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Gatekeepers in Regional Networks of Innovators

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Strong interaction of innovative actors within a local network is commonly said to increase the region-specific knowledge-stock, leading to a comparative advantage. However, it might also lead to a lock-in situation, if local trajectories are directed towards inferior solutions. Accordingly, it is argued that successful clusters are characterised by the existence of gatekeepers, i.e. actors that generate novelty by drawing on local and external knowledge. We study the role and characteristics of gatekeepers within regional innovation systems by applying social network analysis based on patent data for four East-German regions. The regional networks appear to be significantly different with respect to the degree of interaction and with respect to their outward orientation. Concerning the characteristics of gatekeepers, we find that absorptive capacity is more important than size. Public research organisations serve the functions of a gatekeeper to a higher degree than private actors.

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Jel codes: O31; Z13; R11

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1 Introduction

The concept of regional innovation systems combines the idea of innovation as a collective process of knowledge transfer between networked actors with the finding that geographical proximity is conducive to the transfer of new knowledge as it facilitates personal relationships. Personal contact in turn helps to develop trust, enables social control and allows for the transfer of tacit knowledge.

The variety and intensity of personal relationships in a vibrant local network can be captured by notion of local 'buzz' (Storper and Venables, 2004; Bathelt et al., 2004). The underlying assumption is that a high degree of innovative buzz

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increases the region-specific knowledge-stock and should – if it is best practice – lead to a comparative advantage with respect to other localities. However, it might also lead to a lock-in situation, if local trajectories are directed towards inferior solutions (Grabher, 1993; Gertler, 1997; Boschma, 2005). Especially highly specialised regions face the risk of such a technological lock-in. While a dense local milieu generally enhances innovative activity it might also create situations where the actors become so narrowly focussed on a particular type of economic activity that a shift towards new developments is impossible (Camagni, 1991; Malmberg and Maskell, 1997). Accordingly, Bathelt et al. (2004) argue that successful clusters are characterised by actors that are aware of these problems and generate novelty by drawing on specific local knowledge, combining it with external knowledge components. In this way, local 'buzz' is linked to global 'pipelines' (Storper and Venables, 2004; Bathelt et al., 2004).

Building on these ideas, we use the term 'gatekeepers' to characterise actors that serve two functions for the regional innovation system: external knowledge sourcing and diffusion within the local system (Allen, 1977; Giuliani, 2005; Giuliani and Bell, 2005; Munari et al., 2005). Within this theoretical framework, we attempt to tackle questions related to the role and characteristics of gatekeepers within regional innovation systems empirically. We employ social network analysis to investigate networks of innovators based on German patent data between 1995 and 2001. The analysis is applied to the networks of four East-German regions, Rostock, Halle, Jena, and Dresden. Linkages, and therefore knowledge transfer, between two innovators (patent applicants) is assumed if they jointly apply for a patent ('co-operation') or if the same inventor worked for both innovators on distinct patents ('scientist mobility') (Cantner and Graf, 2006). Innovators are qualified as external actors if they have applied for at least one patent with an inventor living in the region but are themselves not located in the region.

The paper is organised around the following research questions:

- What is a workable definition of gatekeepers in terms of internal and external linkages and with respect to their position in the local system?
- To what degree do we observe actors which can be characterised as gatekeepers within all regions?
- How can gatekeepers be characterised with respect to size or organisational type (public/private)?
- Do we observe relationships between the openness of the system, internal density and innovative success?

In section 2, we review the literature on the role of extra local linkages in regional innovation systems, present our – pragmatic – definition of gatekeepers, and develop some hypotheses concerning the characteristics of gatekeepers. Section 3 provides information on our methodological approach and data issues. The central part of our paper is section 4, where we analyse the regional networks with respect to their outward orientation and where we characterise the actors in terms of their activity as gatekeepers. To capture changes over time in the regional networks, we take a dynamic view of external relations and gatekeepers in section 5, before we conclude in section 6.

2 Towards a definition of gatekeepers

2.1 External relations in regional innovation systems

Adopting the system of innovation approach as a conceptual framework (Edquist, 1997), we view innovative activity as a collective process characterised by a transfer of knowledge between networked actors. Soon after the systemic view on innovation was established, the phenomenon was put in a regional context (Braczyk et al., 1998; Cooke, 1998), led by empirical evidence that innovative activity is neither uniformly nor randomly distributed across geographical space. The main reasoning is that knowledge, especially if it is partly tacit, can only be transferred via personal contacts and within an atmosphere of trust. This social proximity can more easily be achieved if geographical proximity facilitates face-to-face contacts.

It has to be pointed out though, that there is also the possibility of "too much proximity" (Boschma, 2005). In contrast to a view that only focusses on the benefits of knowledge spillovers within local networks, only recently, several authors have pronounced the importance of interaction with actors external to the local system (Gertler, 1997; Bathelt, 2003; Bathelt et al., 2004). The benefits of a dense local network then have to be seen in light of a fast diffusion of external knowledge within the system and the risks of technological lock-in (Grabher, 1993) by loosing connections to new developments diminish.

To exploit the advantages of proximity while at the same time avoiding the problems of lock-in, innovation systems need an interface between local and global knowledge systems (Kim and von Tunzelmann, 1998). Allen (1977) originally introduced the term "technological gatekeeper" to describe R&D professionals with the intellectual and personal ability to absorb external knowledge and translate it to their internal co-workers. In analogy to the original sense of the term, in an innovation system some distinctive gatekeeper actors, firms or universities, link the system to outside knowledge sources.

In general, this role is assumed to be fulfilled by the large and technologically advanced firms within the local innovation system which have the capacity to scan and exploit external sources and on the other hand the power to push the new knowledge into the local system (Lazerson and Lorenzoni, 1999; Giuliani and Bell, 2005). But the knowledge might also be channelled through multinationals coming from outside the regional system, seeking to exploit special local resources (Giuliani et al., 2005).

2.2 Gatekeepers

As noted above, actors qualify as 'gatekeepers' if they serve two functions for the regional innovation system: external knowledge sourcing and diffusion within the local system (Allen, 1977; Giuliani, 2005; Munari et al., 2005). In terms of network relations this means that a gatekeeper has to interact frequently with partners external to the system and at the same time be integrated within the local system via a sufficient number of internal relations.

In figure 1, we try to categorise actors in terms of internal and external relations. In the bottom left quadrant of the diagram, we expect to see many actors which can be termed as *inactive* as they have only few or no internal as well as external relations to other actors in the process of knowledge generation. Those actors in the bottom right quadrant, which have many linkages to internal actors but are not integrated within the wider technological or national innovation system, can be termed *internally oriented* actors. These actors could be suppliers within a local value chain or public research organisations with a strong commitment to the regional economy like polytechnical universities in Germany often have. Actors in the top left are serving the function of external knowledge sourcing well but rather use it for their own purposes as they are not sufficiently integrated within the local system to let their knowledge diffuse to other local actors. Large multinational firms could serve as the typical case of *externally oriented* actors as they locate in different systems keeping their external linkages but having problems (or no incentives) to interact with local actors. Finally, in the top right we can identify actors which have sufficient internal and external relations to qualify as a *gatekeeper*. Concerning the characteristics that qualify an actor to be a gatekeeper, we develop our hypotheses in the following.

Since the establishment of external linkages is subject to investments in technological and management capabilities and needs time to develop (Markusen, 1996; Lindholm Dahlstrand, 1999), large actors should be better able to serve the function of external knowledge sourcing compared to smaller ones. Regarding the diffusion of external knowledge within the regional network, size seems

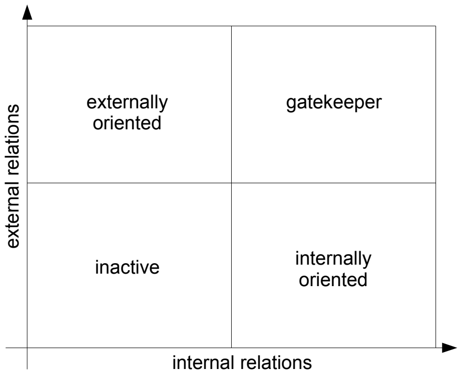


Figure 1: Definition of gatekeepers

also to be favourable as large actors tend to have many linkages within the region. This leads us to our first hypothesis.

