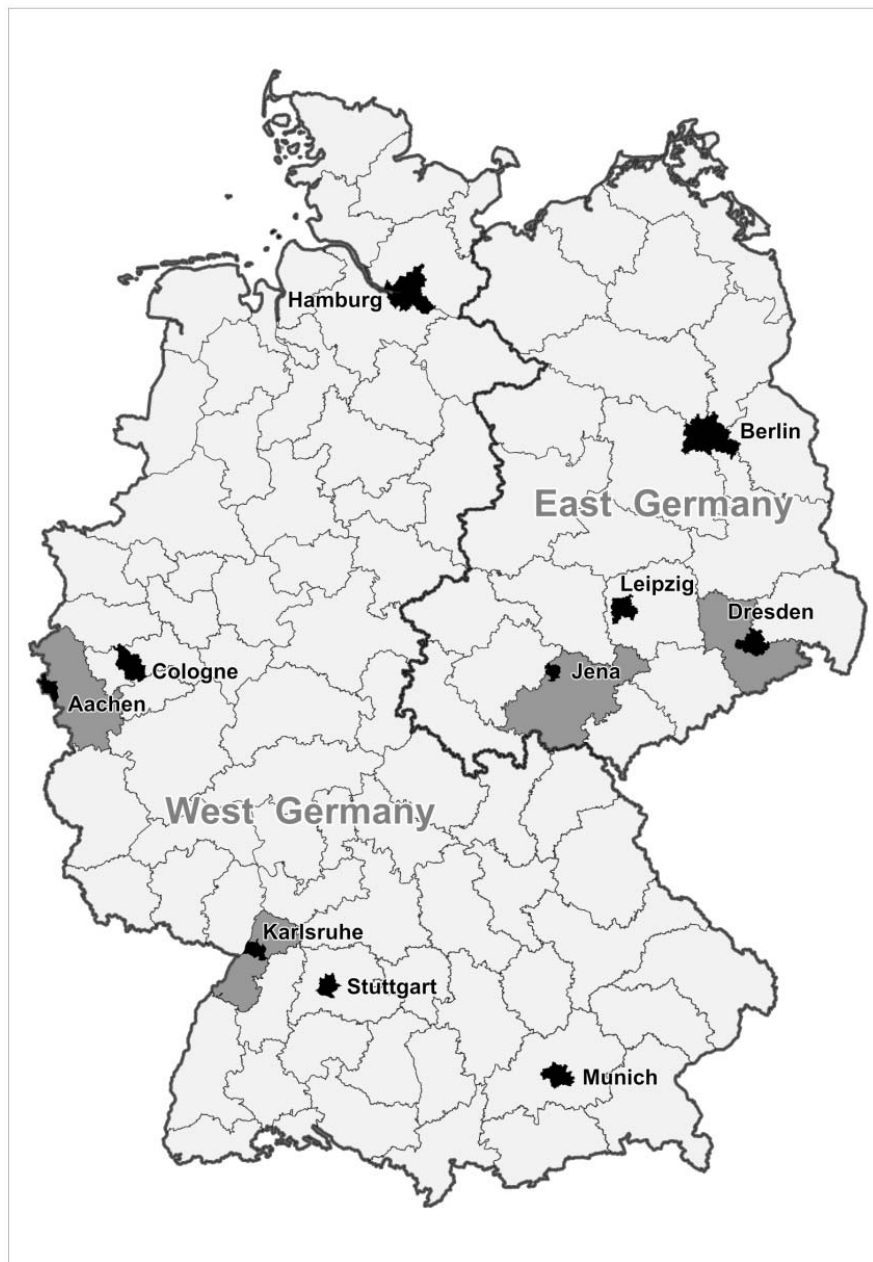


Figure 1: The case-study regions

reason is of a methodological nature: since patents are assigned to the residence of the inventor, taking just a core-city as a region would lead to an underestimation of patenting activity since many inventors have their private residence in surrounding districts. Figure 1 shows the location of the four case-study regions. While Aachen and Karlsruhe are located close to other regions with a high level of innovation activity (e.g., Bonn and Cologne in the

case of Aachen; Stuttgart and Mannheim in the case of Karlsruhe), the two East German regions appear to be quite isolated in this respect. This pertains particularly to Jena which represents a 'cathedral in the desert' even within its planning region (Graf, 2006).

4.2 Characteristics and general performance of case-study regions

The size of the four case-study regions ranges between nearly 800,000 inhabitants in the Jena region to about 1,250,000 thousand inhabitants in the region of Aachen (Table 1). All four regions have a considerable tradition in manufacturing industries: electronics and mechanical engineering in Dresden, optics and precision mechanics in Jena, electronics and electrical engineering in Aachen⁴, and electrical engineering, mechanical engineering, and vehicles construction in Karlsruhe. The fact that the two East German regions have a considerably smaller establishment size in the manufacturing sector is most probably a result of the transformation process that has led to a split-up of large entities often followed by further employment decline due to unfavorable economic performance. Moreover, many East German establishments are small because they were set up after German unification. The higher start-up rates in the two East German regions are also a result of the transformation process and reflect an adjustment of entrepreneurship to the West German level. The share of R&D employees⁵ is considerably lower in the Eastern regions but both show a higher share of employees with a tertiary degree.

The amount of third-party funds per professor may indicate several things. First, since external funds are predominantly allocated by means of highly competitive procedures, the amount of third-party funds per professor can be regarded as an indicator of the quality of research. This is particularly

⁴ The Aachen region has experienced a considerable shift from coal mining to more manufacturing industries since the 1970s. In the period of our analysis, the mining sector did not play an important role anymore. The economies of the other three case-study regions have not been subject to such a dramatic change of their sector structure.

⁵ Employees are classified as working in R&D if they have a tertiary degree and work as engineers or natural scientists.

Table 1: Innovation and performance indicators for case-study regions

	<i>East Germany</i>		<i>West Germany</i>	
	<i>Dresden</i>	<i>Jena</i>	<i>Aachen</i>	<i>Karlsruhe</i>
Number of population	1,032,659	788,236	1,247,270	1,087,776
Number of employees (private sector)	289,647	198,501	271,232	324,759
Average establishment size (number of employees) overall	7.43	6.86	7.87	9.68
Average establishment size (number of employees) in manufacturing	14.25	14.80	19.32	24.45
Average establishment size (number of employees) in services	5.52	4.37	4.77	5.66
Share of employees in manufacturing in total private sector employment	25.91	30.13	37.57	42.46
Start-up rate private sector	7.17	7.78	7.05	5.50
Share of R&D employees	3.16	2.44	3.69	3.98
Share of employees with tertiary degree	12.65	10.83	7.83	8.07
Third-party funds per professor (in 1,000 €) ^b	72.92	39.73	169.25	109.11
Third-party funds from private firms per professor (in 1,000 €) ^b	14.49	5.56	169.25	35.18
Third-party funds from German Science Foundation (DFG) per professor (in 1,000 €) ^b	17.75	16.89	43.85	36.89
Third-party funds per professor (in 1,000 €) in departments of engineering and natural sciences only ^b	119.81	66.33	234.99	131.20
Number of Fraunhofer Institutes ^c	10	1	3	2
Number of Max Planck Institutes ^c	3	3	0	0
Patents of private firms per 1,000 employees 1995-2001	0.77	0.58	1.37	1.44
Patents of private firms per 1,000 R&D employees 1995-2001	21.63	22.86	46.11	38.92
Efficiency of the RIS 1995-2000 (Fritsch and Slavtchev, 2008)	0.354	0.394	0.769	0.613