Hypothesis 1 *There is a positive correlation between the size of an actor and the extent to which this actor serves the function of a gatekeeper within a regional network.*

Besides the capabilities of managing external relations and being an integrative player in the local network, a sufficient level of absorptive capacity is needed to understand and make use of external knowledge, previously not present in the firm or in the region (Cohen and Levinthal, 1990). At best, absorptive capacity is accompanied by the ability of transforming and processing external knowledge to make it applicable to internal actors (Giuliani and Bell, 2005).

Hypothesis 2 *An actor's level of absorptive capacity positively influences the probability of being a gatekeeper.*

In addition to the capabilities to be a gatekeeper in terms of management capabilities and absorptive capacities, the willingness to share knowledge and to cooperate with other actors is a prerequisite for the diffusion of external knowledge. Since the incentive structure between private and public actors is clearly different (Dasgupta and David, 1994), we assume that public research organisations are more willing to share their knowledge as compared to private firms. Besides this fundamental norm of 'open science' another development leads us to our hypothesis. In becoming more and more entrepreneurial, public research should be increasingly linked to industry in the form of cooperative research but also through start-up activities (Etzkowitz, 1998).

Hypothesis 3 *Public research organisations serve the functions of a gatekeeper to a higher degree than private actors.*

Before we proceed to test these hypotheses in section 4, we explain our methodological approach of social network analysis and the underlying data in the subsequent section.

3 Methodology and Data

Different from other approaches, social network analysis focuses on relations. This is to say, insights are mainly expected from the investigation of the interplay and communication between actors and only to a lesser extent from looking at the isolated actors' characteristics. Consequently, social network analysis is an appropriate methodology for identifying and studying gatekeepers as gatekeepers are themselves defined by their special ability to build and maintain relations between internal and external actors.

To make use of the methodology of social network analysis, data have to be relational, too. Patent data meet this requirement: They provide information about the persons involved in the underlying innovative activity and can therefore be used to derive relations between these persons. As patents are created through a formally prescribed procedure the resulting databases are publicly accessible, consistent and complete in the sense that any innovative effort that was judged to be worth a patent application is included. Of course, there are other mechanisms of appropriating the returns to innovative activities with secrecy being one of the most important ones (Cohen et al., 2000). The propensity to patent also varies substantially between sectors. Patenting is more important in manufacturing than in services (Mairesse and Mohnen, 2003) and estimates by Arundel and Kabla (1998) suggest that in most sectors less than 50% of the innovations are patented. With these peculiarities of our data in mind, we investigate networks of innovators based on German patent applications at the German Patent Office which were disclosed from 1995 to 2001.

Methodically, one has the choice to relate patent applicants or patent inventors. The former, in most cases private firms or public research bodies, hold the property rights to economically exploit the invention, should it become a successful innovation. We call them (potential) innovators. The latter are the individuals who actually performed the research leading to the patent application. Knowledge is assumed to flow between people who know each other from joint research projects rather than between the innovators. Therefore, it is common to link the inventors of patents directly (Balconi et al., 2004; Fleming et al., 2004, 2006; Singh, 2005), but these connections can also be used to identify channels of knowledge transmission between the innovators in linking them via common inventors (Breschi and Lissoni, 2003; Cantner and Graf, 2006; Graf and Henning, 2006). While the function of a gatekeeper could in principle be served by individuals as well as by organisations, we find it more appropriate to pursue the latter approach and study organisations as they are are less mobile than individuals and are therefore more easily identified as local or external actors.

The basic assumption within this methodology is that two innovators are related if at least one inventor has developed a patent for both innovators. In practical terms this mean that a relation is established between A and B if we find an inventor on a patent by A and on a patent by B. There are two possibilities of how this might appear.

1. The innovators are joint assignees of the same patent. In this case we assume a previous research *co-operation*.
2. The same inventor is named on two distinct patents assigned by different innovators. In this case we assume *mobility* of the inventor between the innovators.[1]

We interpret the linkages (inventors) between the nodes (innovators) as possible channels of knowledge transmission (Fleming et al., 2006). In the case of co-operations, we do not know to which of the innovators the members of the inventing team belong, but we do know that all of them know someone from all co-applicants. As such, a co-operation produces a link between the co-applicants with a weight, corresponding to the number members of the inventing team. In the case of mobility, the interpretation is less trivial. First, it might be interpreted as a directed flow of knowledge (incorporated in the inventor who moves) from one innovator to the other. Second, mobility can also be interpreted as a (possible) channel of knowledge transmission as the linking inventors know past and present collaborators from both innovators. Having discussed the commonalities and differences between the two cases, we continue to analyse co-operation and mobility separately, but combine them to the network of personal relationships whenever it seems appropriate.

To perform a regional analysis, we also have to discuss the geographical assignment of patent applications. If the goal is to sketch inventive activity within the region, the first best solution is to use the address of the research lab where the R&D was performed. As patent statistics do not provide this information, the second best solution is to use the applicant's address assuming that the firm or university holding the patent should have their lab on site. Unfortunately, we face the problem that several, especially large, organisations often have many and regionally dispersed subsidiaries, but apply for patents centrally, on behalf

[1]Mobility, in this definition, includes also cases of inventors contracted by different innovators without actually being their employee, e.g., consulting inventors.

of the headquarter instead of the subsidiary where the research actually was conducted. The common solution to this difficulty is to refer to the inventors' residence instead of the innovator's, following the assumption that people normally live not far away from the place where they work. Consequently, we base the regional networks on all patent applications with at least one inventor residing in the respective region.

The analysis is applied to the networks of four East-German regions, Rostock, Halle, Jena, and Dresden. The size of the regions differs between about 400,000 inhabitants (Rostock) an 1,000,000 inhabitants (Dresden). The geographical boundaries of the regions are defined as German planning regions ("Raumordnungsregionen"). Designed to represent socio-economic entities, they normally comprise several districts ("Kreise", i.e., German NUTS3 level units), namely a core city and its surrounding area. Each region exhibits a research university and a number of public research organisations such as institutes of the Fraunhofer society, the Leibniz society, and the Max-Planck society. All regions have considerable tradition in manufacturing industries: electronics and mechanical engineering in Dresden, optics and precision mechanics in Jena, chemicals in Halle, shipbuilding and mechanical engineering in Rostock. Two different types of regions arise ex ante as Jena and Dresden on the one hand are often labelled as East-German boom regions having successfully managed economic transformation after German reunification, whereas Rostock and Halle on the other hand are said to lag behind.

The last step is to discriminate between internal and external innovators. Innovators are qualified as external actors if they have applied for at least one patent with an inventor living in the region (otherwise the patent would not have been included into the regional sample in the first step), but are themselves not located in the region according to their address. To correct for the misleading effects of headquarter patenting mentioned above, the list of these (presumed) external actors was then carefully checked to allocate them correctly, whenever they could be identified as a local (and therefore internal) subsidiary (see appendix A for further details of this procedure).