^a All^b Private universities and university hospitals excluded.^c As of 2008.

true for external funds from the German Science Foundation (DFG), which are designated to basic research. Funds from private firms signify university–industry linkages that may result in relatively pronounced knowledge spillovers.⁶ An important difference between the two Eastern and the two Western regions is the lower level of third-party funds per professor in the East. Since the departments of engineering and natural sciences tend to have the highest levels of external funding, we restrict this indicator to these departments only. While Aachen is the clear leader with respect to this indicator, we find Karlsruhe and Dresden in a middle position while Jena is lagging behind, having only less than 30 percent of the level of Aachen.

The two East German regions are well equipped with non-university public research institutes of the Max Planck Society with a focus on basic research and of the Fraunhofer Society which are designated to transfer results of basic research to private sector innovators. Particularly, Dresden has a remarkably high number of ten institutes of the Fraunhofer Society. Comparing patents as an important output measure of innovation activity, the two West German regions seem to perform much better than their Eastern counterparts. This becomes particularly clear if one takes the number of patents per R&D employee as indicator, which can be regarded as a measure of the productivity of R&D activity. Estimates of the efficiency of German RIS in the 1995-2000 period by Fritsch and Slavtchev (2008) reveal a much better performance of Aachen (0.769) and Karlsruhe (0.613) as compared to Dresden (0.354) and Jena (0.394).⁷

This first inspection of innovative resources and innovation performance in the four case-study regions shows a clear impact of the socialist heritage and the subsequent transformation process in the two East

⁶ Although we have no information about the location of the respective private firms, we know from other studies (e.g., Fritsch and Schwirten, 1999) that industry-university cooperation tends to be concentrated in the university's vicinity

⁷ These estimates are based on a knowledge production function with the number of patents as R&D output and the number of R&D employees as R&D input; for details see Fritsch and Slavtchev (2008). A value of 0.769 in the case of Aachen means that the RIS reaches 76.9 percent of the value for the RIS with the highest R&D productivity. Dresden and Jena reach only 35.4 percent and 39.4 percent of that level.

German regions. All four regions are comparable with regard to the preconditions for innovation activity on the resource-side, but the two West German regions clearly perform better. In the following section, we analyze the networks of inventors in the four regions in order to explain the differences in the efficiency of the RIS.

5. Regional networks of inventors

The innovation systems approach suggests that the division of innovative labor is of crucial importance for innovation performance. (Lundvall and Johnson, 1994; Capello and Faggian, 2005; Malmberg and Maskell, 2006). We employ the methodology of social network analysis to investigate the relationships between innovative actors in order to explain the observed regional differences in innovative performance.

5.1 Method: Social network analysis and patent data

Our analysis of the networks of inventors is based on patent applications at the German Patent Office which were disclosed between 1995 and 2001. The regional assignment of patents is based on the information about the inventors' residence, i.e., we use all patent applications with at least one inventor residing in the respective region to construct the networks. Each patent application provides information about the applicant (the innovator) and about the respective inventor(s). We assume two innovators to be related if at least one inventor has developed a patent for both innovators. In other words, a relation is established between innovators A and B if we find an inventor on a patent applied for by A and on a patent applied for by B. There are two possibilities of how this might occur:

- First, the innovators jointly apply for a certain patent. In this case, we assume a previous research cooperation and there are as many linkages between all co-applying innovators as there are inventors.
- Second, the same inventor is named on two distinct patent applications submitted by different innovators. In this case, we assume mobility of the inventor between the innovators.

Both types of linkages are related to the notion of knowledge transfer through personal relationships (e.g., Almeida and Kogut, 1999). The main idea is that organizations, i.e. firms or research institutes, interact via scientists who know each other either through working on joint projects (cooperation) or as they move from one organization to the other (mobility). Of course, mobility does not only encompass the case of individuals changing jobs between existing organizations but also spin-off processes in which new entities are formed by employees of incumbents.⁸

Since during the period under analysis German patent law allowed university professors to patent for their own account and not under the name of their university, the number of university patent applications is underestimated in our data. The number of patent applications from public research is further underestimated because universities may trade intellectual property rights for financial support in university-industry cooperation projects, i.e. the private firm sponsors the research carried out in the university's lab but claims the exclusive right to patent the invention in exchange. In consequence, there is not only an underestimation of public research patent activity, but even more importantly, a number of university-industry cooperations leading to patent output will not be identified as cooperative activity at all.

5.2 Overall structure of inventor networks

A comparison of the patent numbers that underlie our analysis shows that actors in Aachen and Karlsruhe filed many more patents than actors in Jena or Dresden, with the number of patent applications in Karlsruhe almost tripling those of Jena (Table 2). In terms of the numbers of applicants (the network actors), the differences are not quite as pronounced with Aachen and Karlsruhe, comprising roughly twice as many applicants as Jena. The higher numbers of patent applications per actor (Dresden 3.21 patents per applicant, Jena 3.02, Aachen 3.46, Karlsruhe 4.16) is probably a result of the smaller average size and corresponding lower levels of R&D of actors in the

⁸ For a detailed description of the method see Graf (2006).