4 Static view

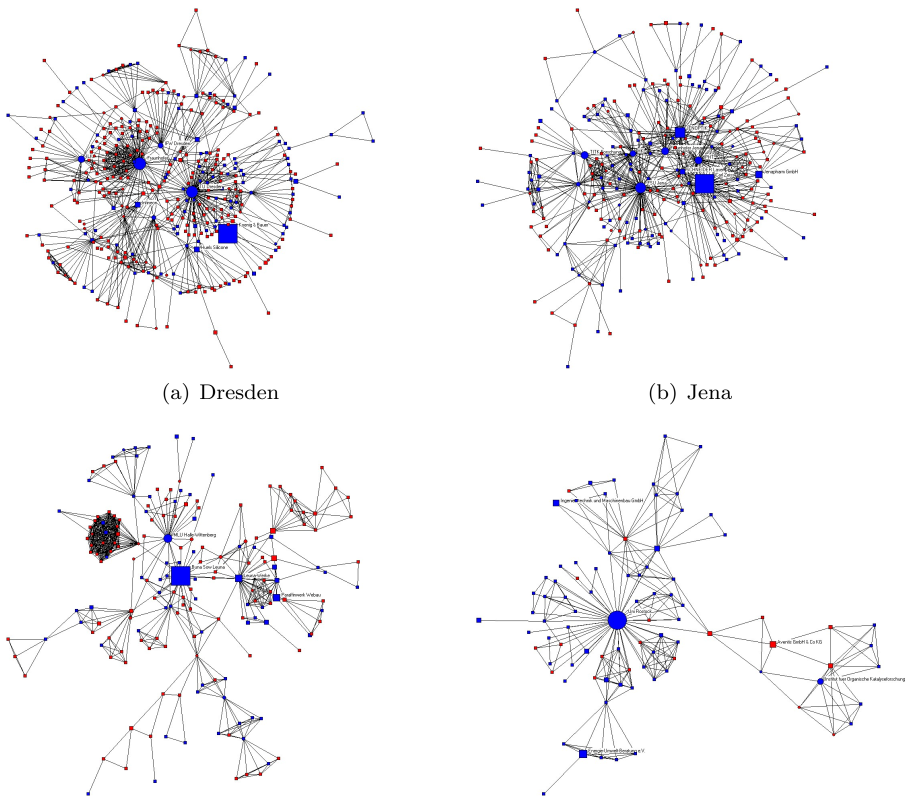
As has been indicated above, we perform our analysis in this section taking a static view while a dynamic view is taken in the following section. Static means that we do not discriminate between relations at the beginning of the period, i.e. 1995 and the end in 2001. In the case of scientist mobility, this might lead to linkages between two innovators where the common inventor has worked for one innovator in 1995 and another one in 2001, while he might have worked for a third innovator in between. Therefore, the intrinsic assumption here is that relationships between actors are rather long lasting and persistent.

4.1 Data description

To provide a first, rough impression of the four regional networks, we present a visualisation of the main components in figure 2. We distinguish between public organisations (circles) and private actors (squares), which can be either firms or individuals, and between actors located within the region in focus (blue) and external ones (red). The size of the nodes is proportional to the number of patents filed by each actor. As we analysed the general structure of these networks in depth in Graf and Henning (2006), we will just comment on a few characteristic features. The networks (i.e. the main components) of Dresden and Jena show a higher density and less cutpoints than the ones in Halle and Rostock. We can observe a multitude of central actors (public and private) in Jena and two dominating, public actors in Dresden, whereas in Halle and Rostock there is one dominating, central actor. In Halle this is a chemical firm and in Rostock it is the university.

To analyse the outward orientation of the four networks, we summarise the data with respect to patents, actors and relations in table 1. We distinguish the patents according to the location of the innovator (the patent applicant) in rows two to five. Rostock is the region with the highest share of patents held by internal actors (78%), while in Halle only 58% are held by locals. Jena and Rostock differ from the other two as the share of patents from the other parts of their Bundesland is significantly lower, which means that external relations are mostly to the rest of Germany. The picture changes slightly when we take a look at the location of actors that are members of the network. The share of internal actors is generally lower then the share of local patents, except for Rostock where there is almost no difference. This is not really surprising as by our procedure, we capture all patents by local actors, but only the ones of external actors where there is some relation (via a local inventor) to the respective region. In Halle there are even less actors from within the region than external ones. For the interested reader, the spatial distribution of network members is depicted in the four maps in figure 7 in appendix B.

In the description of relations constituting the networks, we distinguish between the type of relations, co-operations, mobility, and total relations, and between the involved actors in these relations, between internal actors (internal relations), between external actors, and between internal and external actors (external relations). Relations between external actors are not really of interest, but they are documented to reach 100% of all relations. It leads to the



(a) Dresden (b) Jena

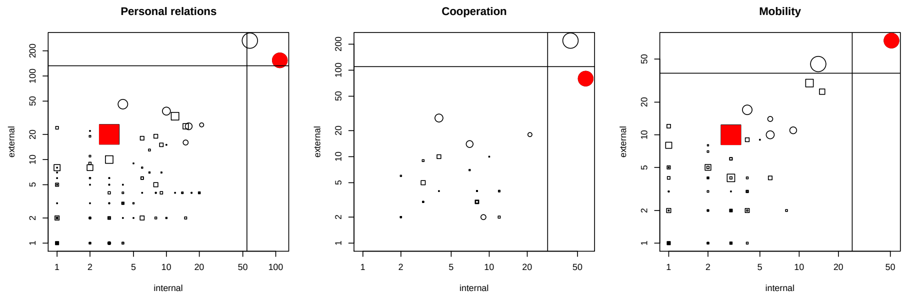
(c) Halle (d) Rostock

Notes: circles indicate public organisations, squares private ones; internal actors are blue and external ones red; node size is proportional to the number of filed patents

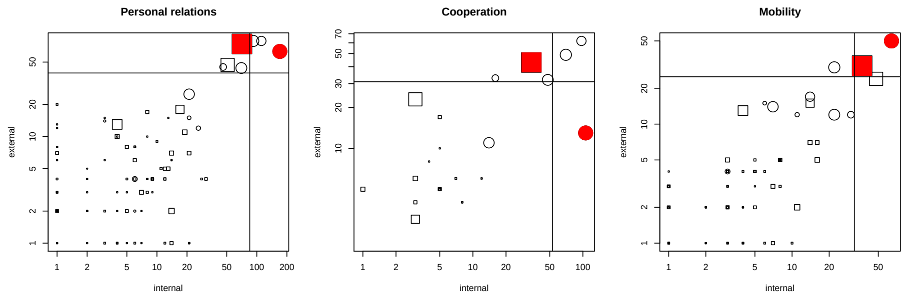
Figure 2: Main components of the regional networks

interesting result though, that the shares of internal, as well as external relations in Jena are higher than the ones in Halle. Overall, we find Rostock to be the most inward oriented network and Dresden and Halle to be the most outward oriented networks with more than twice as many external relations than internal ones. Jena lies in between with a high share of external relations but a dense internal network.

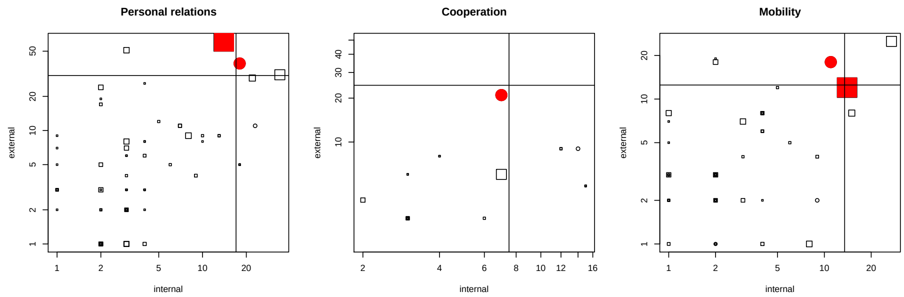
With this first impression of the four regions in mind, we now turn our view to the actors that are responsible for these external relations and the dissemination of external knowledge within the system. Will we find actors that can be called gatekeepers in all regions, or is it rather that some actors are more outward focussed in their relations and others that are more inward oriented?