Table 2: Characteristics of the inventor networks in case-study regions

	<i>East Germany</i>		<i>West Germany</i>	
	<i>Dresden</i>	<i>Jena</i>	<i>Aachen</i>	<i>Karlsruhe</i>
<i>Number of Patents</i>	3,720	2,094	5,508	6,072
by type of applicant (%)				
– individual	19.2	18.8	25.5	19.5
– public	23.7	25.7	14.8	8.7
– firm	57.2	55.5	59.7	71.8
by location of applicant (%)				
– same region	70.3	75.0	65.8	66.8
– same Federal State	7.2	3.2	21.9	18.8
– rest of Germany	21.4	21.2	10.2	11.9
– abroad	1.0	0.7%	2.1	2.4
<i>Number of Actors</i>	1,158	694	1,591	1,460
by type (%)				
– individual	40.2	38.3	50.0	46.7
– public	5.6	8.6	1.8	2.2
– firm	54.2	53.0	48.2	51.1
by location (%)				
– same Region	51.8	56.2	61.2	60.2
– same Federal State	11.1	6.3	17.9	16.8
– rest of Germany	35.1	35.9	16.4	19.0
– abroad	2.0	1.6	4.5	4.0
<i>Total number of linkages^a</i>	4,106	3,614	4,036	3,754
– share internal (%)	30.8	42.4	49.3	25.6
– share external (%)	69.2	57.6	50.7	74.4
<i>Number of cooperation linkages^a</i>	2,570	2,100	2,374	1,906
– share internal (%)	31.0	41.7	50.5	26.7
– share external (%)	69.0	58.3	49.5	73.3
<i>Number of mobility linkages^a</i>	1,536	1,514	1,662	1,848
– share internal (%)	30.5	43.3	47.7	24.5
– share external (%)	69.5	56.7	52.3	75.5
<i>Share of mobility linkages (%)</i>	37.4	41.9	41.2	49.2
<i>Network measures</i>				
Number of components	549	309	910	875
Size of largest component	359	259	254	344
Share in largest component (%)	31.0	37.3	16.0	23.6
Share of isolates (%)	35.1	32.6	42.5	48.3
Centralization ^b	0.094	0.115	0.022	0.046
Density (valued) (%)	0.44	0.92	0.21	0.25
Density (binary) (%)	0.19	0.39	0.10	0.11
Mean degree (valued)	5.069	6.383	3.382	3.627
Mean degree (binary)	2.225	2.689	1.612	1.604
Average distance within main component	3.374	3.103	4.423	4.032
<i>Cooperation</i>				
Mean degree (valued)	3.021	3.839	1.898	1.879
Mean degree (binary)	0.805	0.896	0.569	0.518
<i>Mobility</i>				
Mean degree (valued)	2.048	2.545	1.483	1.748
Mean degree (binary)	1.435	1.830	1.046	1.101
^a Only relations with at least one internal actor involved.				
^b Based on degree centrality.				

two East German regions. Another significant difference between the East German and the West German regions is the relative importance of patent applications of public research institutions. While in Dresden and Jena roughly every fourth patent has been filed by universities or other public research institutes, this share is only 9 percent in Karlsruhe and 15 percent in Aachen.⁹

It is quite remarkable that the inventor networks in the two East German regions are to a much higher degree integrated than in the two West German regions. In Dresden as well as in Jena, the share of actors in the largest component is much higher and the share of isolated actors who are not connected to other actors at all is much lower than in Aachen and Karlsruhe (table 2). Since the actors in the two East German networks have a larger average number of links to other actors (mean degree), the network density, i.e. the share of realized links over all possible links, is also higher there.¹⁰ The considerably higher number of relationships in the two East German RIS holds for both types of links, those based on cooperation and those related to mobility of inventors. While a higher level of mobility links in the East German RIS may have been expected as a result of the turbulent transformation process during which relatively many persons had to change their employer¹¹, the higher number of cooperative links may be regarded as surprising, given the disruptive effects of the transformation process on personal ties and networks (Albach, 1994). The higher average numbers of cooperative links that we observe in the two East German RIS can be

⁹ Public research comprises the universities, technical colleges ("Fachhochschulen") as well as non-university publicly funded scientific institutes. The latter are in most cases members of one of large German scientific institutions: the Max Planck Society, the Leibniz Association, and the Fraunhofer Society.

¹⁰ The density measure is somewhat problematic in comparing networks of different sizes as the number of possible linkages increases geometrically while the actual number of linkages usually does not since inventors are constrained in their capacities to have contacts to other actors. Centralization and mean degree are reported for a valued and a binary version of the networks, the former accounting for the intensity of relations (number of common patents) and the latter just for the number of partners.

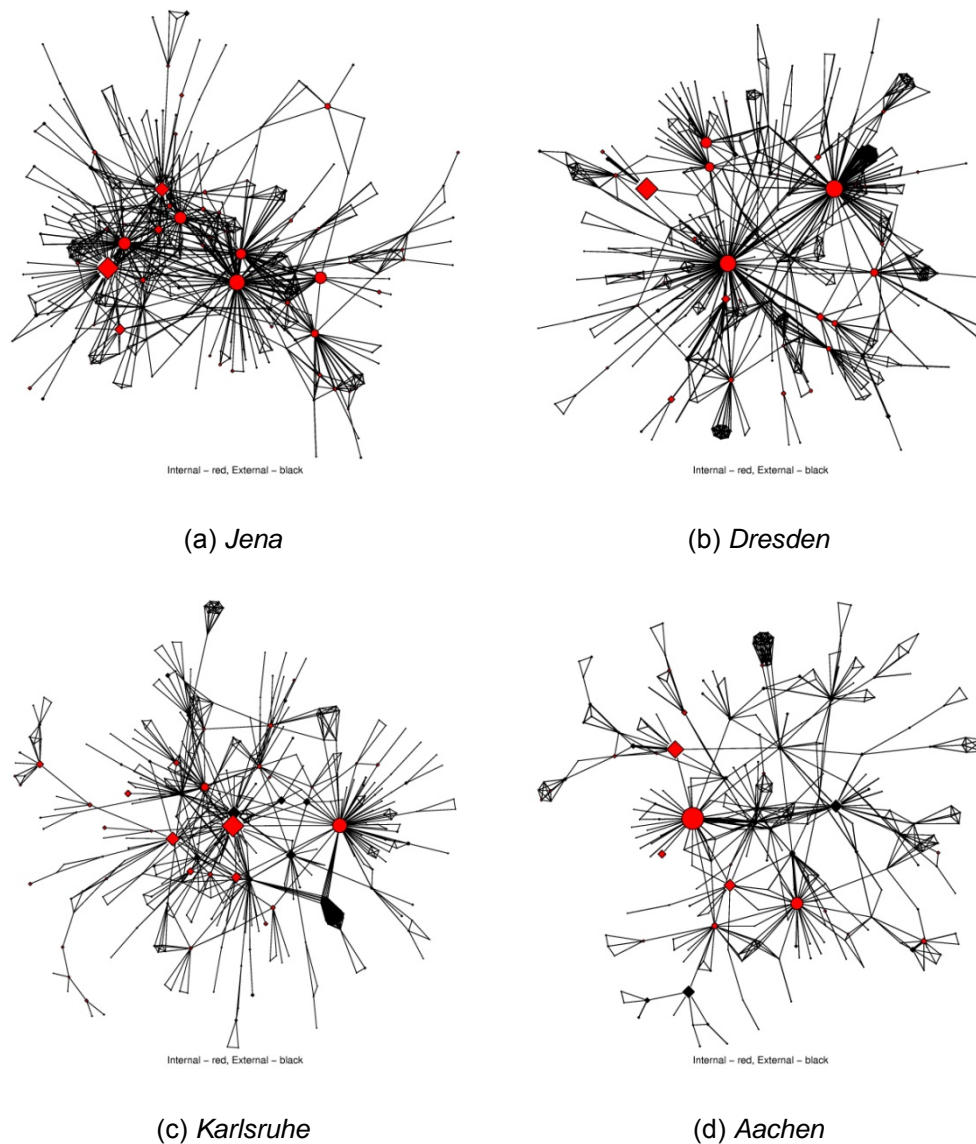
¹¹ The share of mobility linkages over all linkages ranges from 49.2 percent in Karlsruhe to 37.4 percent in Dresden (table 2). The figures do not indicate a more pronounced role of mobility in the East as might have been expected as a result of the East German transformation process.

regarded as a heritage of a more open attitude towards R&D cooperation under a socialist regime. Obviously, many of the relationships established under the past system proved stable enough to survive the radical reorganization of the East German RIS caused by the transition. If we distinguish between the types of linkages, cooperation and mobility, we observe no big difference between the two linkage-types with respect to the shares of internal and external relations. Besides the higher levels of interaction in the two Eastern regions, we observe another structural difference. The networks in Dresden and Jena are far more centralized¹² than in the West, i.e. linkages are more concentrated on few key actors.

The higher degree of integration in the two East German regions does not only hold for the networks as a whole but also for their main components (figure 2). The networks in East Germany seem to be more tightly knit than their West German counterparts. Accordingly, the average distance between actors within the main component¹³ is also smaller in the two East German regions. Especially when comparing Jena and Aachen, we observe a dense pattern of relationships with quite a large number of central actors in Jena, whereas in Aachen the network appears to be less dense with no easily identifiable centre. The main component of the inventor network in Dresden is clearly dominated by two actors from public research (the Technical University of Dresden and the Fraunhofer Society) that have by far the highest number of linkages. In the other regions, actors from public research do not play such a dominant role.

¹² The network centralization is given by $C = \frac{\sum_{i=1}^g (\max C_D(i) - C_D(i))}{g-2}$, where $C_D(i)$ is the normalized degree centrality.

¹³ The average distance is the mean distance in terms of number of actors between any two actors in a component.



Notes: Actors located within the region (headquarter or subsidiary) are marked in red, external actors are in black. Squares indicate a private actor, whereas public research organizations are circles. The size of a node is proportional to the number of patents filed.

Figure 2: Main components of regional networks

5.3 Internal versus external relations

According to the RIS approach, the functioning of a regional innovation system depends on the interaction within the region *and* on the connections of regional actors to the 'outer world' of external knowledge sources (Bathelt et al., 2004; Graf, 2010). We use a number of different measures for

analyzing the relative importance of extra-local linkages (table 2). Since the regional networks are based on patents with at least one inventor located in the respective region, applicants might be from different locations. This can result from commuting inventors, from inventors working for firms that have their headquarters in a different region, or from co-applications of actors from distinct localities. Analyzing the number of patents by location of the patent-applicant, we can see that between two-thirds and three-quarters of all patents are from applicants located in the same region as one of the inventors with the highest share in Jena and the lowest share in Aachen. Counting only actors, not patents, the share of locals is lower in all regions, which is not surprising since we do account for all patents by locals, but only for those patents by external actors that are invented in collaboration with locals.

A rather interesting observation from both measures (patents and applicants) is the different degree of integration of the regions into their surrounding space. The two West German regions show a much larger share of linkages to actors located within the same Federal State, indicating a considerably higher level of interaction with neighboring regions than their East German counterparts which appear to be more isolated within their surrounding spatial environment. The two West German regions also seem to be better integrated into international knowledge flows, having much higher shares of actors involved which are located abroad. Having classified actors as internal or external, we can proceed to analyze the relations between actors according to their location. Internal linkages are linkages between actors that are both located within the region. External linkages are those between an internal and an external actor.¹⁴ The outward orientation as measured by the share of external relationships is highest in Karlsruhe

¹⁴ Linkages between external actors are not considered here as they have little to do with the regional network. They are, however, included in the network and affect the network statistics.

and lowest in Aachen, which is rather surprising given the large share of external actors in the Aachen network.¹⁵

Analyzing the number of external linkages of local actors gives a first impression of a region's integration into interregional knowledge flows. A large number of interregional linkages is, however, not sufficient for a system to effectively integrate external knowledge because it does not say anything about how this knowledge is disseminated in the region.¹⁶ Therefore, we assume a more micro-perspective and try to identify those actors who have the role of a gatekeeper for the RIS by absorbing external knowledge and passing it on to local actors.

5.4 Gatekeeper

'Gatekeepers,' i.e. actors who are well integrated into global knowledge flows as well as connected to regional actors, play a key role in the connection of RIS to the 'outer world' (Graf, 2010; Giuliani, 2005; Giuliani and Bell, 2005). Gatekeepers serve two functions for the regional innovation system: external knowledge sourcing and the diffusion of the knowledge within the local system, thereby acting as brokers of knowledge (Giuliani, 2005; Wink, 2008).

In order to identify regional gatekeepers, we plot the actors of each network according to the number of their internal and external connections (Figure 3). The scaling of the four figures is identical in order to make them comparable. Private actors (firms and individuals) are represented by squares; public research institutes and universities are shown as circles. The size of the symbols corresponds to the number of patent applications

¹⁵ The results for actors in the same Federal State may be distorted by the fact that the two East German States Saxony (Dresden) and Thuringia (Jena) are much smaller than Baden-Württemberg (Karlsruhe) and North-Rhine-Westphalia (Aachen) in terms of inhabitants and economic activity so that opportunities to relate to other actors in the same State are smaller in the East.

¹⁶ It might well be the case that some actors hold the bulk of external relations but are not sufficiently integrated into the RIS to transfer the external knowledge to other actors of the system.