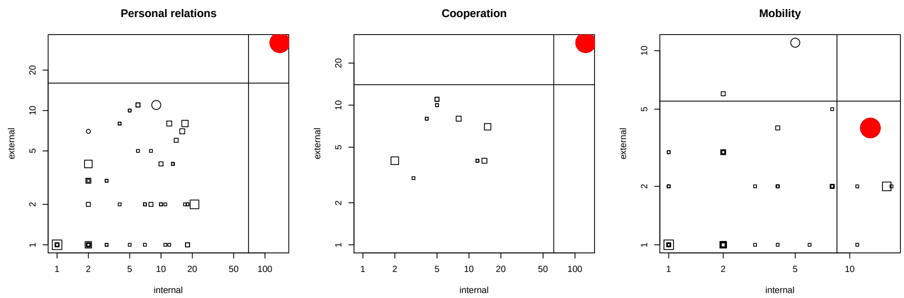
(a) Dresden



(b) Jena



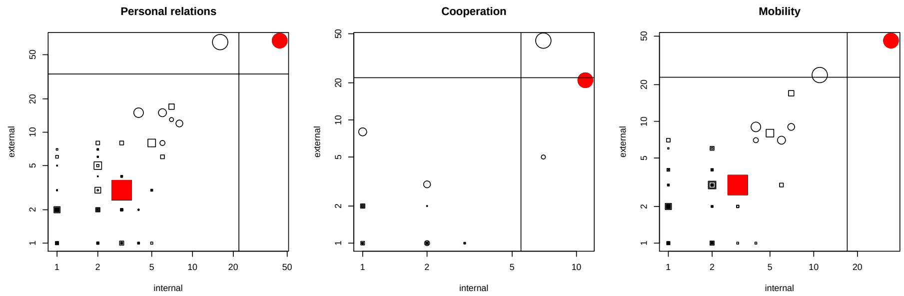
(c) Halle



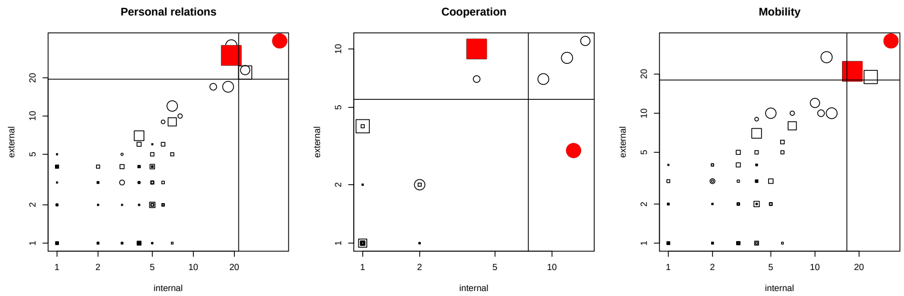
(d) Rostock

Note: only internal actors

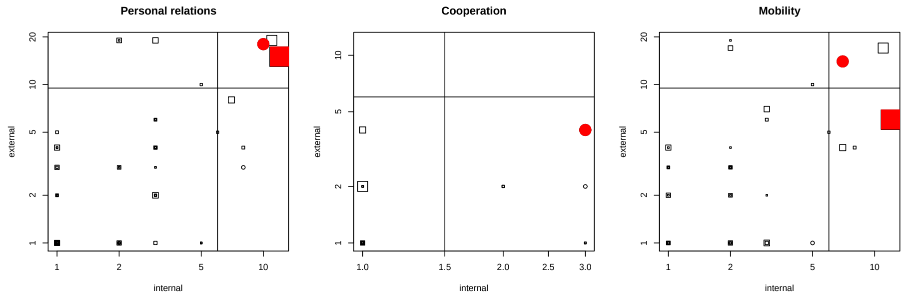
Figure 3: Identification of gatekeepers via number of relations (logscale)



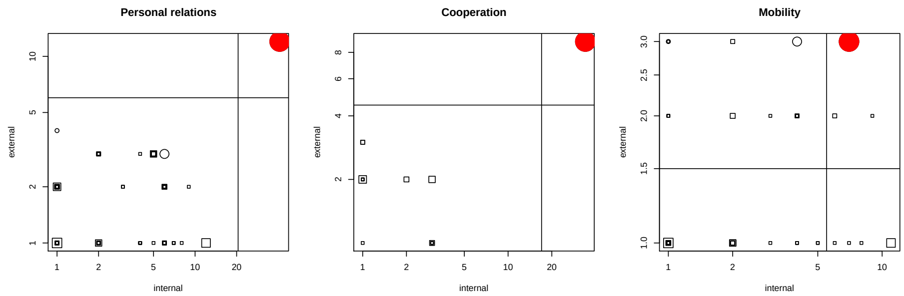
(a) Dresden



(b) Jena



(c) Halle



(d) Rostock

Note: only internal actors

Figure 4: Identification of gatekeepers via number of partners (logscale)

Table 1: Data description: patents, actors, and relations

	Dresden	Jena	Halle	Rostock
Patents	3720	2094	1385	618
Region (ROR)	70.3%	75.0%	58.4%	78.2%
Bundesland	7.2%	3.2%	6.9%	2.9%
Germany	21.4%	21.2%	33.9%	17.3%
Abroad	1.0%	0.7%	0.8%	1.6%
Actors	1158	694	546	345
ROR	51.8%	56.2%	48.2%	73.6%
Bundesland	11.1%	6.3%	7.3%	4.3%
Germany	35.1%	35.9%	42.9%	19.7%
Abroad	2.0%	1.6%	1.6%	2.3%
Total relations	5870	4430	3278	1690
within internal actors	21.5%	34.6%	17.9%	60.1%
within external actors	30.1%	18.4%	41.1%	7.8%
between in- and external actors	48.4%	47.0%	40.9%	32.1%
Relations through co-operation	3498	2664	1730	1150
within internal actors	22.8%	32.9%	19.3%	62.6%
within external actors	26.5%	21.2%	36.2%	7.1%
between in- and external actors	50.7%	45.9%	44.5%	30.3%
Relations through mobility	2372	1766	1548	540
within internal actors	19.7%	37.1%	16.4%	54.8%
within external actors	35.2%	14.3%	46.6%	9.3%
between in- and external actors	45.0%	48.6%	37.0%	35.9%

4.2 Existence of gatekeepers

We now try to apply our theoretical considerations of section 2 concerning the definition of gatekeepers to the four regions under inspection. As we will see, we stumble over some quite severe problems in deciding which actors to identify as gatekeepers in the real world. Our first step in this direction is to take the 'model' of figure 1 quite literally and plot the number of internal and external relationships of each local actor[2] in the four regions in figures 3(a) and 4(a). The size of the points is proportional to the number of filed patents and as in the network visualisations in figure 2, squares indicate private actors and circles public research organisations. The red circle is the local university and the red square is the largest local firm in terms of patents. The difference between the two figures is in the counting of relations. In figure 3(a), we use the actual number of common inventors between each actor and its related actors, while in figure 4(a), we take a binary version of the adjacency matrix as a basis, which means that we count the number of internal and external actors to which each actor is linked. To distinguish the two, we use the term 'relations' in the first case and 'partners' in the second. The observations are plotted on a logarithmic

[2] Obviously it makes no sense to include actors that are not located in the respective region, as internal and external relations have a reversed interpretation and the focus of the whole study is on the region.

scale as to better better assess the bulk of actors with rather low values in each category of internal and external relations and at the same time to get rid of the actors without internal or external relations. The lines, which are drawn for orientation mainly, indicate the middle between zero and the maximum value we observe in each plot. In doing this, we cannot easily compare actors between regions as the maximum values vastly differ between the regions.

Looking at the first graph in each row, we can identify at least one gatekeeper in all regions. In Dresden the two central actors that we identified in the description of the network above, can now both be classified as gatekeepers. The red circle is the Technical University Dresden and the other gatekeeper is the Fraunhofer-Society with its research institutes. The other actors that have both internal and external relations are far back and would be considered as inactive in accordance with figure 1. Considering the case of Jena, we run into the first problem of our definition of gatekeepers. Blindly applying the rule that we used for drawing the lines ('more than half of the maximum of relations') would lead to the observation that there are only three gatekeepers. The four actors that would have to be considered as externally oriented have a significant number of internal relations as well and as such we would interpret the plot as indicating that the gatekeeper function is served by seven actors; five being public institutions, and two being private firms.

Sticking to this less strict interpretation of our definition of gatekeepers, we can identify four gatekeepers in Halle, three of which are private firms, but also two internally and one externally oriented actor. In Rostock the situation is very clear as the local university has by far the largest number of internal as well as external relations.