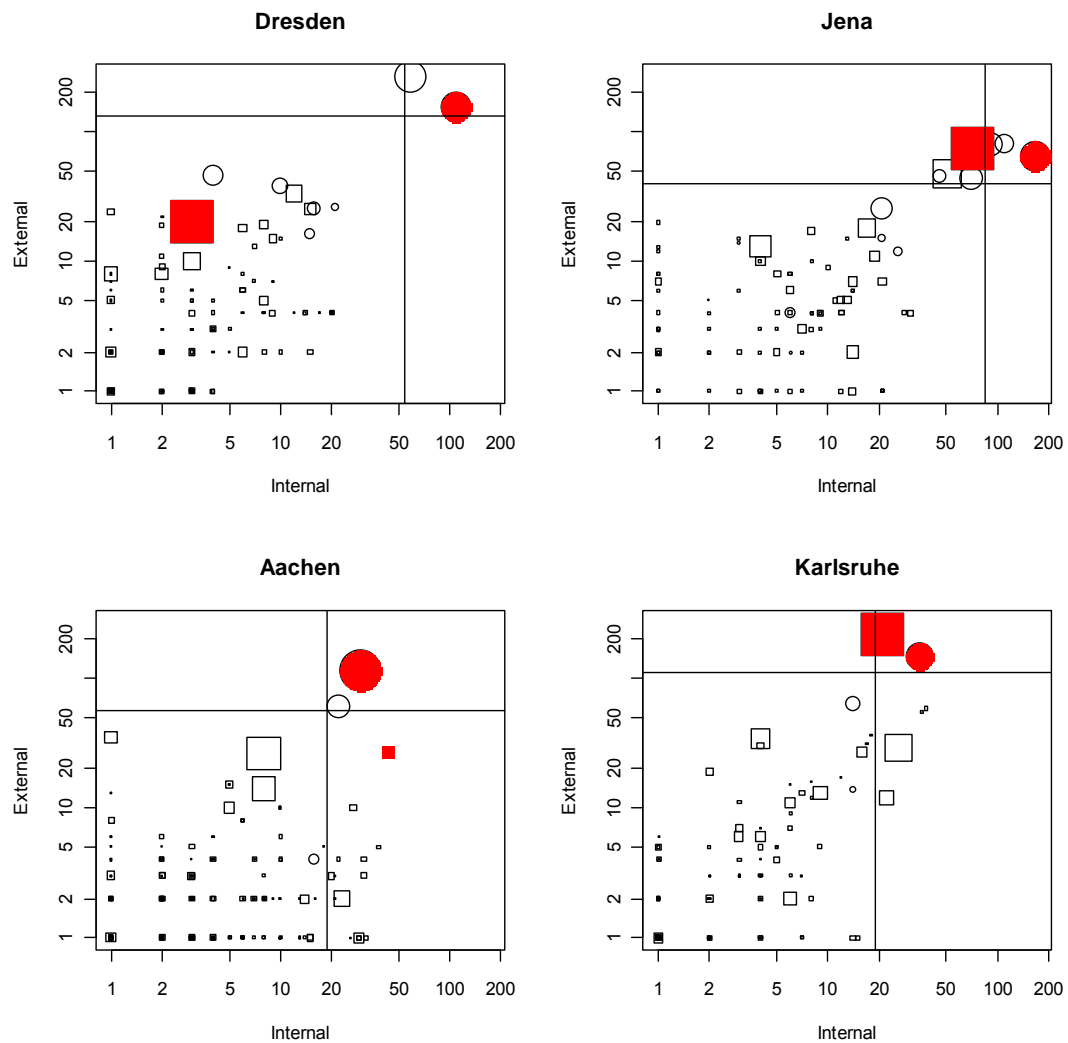


Figure 3: Gatekeepers in the regional networks of inventors

submitted by the respective actor. For most actors, internal and external contacts seem to go hand in hand but with different intensities. Actors in Jena appear more inward oriented than those in Dresden, Aachen, and especially in Karlsruhe. Calculating a gatekeeper index defined as a brokering position between internal and external actors (Gould and Fernandez, 1989) for the regional actors, we find a strong concentration of gatekeeping activity on some few actors (see Table A1 in the Appendix). For example, in Dresden the two actors with the highest numbers of relationships, the Technical University of Dresden and the Institutes of the Fraunhofer Society, score thirty and ten times higher than the third actor in

the list. In Karlsruhe the top gatekeeper (Forschungszentrum Karlsruhe) receives a score three times higher than that of the runner-up (Bosch) and ten times that of the local university (Technical University of Karlsruhe). In Aachen, the same distributional characteristics apply but on a lower level, while in Jena the gatekeeper function seems to be served by various actors.

It is a common feature of all regions that the local university and large research institutes, such as Fraunhofer Institutes, are top ranked according to the gatekeeper index (Table A1 in the Appendix). In Jena and in Karlsruhe private firms such as Carl-Zeiss in Jena and Bosch in Karlsruhe also assume a pronounced role as a gatekeeper.

5.5 Dynamic perspectives

The analysis in the previous sections was performed for a period of seven years. Taking such a long time period has the advantage that the structures of the networks are well visible. A disadvantage is, however, that changes of this structure over time cannot be analyzed. In order to investigate such changes over time we divide the observation period into three overlapping sub-periods, 1995-97, 1997-99, and 1999-2001. Networks constructed for shorter time periods tend to be much smaller than networks for longer time periods because of smaller numbers of patents and respective links.

Table A2 in the Appendix presents network statistics for the four regions in the sub-periods. Figure 4 shows the development of the structure of components. Selected network indicators are visualized in Figure 5. First of all, we notice that all networks increase in size and with regard to the number of actors in the largest component. This increase is not only in absolute terms but also with regard to the share of actors within the main component. At the same time, the share of isolates is decreasing, which is in line with the general tendency in science to increasing collaboration and larger teams (Wuchty et al. 2007). Differences between the regions arise with regard to the development of the average number of links per actor

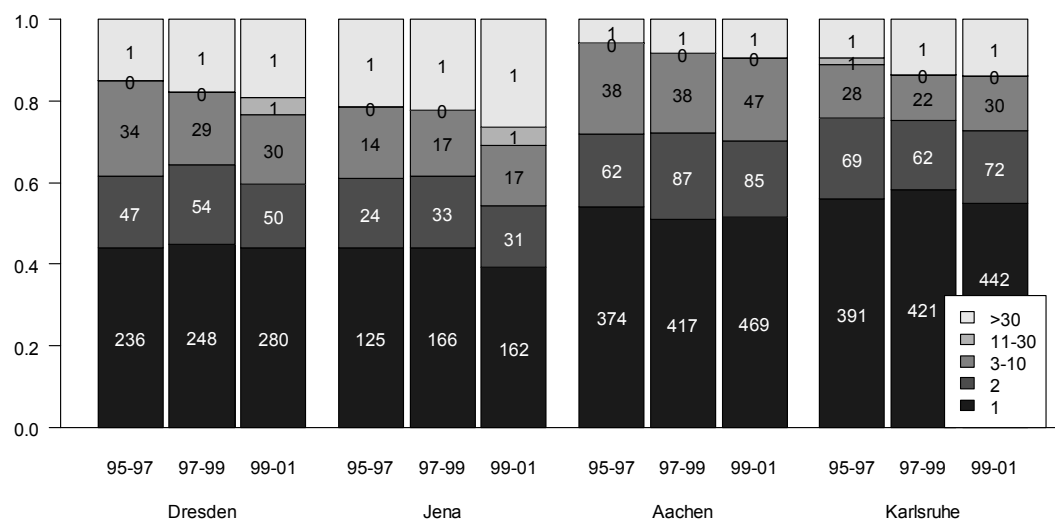


Figure 4: Component distribution in the four networks in three sub-periods

(mean degree) and the level of network centralization. While there is a sharp increase of the mean degree in Jena and to a lesser extent in Dresden, the values for the two West German regions, Aachen and Karlsruhe, remain more or less constant. Both East German regions also show a strong tendency towards increasing centralization of the network, which is far less pronounced in Aachen and in Karlsruhe. Jena is the only case-study region where the average distance within the main component is decreasing, indicating an increasing degree of integration of this part of the network. While no clear trend in this respect can be found for Dresden and Aachen, we see an increase of the average distance within the main component of the Karlsruhe region indicating disintegration.

Examining the numbers of relations to external actors, we find a considerable increase in all four regions (Figure 6). The highest level of dynamics in this respect can be found in the two East German regions: In Jena, the number of external relations almost doubled from 520 to 956 and in Dresden it increased by about 50 percent while the increase in Aachen and

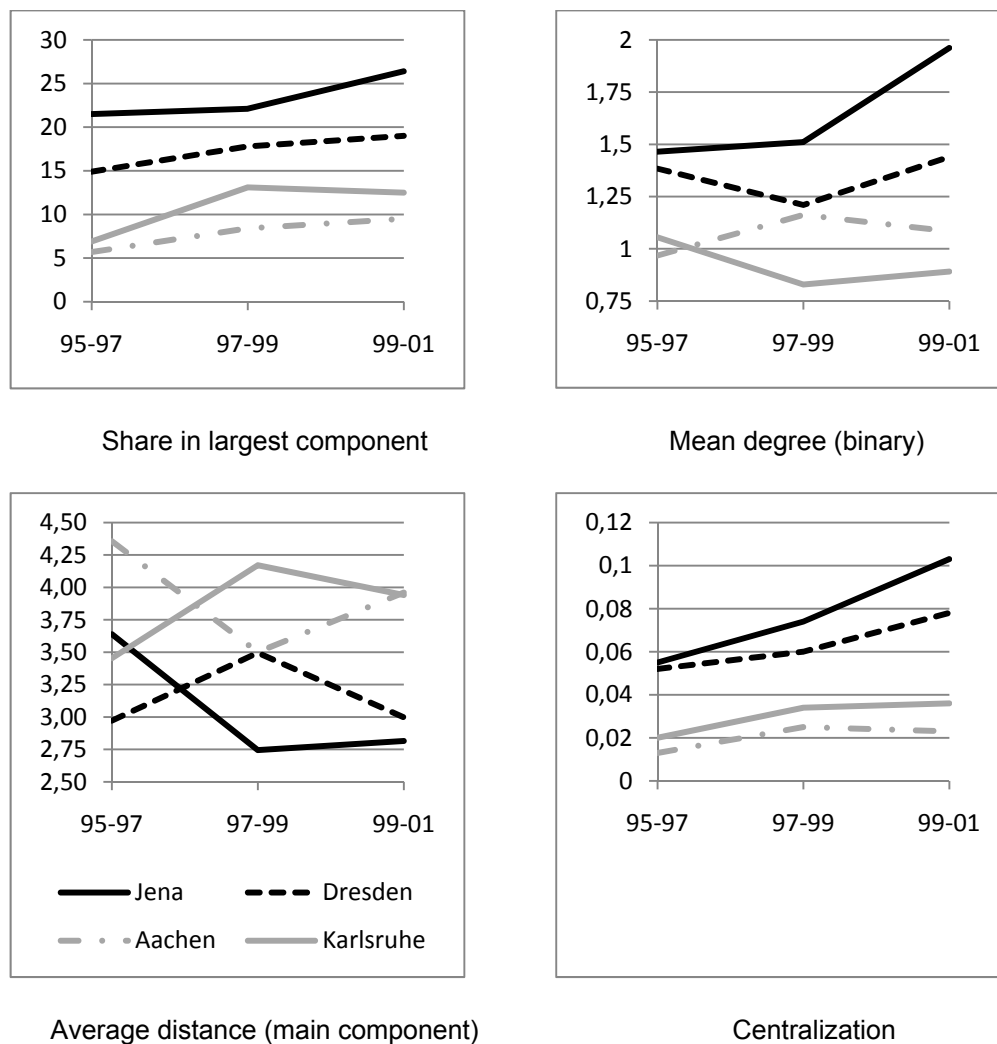


Figure 5: Dynamics of the regional networks

Karlsruhe is about 25 percent. The development of the share of external relations indicates the most pronounced reorientation in Dresden, where the share of external relations rose from 60 percent in the mid 1990s to 75 percent by the turn of the millennium. While there is a slight decrease in the share of external relations in Jena, we find a small increase in Aachen and in Karlsruhe.

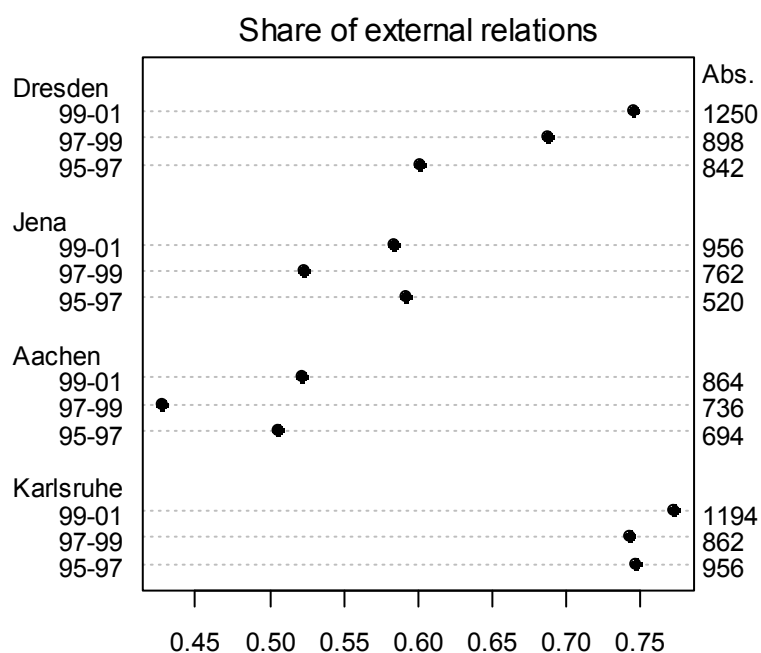


Figure 6: Development of external orientation

6. The subsequent performance of the RIS

It is quite plausible to assume that main effects of the quality of an RIS on its performance do not become immediately visible but occur with a considerable time-lag. It is, therefore, of interest to compare the performance of the four RIS under inspection in the subsequent period. We have already shown that in the period for which we have analyzed the regional innovation networks, the years 1995-2001, the two East German RIS had a much lower efficiency than their West German counterparts (see table 1 based on Fritsch and Slavtchev, 2008). In terms of patents of private firms per 10,000 employees or per 1,000 R&D employees, both East German regions did not reach much more than about half of the values of Aachen and Karlsruhe (table 4). Between this first and the subsequent period 2002-2005, we find much higher growth rates of the number of patents per employee or per R&D employee in the two East German regions, indicating a considerable degree of convergence in the levels of regional patent productivity. Notwithstanding these relatively high growth rates, the two East German regions had, however, in many respects not reached the levels of the West German

regions. An exemption is the number of patents of private firms per 1,000 employees, where Dresden had reached the level of the Aachen region in the 2002-2005 period.