Taking into account the different scaling of the plots, we could summarise that Dresden and Jena are highly interactive, with Dresden being more outward oriented. Halle is also outward oriented but lacks internal density and for Rostock the opposite seems to be the case. This general picture does not change if we consider the the number of partners in figure 4.

4.3 Characteristics of gatekeepers

We have seen above, that a clear cut definition of a gatekeeper is rather difficult, especially when comparing different regions, where modes and number of interactions differ quite severely. We still believe that our approach provides some insights into the organisation of regional innovation networks, internally and externally. Based on these insights, we now want to analyse the general characteristics of actors that show features of gatekeepers. Since we can only observe the tendency to be a gatekeeper in terms of internal and external rela-

Table 2: Variable description

Name	Description	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Dependent variables							
*int*1	number of internal relations; degree with respect to internal network members	0	0	0	2.92	3	170
*int*2	number of internal partners; same as *int*1, but based on a binary adjacency matrix	0	0	0	1.25	2	44
*ext*1	number of external relations; degree with respect to external network members	0	0	0	2.26	2	265
*ext*2	number of external partners; same as *ext*1, but based on a binary adjacency matrix	0	0	0	0.99	1	67
*gat*1	gatekeeper variable; calculated as the product of *int*1 and *ext*1	0	0	0	61.44	0	16786
*gat*2	gatekeeper variable; calculated as the product of *int*2 and *ext*2	0	0	0	8.32	0	2948
Explanatory variables							
pub	binary variable; 1 for public organisations and 0 otherwise	0	0	0	0.02	0	1
pat	number of filed patents	1	1	1	3.64	2	412
ac	absorptive capacity; number of distinct inventors mentioned on patents of the applicant	1	1	2	5.01	3	360
D.dum	binary variable; 1 for actors located in Dresden and 0 otherwise	0	0	0	0.40	1	1
J.dum	binary variable; 1 for actors located in Jena and 0 otherwise	0	0	0	0.26	1	1
H.dum	binary variable; 1 for actors located in Halle and 0 otherwise	0	0	0	0.17	0	1
R.dum	binary variable; 1 for actors located in Rostock and 0 otherwise	0	0	0	0.17	0	1

Table 3: Types of actors in the sample

	N	Share
Gatekeepers ($int1 > 0$ and $ext1 > 0$)	339	22.5%
Only internal ($int1 > 0$ and $ext1 = 0$)	387	25.7%
Only external ($int1 = 0$ and $ext1 > 0$)	149	9.9%
No relations ($int1 = 0$ and $ext1 = 0$)	632	41.9%
Total	1507	100.0%

Note: internal actors of the four regions tions, we generate the variable *gat*1 by multiplying the number of internal and external *relations* to capture the features of gatekeepers (see table 2). Thereby an equal amount of both types of interactions receives a higher value than if the same amount of relations is mainly internal or external. In this definition, *gat*1 captures the *intensity* of contacts but provides no information about its variety; an actor might have many channels of knowledge transmission with a single partner (intensity of contacts) or with many different ones (variety of contacts). To capture this *variety* of contacts, we generate the second gatekeeper variable *gat*2, which is based on the number of distinct *partners*.

Our information about the characteristics of actors is unfortunately rather restricted. Since actors are patent applicants, they include not only firms and research institutions, but also individuals for whom it is impossible to gather information from other sources, and therefore, we can only use information which can be extracted from the patent data. Actors are identified as public research organisations by the binary variable *pub*. To proxy for the size of an actor, we use the number of filed patents. To capture absorptive capacity, we use the number of distinct inventors who appear on patents filed by each actor. Apparently, this variable could also be used to proxy for size, but the idea is that the breadth of the knowledge base of an organisation should be proportional to the number of different people involved in the R&D process of that organisation.

To test these hypotheses, we pool our data on individual actors in the four regions. Table 2 then gives the description of our variables and table 3 provides a rough distribution of actors in terms of their types of relations. We end up with 1507 actors, 339 of which can be characterised as 'gatekeepers' in the sense that they had at least one internal and external relation over the seven year period. 26% of all actors only interact with co-located actors and 10% are only related to external actors. 42% of the actors are isolated, i.e. they have neither cooperated nor can we observe mobility of inventors for them.

Our econometric approach in characterising gatekeepers is to run regressions of the characterising variables in table 2 on both gatekeeper variables, *gat*1 and *gat*2. It has to be noted that the use of patent data to measure interaction is a very rough as there are many more forms of interaction with other actors than are documented. As such, we highly underestimate real interactions of actors in the process of innovation. As a consequence for our econometric analysis, we have to be aware that actors with a gatekeeper variable of zero might well have relations to internal and external actors. In that case our dependent variable is censored to the left and the appropriate econometric tool would be the use of a Tobit model. To show the robustness of our results, we nevertheless document both models, OLS (tables 4 and 5) and Tobit (tables 6 and 7), and run the regressions on both gatekeeper variables. As can easily be seen from the tables, the results do not differ much between these four procedures.

In all regressions, we control for region specific influences by including regional dummies, but they do not show any significant influence. With respect to our first hypothesis, the relevance of size, we find mixed evidence. In models I of each table, we observe a significant positive influence, but when we include absorptive capacity (*ac*) in models III–V, the sign of the coefficient changes and becomes negative. The inclusion of *ac* also leads to a noteworthy increase in the explained variance of our model. This result might be due to collinear regressors (the correlation between *pat* and *ac* is 0.84), but all tests for multicollinearity are negative. The inclusion of a squared term for *pat* in model V also does not change our observation of a negative influence of size on being a gatekeeper.

Absorptive capacity seems to be very important for being a gatekeeper, as the coefficients are always positive and significant and the explanatory power of model II, where only *ac* and the dummy for public organisations (*pat*) are included as independent variables, is already rather high. This result is in line with our second hypothesis.

As stated in hypothesis 3, we expect public research organisations to serve the functions of a gatekeeper better than private actors. The openness of science, the need to cooperate to acquire external funds, and their mission to educate and release their graduates and former employees to the (local) labour market should lead to a high degree of interaction with internal and external actors (see Revilla Diez, 2000). Our hypothesis is confirmed by the positive coefficients of *pub* in all models except for model III in table 5.

To investigate a joint effect of size and absorptive capacity, the interaction term $pat \cdot ac$ is included in model IV. As we would expect, this coefficient is positive and significant and increases the R^2 by roughly 10% in the OLS regressions. This result can be interpreted in a way that size on its own is not sufficient for being a gatekeeper, but rather has to be accompanied by high absorptive capacity in order to make interactions useful for the internal innovation process.

Overall, it seems that size is not so important for being a gatekeeper, but it is rather absorptive capacity and a public mission which are favourable. It is our impression that absorptive capacity is especially important for the acquisition of external knowledge and public research organisations are relatively more internally oriented.[3]

[3]First, simple analyses point in that direction, but a rigorous examination of this aspect lies beyond the scope of this paper.