Table 3: Indicators for the development of patent productivity in the four RIS under study

	<i>East Germany</i>		<i>West Germany</i>	
	<i>Dresden</i>	<i>Jena</i>	<i>Aachen</i>	<i>Karlsruhe</i>
Patents of private firms per 1,000 employees 1995-2001	0.77	0.58	1.37	1.44
Patents of private firms per 1,000 employees 2002-2005	1.47	0.87	1.48	1.87
<i>Change (%)</i>	<i>90.91</i>	<i>50.0</i>	<i>8.03</i>	<i>29.86</i>
Patents of private firms per 1,000 R&D employees 1995-2001	21.63	22.86	46.11	38.92
Patents of private firms per 1,000 R&D employees 2002-2005	33.85	32.49	45.76	44.61
<i>Change (%)</i>	<i>56.50</i>	<i>42.13</i>	<i>-0.07</i>	<i>14.62</i>

It would be well in line with the systemic view on innovation processes to assume that at least a part of the relatively high growth rates of patent productivity in the two East German RIS during the 2002-2005 period resulted from the rather advantageous characteristics of their network structure. Even if we cannot exclude that other factors may also have played an important role in this respect, the characteristics of the two East German RIS that we have found suggest further strong improvements in the performance of the two East German RIS.

7. Discussion

Much to our surprise, we found that the two leading RIS in the eastern part of Germany showed a considerably larger degree of interaction than two roughly comparable systems in West Germany, which are clearly more efficient in terms of innovation and patenting. These differences between the case-study regions with regard to interaction seemed to be even increasing, not decreasing over the period of analysis. At least at first sight this finding seems to contradict the innovation systems approach which stresses the interactive nature of innovation processes. There are at least two factors that may explain this astonishing result. A first explanation for the relatively poor performance of the East German RIS is the ongoing transformation of the East German economy during the period of analysis. Obviously, innovation processes in Dresden and Jena have – to a considerable degree – been hampered by economic problems and the resulting re-organization of the East German economy. This clearly indicates that more general conditions that are not specific to a certain region can play a considerable role in the performance of RIS.

A second explanation could be different degrees of embeddedness of the RIS in their proximate geographic environment. While the two East German RIS under inspection, Dresden and particularly Jena, represented “cathedrals in the desert,” the two RIS in the West, Aachen and Karlsruhe, were much better linked to their surrounding spatial environment and have a higher share of relationships to actors located abroad. If the links to other regions in the vicinity should have a significant effect on the performance differences that we observed between the RIS in East and West Germany, this would clearly suggest that the larger regional environment plays a considerable role. We conclude that focusing on a single region without accounting for the general economic environment and for innovation activities in the adjacent regions is not sufficient for explaining the performance of RIS. There can be no doubt that regions *do* differ with regard to their innovation performance and that regional conditions play a rather important role in explaining such differences, but this insight should not lead

to negligence of the effect that the wider spatial environment, particularly the national innovation system in which the regions are embedded in, has on their performance! This is particularly relevant for a comparison of regions located in different countries.

As far as innovation activities benefit from cooperative links, division of innovative labor and networking, the two East German regions in our sample are on the right track and have good prospects to perform equally well or even better than their West German counterparts in the future. This can be particularly expected after the phasing-out of the East German transformation process. Therefore, we expect that the two East German case-study regions in our sample, Dresden and Jena, will catch up to their West German counterparts and maybe outperform the two West German regions some day. Our analyses also show, however, that such developmental processes take considerable periods of time, often many decades, until the effect of conducive regional conditions has fully unfolded.

References

- Albach H (1994) *The Transformation of Firms and Markets: A Network Approach to Economic Transformation Processes in East Germany*. Almqvist & Wiksell, Stockholm.
- Almeida P, Kogut B (1999) Localization of knowledge and the mobility of engineers in regional networks, *Management Science* 45: 905-917.
- Asheim B, Gertler M (2006) Regional Innovation systems and the Geographical Foundations of Innovation. In: Fagerberg J, Mowery DC, Nelson RR (eds) *The Oxford Handbook of Innovation*, Oxford University Press, Oxford.
- Bathelt H, Malmberg A, Maskell P (2004) Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation, *Progress in Human Geography* 28: 31–56.
- Boschma R (2005) Proximity and innovation: A critical assessment. *Regional Studies* 39: 61-74.
- Breschi S, Lissoni F (2009) Mobility of skilled workers and co-invention networks: An anatomy of localized knowledge flows. *Journal of Economic Geography* 9: 439-468.
- Brezinski H, Fritsch M (1995) Transformation: The Shocking German Way. *Moet-Most* 5 (4): 1-25.
- Cantner U, Graf H (2006) The network of innovators in Jena: An application of Social Network Analysis. *Research Policy* 35: 463-480.
- Capello R, Faggian A (2005) Collective learning and relational capital in local innovation processes. *Regional Studies* 39: 75-87.
- Cooke P (1998) Introduction: Origins of the concept. In Braczyk HJ, Cooke P, Heidenreich M (eds) *Regional innovation systems: The role of governances in a globalized world*. UCL Press, London, pp. 2-25.
- Dosi G, Llerena P, Labini MS (2006) The relationships between science, technologies and their industrial exploitation: An illustration through the myths and realities of the so-called 'European Paradox'. *Research Policy* 35, 1450–1464.
- Edquist C (1997) Systems of innovation approaches – Their emergence and characteristics. In: Edquist C (ed) *Systems of innovation: Technologies, institutions and organizations*, Pinter, London, pp. 1-35.
- Fritsch M, Werker C (1999) Systems of Innovation in Transition. In: Fritsch M, Brezinski H (eds) *Innovation and Technological Change in Eastern Europe – Pathways to Industrial Recovery*. Elgar, Cheltenham, pp 5-22.
- Fritsch M, Schwirten C (1999) Enterprise-university co-operation and the role of public research institutions in regional innovation systems. *Industry and Innovation* 6: 69-83.