Table 4: Explaining gatekeepers – OLS regression with dependent variable *gat*1 (internal × external relations)

N = 1507	I	II	III	IV	V
(Intercept)	-64.28 (0.01)	-104.48 (0.00)	-97.67 (0.00)	-15.15 (0.24)	0.85 (0.94)
pub	1131.75 (0.00)	230.35 (0.00)	133.10 (0.06)	546.02 (0.00)	591.03 (0.00)
pat	24.29 (0.00)		-12.05 (0.00)	-28.27 (0.00)	-27.26 (0.00)
pat^2					0.04 (0.00)
ac		31.14 (0.00)	40.23 (0.00)	23.15 (0.00)	17.00 (0.00)
ac^2					0.11 (0.00)
$pat \cdot ac$				0.16 (0.00)	
J.dum	35.22 (0.33)	4.86 (0.85)	-9.01 (0.72)	9.43 (0.64)	9.47 (0.61)
H.dum	-20.06 (0.62)	-15.52 (0.60)	-21.92 (0.44)	-14.09 (0.53)	-11.86 (0.57)
R.dum	23.89 (0.56)	33.77 (0.26)	24.90 (0.38)	13.09 (0.57)	11.12 (0.60)
R^2	0.45 (0.44)	0.72 (0.71)	0.74 (0.74)	0.83 (0.83)	0.85 (0.85)
F-stat (DF)	241.58 (1501)	756.32 (1501)	703.21 (1500)	1060.05 (1499)	1084.24 (1498)

P-values in parentheses

Table 5: Explaining gatekeepers – OLS regression with dependent variable *gat*2 (internal × external partners)

N = 1507	I	II	III	IV	V
(Intercept)	-7.32 (0.02)	-12.92 (0.00)	-11.86 (0.00)	-1.97 (0.32)	1.62 (0.35)
pub	132.78 (0.00)	12.28 (0.24)	-2.87 (0.77)	46.62 (0.00)	62.57 (0.00)
pat	3.06 (0.00)		-1.88 (0.00)	-3.82 (0.00)	-3.07 (0.00)
pat^2					0.00 (0.00)
ac		4.05 (0.00)	5.46 (0.00)	3.42 (0.00)	1.61 (0.00)
ac^2					0.02 (0.00)
$pat \cdot ac$				0.02 (0.00)	
J.dum	4.00 (0.42)	0.15 (0.97)	-2.01 (0.57)	0.20 (0.95)	0.95 (0.72)
H.dum	-1.32 (0.82)	-0.58 (0.89)	-1.58 (0.69)	-0.64 (0.85)	-0.13 (0.97)
R.dum	2.70 (0.64)	4.22 (0.32)	2.84 (0.48)	1.42 (0.68)	1.17 (0.70)
R^2	0.39 (0.39)	0.67 (0.67)	0.70 (0.70)	0.78 (0.78)	0.83 (0.83)
F-stat (DF)	194.51 (1501)	613.05 (1501)	588.10 (1500)	755.96 (1499)	920.16 (1498)

P-values in parentheses

Table 6: Explaining gatekeepers – Tobit regression with dependent variable *gat*1 (internal × external relations)

N = 1507	I	II	III	IV	V
(Intercept)	-1347.58 (0.00)	-991.35 (0.00)	-938.22 (0.00)	-742.86 (0.00)	-676.93 (0.00)
pub	1943.71 (0.00)	620.58 (0.00)	490.18 (0.00)	766.31 (0.00)	759.38 (0.00)
pat	29.94 (0.00)		-12.76 (0.00)	-24.46 (0.00)	-49.28 (0.00)
pat^2					0.09 (0.00)
ac		35.80 (0.00)	45.29 (0.00)	32.11 (0.00)	43.16 (0.00)
ac^2					0.06 (0.00)
$pat \cdot ac$				0.11 (0.00)	
J.dum	148.37 (0.16)	58.40 (0.42)	26.47 (0.70)	44.33 (0.44)	22.66 (0.68)
H.dum	130.60 (0.27)	80.68 (0.31)	58.21 (0.45)	50.66 (0.44)	39.49 (0.52)
R.dum	110.58 (0.37)	111.83 (0.17)	90.28 (0.25)	66.39 (0.32)	46.73 (0.46)
Log(scale)	7.04 (0.00)	6.64 (0.00)	6.59 (0.00)	6.43 (0.00)	6.37 (0.00)
Pseudo R^2	0.05	0.10	0.11	0.12	0.12
Chisq (df)	358.98 (5)	687.33 (5)	723.04 (6)	800.55 (7)	839.00 (8)

P-values in parentheses

Table 7: Explaining gatekeepers – Tobit regression with dependent variable *gat*2 (internal × external partners)

N = 1507	I	II	III	IV	V
(Intercept)	-185.89 (0.00)	-140.36 (0.00)	-131.50 (0.00)	-113.14 (0.00)	-96.75 (0.00)
pub	243.89 (0.00)	64.92 (0.00)	44.05 (0.04)	75.02 (0.00)	84.45 (0.00)
pat	3.85 (0.00)		-1.99 (0.00)	-3.22 (0.00)	-5.85 (0.00)
pat^2					0.01 (0.00)
ac		4.73 (0.00)	6.20 (0.00)	4.82 (0.00)	5.15 (0.00)
ac^2					0.01 (0.00)
$pat \cdot ac$				0.01 (0.00)	
J.dum	18.92 (0.20)	7.36 (0.48)	2.40 (0.81)	4.39 (0.62)	2.86 (0.72)
H.dum	20.70 (0.21)	14.59 (0.21)	11.05 (0.31)	10.51 (0.29)	9.01 (0.31)
R.dum	14.13 (0.41)	14.76 (0.22)	11.40 (0.31)	9.00 (0.38)	6.15 (0.50)
Log(scale)	5.08 (0.00)	4.71 (0.00)	4.65 (0.00)	4.56 (0.00)	4.45 (0.00)
Pseudo R^2	0.06	0.11	0.12	0.13	0.14
Chisq (df)	313.82 (5)	610.70 (5)	652.09 (6)	691.39 (7)	750.84 (8)

P-values in parentheses

5 Dynamic view

To supplement our analysis of regional differences with respect to internal buzz and external pipelines, we now investigate the development of the regional innovation networks over time. In taking this dynamic view, we can also examine the persistence of specific gatekeepers or general trends in their development. In the following, our period of observation is divided into three overlapping subperiods of an equal length of three years.

5.1 Data description

A first impression of the general development of the regional innovation networks is given in figure 5, where the shares of internal patents and actors are presented in the plots of the top row and the internal and external shares of relations in the bottom row, absolute numbers are given in the column to the right of each plot.[4]

The shares of internal patents and actors are both rather stable in Dresden and Jena, while both increase sharply in Halle and decrease sharply in Rostock. Dresden becomes more outward oriented and internal relations even decrease in absolute terms, which is surprising, given the increasing numbers of internal patents and actors. The innovation system of Jena is the most stable one with respect to the shares of internal and external relations, but it is highly dynamic in terms of absolute interactive activity. Given that internal patents and internal actors in Dresden are roughly 50% higher than in Jena, it is quite surprising that the number of internal relations in the latest two periods reaches only two thirds of the level in Jena. The local 'buzz' in Jena is clearly more pronounced, but even the external relations reach 75% of the level of Dresden, which means that actors in Jena have on average more external relations than the average actor in Dresden.

In Rostock the increase of external patents and actors goes hand in hand with an increase (decrease) of external (internal) relations. Looking at the absolute numbers, we see that external relations more than triple between the first and the last period. Given that this is the region that is by far most inward oriented it clearly seems as a development in the right direction. In Halle, despite the fact that more internal interaction would be possible, the share of internal relations decreases from an already low level, and internal interactions even decrease in absolute numbers. This clearly indicates a lack of internal density of the innovation system. Either this is due to a lack of technological overlap between local firms or there is a lack of knowledge about what other locals do or that

[4]The plot is based on the numbers in appendix C.