- Fritsch M (2004) Entrepreneurship, Entry and Performance of New Businesses Compared in two Growth Regimes: East and West Germany. *Journal of Evolutionary Economics* 14: 525-542.
- Fritsch M, Slavtchev V (2008) Determinants of the Efficiency of Regional Innovation Systems. *Regional Studies*, DOI: 10.1080/00343400802251494.
- Fritsch M, Slavtchev V (2010) How Does Industry Specialization affect the Efficiency of Regional Innovation Systems? *Annals of Regional Science* 45: 87-108.
- Giuliani E (2005): Cluster Absorptive Capacity: Why do Some Clusters Forge Ahead and Others Lag Behind? *European Urban and Regional Studies* 12: 269-288.
- Giuliani E, Bell M (2005) The micro-determinants of meso-level learning and innovation: Evidence from a Chilean wine cluster. *Research Policy* 34: 47-68.
- Gould RV, Fernandez RM (1989) Structures of Mediation: A Formal Approach to Brokerage in Transaction Networks. *Sociological Methodology* 19: 89-126.
- Graf H (2006): *Networks in the Innovation Process – Local and Regional Interactions*. Elgar, Cheltenham.
- Graf H, Henning T (2009) Public Research in Regional Networks of Innovators: A Comparative Study of Four East German Regions. *Regional Studies* 43: 1349–1368.
- Graf H (2010) Gatekeepers in Regional Networks of Innovators. *Cambridge Journal of Economics*, DOI:10.1093/cje/beq001.
- Hall PA, Soskice, D (2001) *Varieties of Capitalism: The Institutional Foundations of Comparative Advantage*. Oxford University Press, Oxford.
- Hanson P, Pavitt K (1987) *The Comparative Economics of Research Development and Innovation in East and West: A Survey*. Harwood, London.
- Jaffe AB, Trajtenberg M and Henderson R. (1993) Geographic localization of knowledge spillovers as evidenced by patent citations. *Quarterly Journal of Economics* 108: 577-598.
- Kogut B, Zander UB (2000) Did socialism fail to innovate? - A natural experiment of the two Zeiss companies. *American Sociological Review* 65: 169-190.
- Kronthaler F (2005) Economic capability of East German regions: results of a cluster analysis. *Regional Studies* 39: 739-750.
- Lundvall BÅ (ed) (1992) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. Pinter Publisher, London.

- Lundvall BÅ, Johnson B (1994) The learning economy, *Journal of Industry Studies* 1: 23-42.
- Malmberg A, Maskell P (2006) Localized learning revisited. *Growth and Change* 37: 1-18.
- Nelson RR (ed) (1993) *National Innovation Systems: A Comparative Analysis*. Oxford University Press, New York.
- Radiosevic S (1999) Divergence of convergence in research and development and innovation between 'East' and 'West'. In: Fritsch M, Brezinski H (eds) *Innovation and Technological Change in Eastern Europe – Pathways to Industrial Recovery*. Elgar, Cheltenham, oo 23-49.
- Wink R (2008) Gatekeepers and Proximity in Science-driven Sectors in Europe and Asia: The Case of Human Embryonic Stem Cell Research. *Regional Studies* 42: 777-791.
- Wuchty S, Jones BF, Uzzi B (2007) The Increasing Dominance of Teams in Production of Knowledge. *Science* 316 (5827): 1036-1039.

Appendix

Table A1: Gatekeepers according to brokerage score (Top 15)

<i>Dresden</i>		<i>Jena</i>		<i>Aachen</i>		<i>Karlsruhe</i>	
<i>Actor</i>	<i>Index</i>	<i>Actor</i>	<i>Index</i>	<i>Actor</i>	<i>Index</i>	<i>Actor</i>	<i>Index</i>
Technical University Dresden	2,884	Friedrich Schiller University Jena	1,580	FZ Juelich	290	FZ Karlsruhe	1,042
Fraunhofer Dresden	1,001	IPHT e.V.	598	Fraunhofer Aachen	221	Bosch, Karlsruhe	329
Siemens AG Dresden	104	Carl Zeiss Jena GmbH	515	RWTH Aachen	57	Universitaet Karlsruhe (TH)	100
Institut für Fest-koerper- und Werkstofforschung	81	Hans-Knoell-Institut	481	Gartzen, Johannes	35	Fraunhofer, Karlsruhe	94
FZ Rossendorf	80	Jenoptik	477	FEV Motorenteknik	23	LuK	52
HTW Dresden	75	Fraunhofer Jena	255	Philips, Aachen	21	Bruker Analytik GmbH	32
Institut für Luft- und Kaelte-technik gGmbH	56	Hermesdorfer Institut für Technische Keramik e.V.	184	Heil, Guenter	16	Siemens AG, Karlsruhe	22
Institut für Polymerforschung Dresden e.V.	38	Institut für molekulare Biotechnologie	62	Hoecker, Hartwig	13	FlowNet Management & Consult GmbH	21
Infineon AG Dresden	35	Thüringer Institut für Textil- und Kunststoff-Forschung e.V.	50	Sekurit Saint-Gobain	10	BSH GmbH, Bretten	19
VTD Vakuum-technik Dresden GmbH	21	Schneider Laser Technologies AG	41	Guitis, Michael	9	FlowTex Technologie GmbH & Co. KG	18
Feinchemie GmbH	13	Jenapharm GmbH	21	Kraemling, Andreas	7	Becker GmbH	15
Huels Silicone GmbH Nuenchritz	9	Verfahrenstechnisches Institut Saalfeld	21	Scheibenbogen, Markus	7	Daimler-Benz, Rastatt	15
Glatt Systemtechnik GmbH	8	TRIDELTA GmbH	17	Walke, Bernhard	7	Mueller-Glaser, Klaus-D.	15
Hahnewald GmbH	8	Piezsystem Jena GmbH	13	Jet Laser Systeme	6	Seifried, Kai	15
Koenig & Bauer AG Radebeul	8	GESO GmbH	12	Sicowa	6	Stork, Wilhelm	15

Table A2: Development of the regional networks over three sub-periods

	<i>Jena</i>			<i>Dresden</i>			<i>Aachen</i>			<i>Karlsruhe</i>		
	95-97	97-99	99-01	95-97	97-99	99-01	95-97	97-99	99-01	95-97	97-99	99-01
Number of nodes	284	376	413	536	552	636	684	814	904	666	678	752
Number of components	164	217	212	318	332	362	473	540	600	468	473	513
Size of main component	61	83	109	80	98	121	39	68	86	46	89	94
Share of main component (%)	21.5	22.1	26.4	14.9	17.8	19.0	5.7	8.4	9.5	6.9	13.1	12.5
Number of isolates	125	166	162	236	248	280	374	416	468	373	390	414
Share of isolates (%)	44.0	44.1	39.2	44.0	44.9	44.0	54.7	51.1	51.8	56.0	57.5	55.1
Centralization	0.055	0.074	0.103	0.052	0.060	0.078	0.013	0.025	0.023	0.020	0.034	0.036
Density	0.014	0.012	0.012	0.007	0.006	0.006	0.004	0.003	0.003	0.004	0.003	0.003
Density (dichotomized)	0.005	0.004	0.005	0.003	0.002	0.002	0.001	0.001	0.001	0.002	0.001	0.001
Mean degree	3.859	4.346	5.070	3.459	3.094	3.786	2.444	2.663	2.370	2.553	1.926	2.261
Mean degree (dichotomized)	1.465	1.511	1.961	1.384	1.210	1.440	0.968	1.162	1.084	1.055	0.829	0.891
Average distance	3.639	2.745	2.815	2.972	3.496	2.998	4.356	3.500	3.960	3.454	4.171	3.941