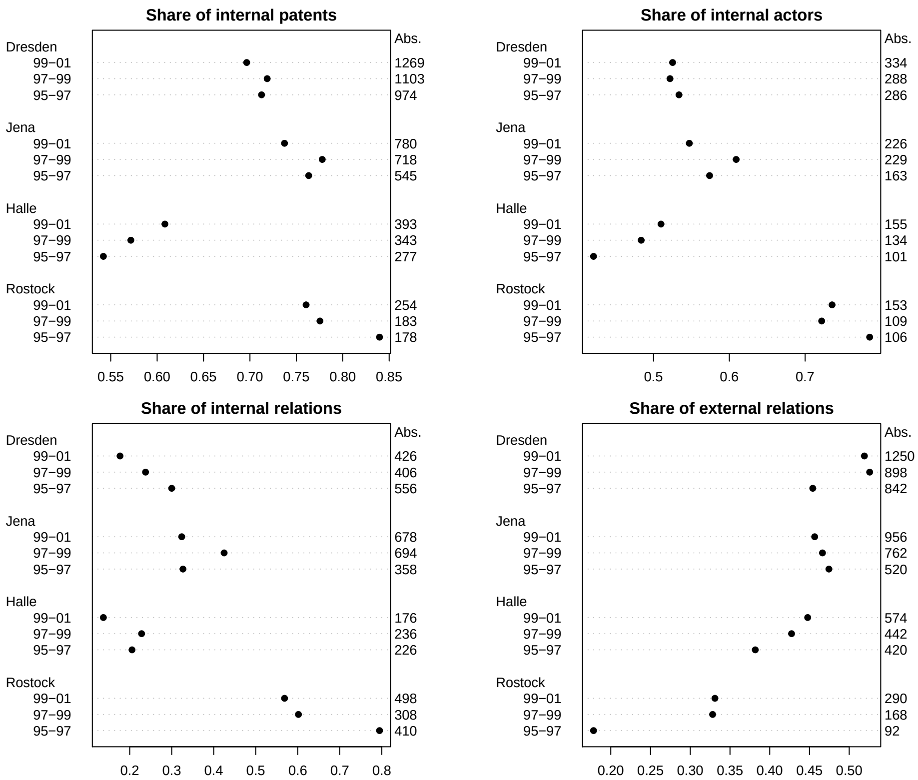
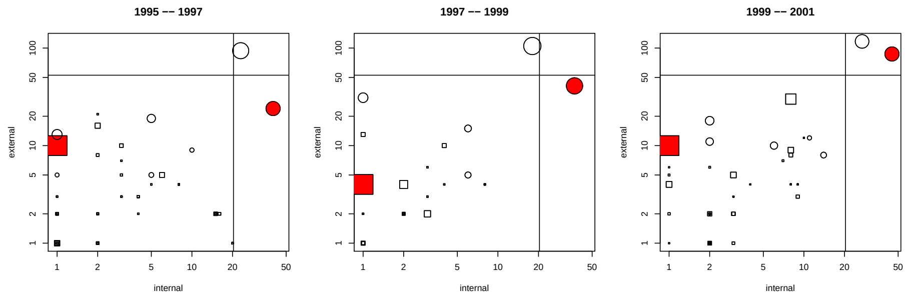


Figure 5: Development of regional networks

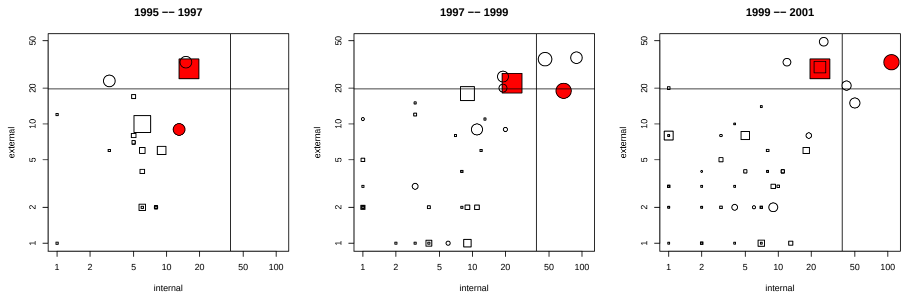
interaction could be useful in generating new knowledge. In either case, for the regional innovation system to develop, internal actors will have to a change this dynamic, which will take longer in the former case, but could be changed more quickly in the latter two.

5.2 Evolution of gatekeepers

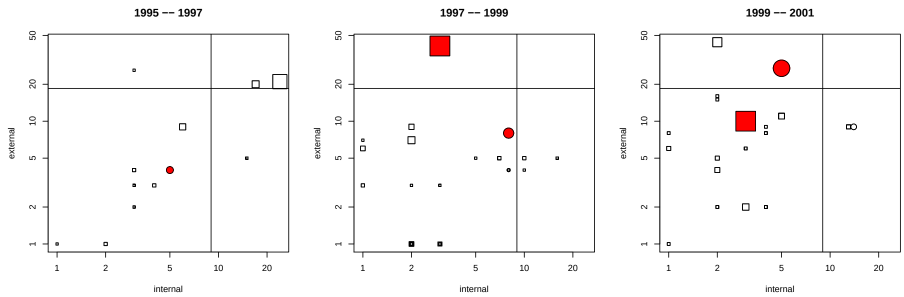
The general development of regional networks in terms of outward orientation and internal density could be based on different structures underneath. A large increase in external relations as in the case of Rostock could be due to the location of a large multinational firm, a shift in orientation of a central local actor like the university, or an increasing outward orientation of a large number of actors. To investigate these issues, we proceed as in section 3 and plot internal against external relations of each actor in figure 6. The diagrams in each row correspond to the development over time for each region. In order to make the plots comparable within one region, we keep the (logarithmic) scaling and the lines for orientation fixed. The lines defining the four quadrants are calculated as the mean of the three maximum values that we observe.



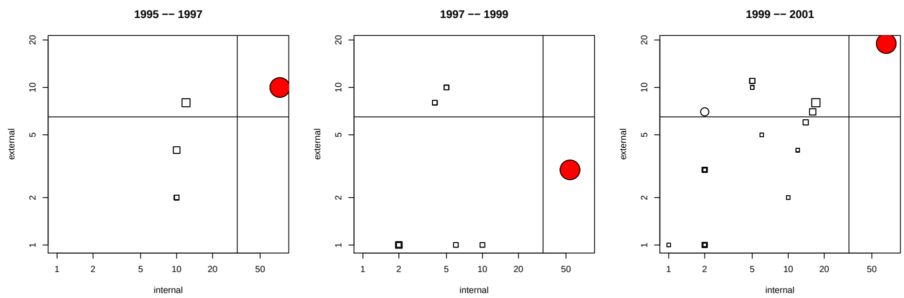
(a) Dresden



(b) Jena



(c) Halle



(d) Rostock

Note: only internal actors

Figure 6: Identification of gatekeepers by number of relations (internal and external)

Our first observation concerns the development of the local university (the red circles) in each region. In Dresden and Jena the universities move to the upper right and end up as *the* gatekeeper in the last period. The university in Halle is moving from the inactive to the external quadrant with absolute numbers of – especially internal – relations being very low. Halle is also the only region without any gatekeeper in the last period 1999–2001.

While in Halle and Rostock the only visible public research organisation is the university, we find Jena and Dresden to be dominated by a number of institutions of public research. In Dresden there is only one firm moving towards a position of a gatekeeper and the largest patenting firm is almost exclusively interacting with external partners. The large firms in Jena are always integrated in the local network while having a number of external linkages. The dynamics that we have observed before in terms of an increasing number of relations shows in this graph as a general movement to the upper right. In Halle this movement is rather to the left which is in line with our previous observations. Maybe it is only because of the low number of actors, but in Rostock the 'take-off' of a number of actors is most visible. The observation above – an increasing outward orientation of the system – can now be accredited in part to the university but mainly to a general tendency to interact with external partners.

6 Conclusions

This study is an attempt to capture the notion of gatekeepers within regional innovation systems empirically. We applied social network analysis on the basis of patent data, which is increasingly used in the analysis of innovation systems and becoming a more and more accepted analytical tool. Our main objective was not to show the relevance of gatekeepers for the success of regional networks, but rather to explore to what extent the principal functions of gatekeepers are served by a number of actors within such a system. While it is difficult to provide a clear cut-off value where actors are called gatekeepers if they are above such a value, we were still able to identify actors which behave more like gatekeepers than others.

In the theoretical part, we developed some hypotheses concerning the characteristics of gatekeepers. Within our sample we found that, contrary to our prediction, size does not play the major role for being a gatekeeper. It is rather absorptive capacity that matters for functioning as a gatekeeper, i.e. to be able to absorb external knowledge and to diffuse it within the local system. As presumed, public research organisations serve the functions of a gatekeeper to a higher degree than private actors.

We could also show that there are significant differences between regions with respect to the observed degree of local ‘buzz’ and global (or rather external) ‘pipelines’. Dresden is very open in this respect while in Jena there is the highest degree of internal interaction. Both regional networks are highly interactive and differ in that respect from the other two regions, Halle and Rostock. Between these two we could also observe strong differences in their interactive structure. In Rostock, a highly inward oriented network, we could observe a development towards the ‘right’ direction as many actors increasingly focus on external relations. No such ‘learning’ can be found in Halle. Despite a clear lack of local interaction, no tendency of actors to change this situation is perceptible.

An important question that we can rather raise than answer is about the ‘optimal’ mix of internal density and external linkages. When it comes to innovative and economic performance, Dresden and Jena are to be considered more successful regions compared to Halle and Rostock. What we find is that both successful regions have something that could be called a functioning internal system with a sufficient amount of external orientation. The ‘mix’ of both is clearly different. In Halle there is no such functioning internal system and in Rostock only recently something like external ‘pipelines’ has developed on a wider basis. Therefore, our answer to the question raised above has to be ‘no’, rather there is a need for both types of interaction in some sufficient amount.

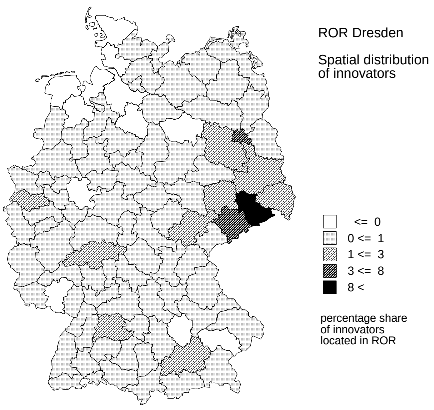
A Assignment of external actors

The databases for each region are extracted from all applications at the German patent office with at least one inventor located in the respective region. Thereby, we find local as well as external innovators in the regional networks as there are co-operations between internal and external innovators or inventors which commute. The address of the innovator, as stated on the patent, provides good but not perfect information about its location. Patents of a local subsidiary or research facility are often assigned to the parent organisation's headquarter or to the organisation which finances the research activity. This is especially true for large firms and research societies such as Fraunhofer and Max-Planck. Consequently, all patents with at least one external innovator were checked for their actual location.

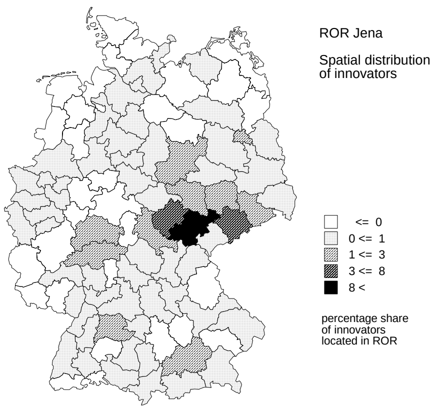
If all inventors of a patent are based in the region and at least some could be identified as members of a local subsidiary or research facility, the patent is associated with the local address of the subsidiary or research facility. If none of the inventors could be traced to a local organisation, but the external innovator has a local subsidiary which could be related with the invention's content, the patent is likewise associated with the address of the local subsidiary.

If only one of the inventors is not based in the region, the patent remains precautionary with the original innovators address. An exception of this rule was made, when it was known that the external innovator holds the patents only for administrative purpose. In this special case, the patent is assigned to a local subsidiary or research facility if at least one inventor was identified as an employee of this local institution. If no inventor could be traced to a local subsidiary or research facility of the assignee, it was checked if the external inventors could be associated with any external institutions. If inventors belonged to other external subsidiaries of the assignee the patent was ascribed to that institution.

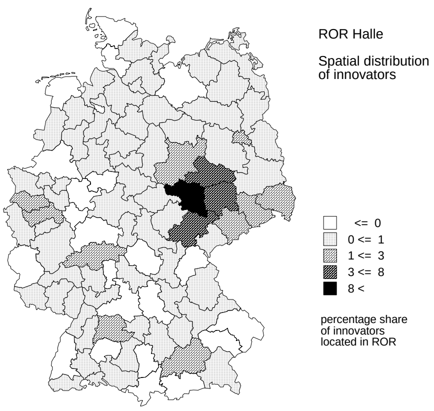
B Spatial distribution of innovators



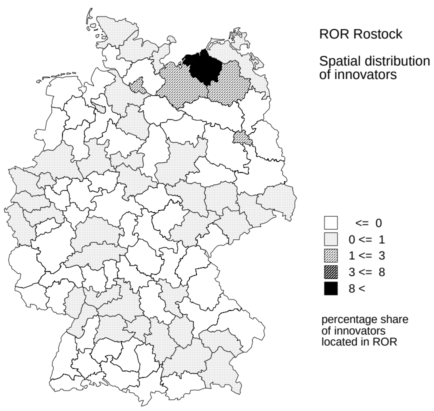
(a) Dresden



(b) Jena



(c) Halle



(d) Rostock

Figure 7: Spatial distribution of innovators

C Development of regional networks

Table 8: Data description – dynamic view

	Dresden			Jena			Halle			Rostock		
	95-97	97-99	99-01	95-97	97-99	99-01	95-97	97-99	99-01	95-97	97-99	99-01
Patents	1367	1535	1822	714	923	1058	511	600	646	212	236	334
ROR	71.3%	71.9%	69.6%	76.3%	77.8%	73.7%	54.2%	57.2%	60.8%	84.0%	77.5%	76.0%
Bundesland	7.4%	7.2%	6.6%	2.9%	2.7%	3.5%	6.1%	7.8%	7.7%	0.9%	3.0%	4.2%
Germany	20.1%	19.5%	22.7%	20.2%	19.3%	21.7%	39.1%	34.3%	30.2%	14.6%	18.6%	17.7%
Abroad	1.2%	1.4%	1.0%	0.6%	0.2%	1.0%	0.6%	0.7%	1.2%	0.5%	0.8%	2.1%
Actors	536	552	636	284	376	413	240	277	304	135	151	208
ROR	53.4%	52.2%	52.5%	57.4%	60.9%	54.7%	42.1%	48.4%	51.0%	78.5%	72.2%	73.6%
Bundesland	11.8%	11.1%	10.5%	6.7%	5.9%	5.3%	8.3%	8.3%	6.3%	1.5%	4.6%	6.3%
Germany	33.0%	34.8%	34.9%	34.9%	32.7%	38.0%	48.3%	42.6%	40.5%	19.3%	21.9%	17.8%
Abroad	1.9%	2.0%	2.0%	1.1%	0.5%	1.9%	1.3%	0.7%	2.3%	0.7%	1.3%	2.4%
Total relations	1854	1708	2408	1096	1634	2094	1100	1034	1282	516	512	876
within internal	30.0%	23.8%	17.7%	32.7%	42.5%	32.4%	20.5%	22.8%	13.7%	79.5%	60.2%	56.8%
within external	24.6%	23.7%	30.4%	19.9%	10.9%	22.0%	41.3%	34.4%	41.5%	2.7%	7.0%	10.0%
between in- and external	45.4%	52.6%	51.9%	47.4%	46.6%	45.7%	38.2%	42.7%	44.8%	17.8%	32.8%	33.1%
Cooperation	1394	1238	1694	812	1296	1452	784	706	722	392	388	662
within internal	31.7%	26.2%	16.8%	32.8%	43.1%	29.8%	21.2%	25.8%	15.8%	79.6%	57.2%	60.4%
within external	22.1%	19.1%	30.1%	20.7%	11.4%	25.8%	41.8%	34.6%	31.3%	3.6%	7.7%	7.3%
between in- and external	46.2%	54.8%	53.1%	46.6%	45.5%	44.5%	37.0%	39.7%	52.9%	16.8%	35.1%	32.3%
Mobility	460	470	714	284	338	642	316	328	560	124	124	214
within internal	24.8%	17.4%	19.9%	32.4%	40.2%	38.3%	19.0%	16.5%	11.1%	79.0%	69.4%	45.8%
within external	32.2%	35.7%	31.1%	17.6%	8.9%	13.4%	39.9%	34.1%	54.6%	0.0%	4.8%	18.7%
between in- and external	43.0%	46.8%	49.0%	50.0%	50.9%	48.3%	41.1%	49.4%	34.3%	21.0%	25.8%	35.5%

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