The Performance of Gatekeepers in Innovator Networks

Holger Graf* Jens J. Krüger†

February 26, 2009

Abstract

We investigate the impact of actors' positions within regional innovator networks on their innovative performance. The networks of four selected regions are based on information on patent applicants and inventors. Count data regressions show positive effects on innovation of both the total number of relations and of access to a larger knowledge base. However, when looking at innovators that are characterised by multiple internal and external contacts, our results suggest that these gatekeepers are not able to reap all the benefits associated with their brokering position. This implies that gatekeepers provide some sort of public good to the innovation system.

Keywords: Innovator networks; Gatekeeper; Zero Inflated Generalised Poisson

JEL Classification: O31; Z13; R11

*Friedrich Schiller University of Jena, Economics Department, Carl-Zeiss-Str. 3, D-07743 Jena, phone: +49(0)3641 943204, fax: +49(0)3641 943202, email: holger.graf@uni-jena.de

†Darmstadt University of Technology, Department of Law and Economics, Residenzschloss, Marktplatz 15, D-64283 Darmstadt, phone: +49(0)6151 163693, fax: +49(0)6151 163897, email: jjk@vwl.tu-darmstadt.de

1 Introduction

Innovation processes by firms or other innovative actors cannot be analysed in isolation. It is a common understanding that actors generate novelty mostly through the combination of existing knowledge which might either be acquired via own learning processes in the past or through interaction with other actors. This interactive feature of innovation is at the core of the systemic view of innovation, which is manifested in the seminal volumes on national innovation systems by Lundvall (1992) and Nelson (1993). This theory has rapidly developed and broadened its coverage from the analysis of national innovation systems to regional (Braczyk et al., 1998), sectoral (Malerba, 2002), or technological systems (Carlsson and Stankiewicz, 1991).

The rising interest in the spatial distribution of economic activities by economists and an equally sharp rise in interest of geographers to incorporate economic theories into their research, led to a major increase in publications on regional innovation systems, clusters, industrial districts, etc. In studying the internal mechanisms of knowledge exchange it soon became clear that for sustainable regional development interaction within the system cannot be sufficient but has to be accompanied by interaction with external actors (Storper and Venables, 2004; Bathelt et al., 2004). Within a regional innovation system only few actors have the capabilities and/or incentives for widespread interaction with local and external actors, though. These actors serve as technological gatekeepers for the innovation system (Allen, 1977; Giuliani, 2005; Giuliani and Bell, 2005; Munari et al., 2005). Depending on the perspective of the analysis, gatekeepers can be found on various levels. Within organisations, gatekeepers link different divisions. In establishing linkages between organisations, they might be found in either of the connected organisations. In our setting, organisations themselves can be gatekeepers if they interact with actors inside the regional innovation system but also hold contacts to external actors.

On the regional level it is quite clear that these external contacts are vital for the innovative performance if they reach into the local system. The variety and intensity of personal relationships in a vibrant local network is captured by the notion of local 'buzz' (Storper and Venables, 2004; Bathelt et al., 2004). A high degree of innovative buzz should increase the region-specific knowledge-stock and – if it is best practice – lead to a comparative advantage with respect to other localities. 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 emphasised 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 risk of a technological lock-in (Grabher, 1993), i.e. loosing connections to new developments, diminishes. Obviously, highly specialised regions face a higher risk of such a technological lock-in. 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. This argument is supported by Broekel and Meder (2008) who show the importance of both types of relations (internal and external) for the electronics industry in Germany. All this points towards the important role of gatekeepers for a (regional) innovation system as a whole.

From an individual perspective, the benefits are not so clear. Given that, generally, linkages in the research process are important (e.g. Ahuja, 2000), we can still ask why firms should share their externally acquired knowledge with actors at their own location? Based on previous research, we know that gatekeepers are characterised by high absorptive capacity (Giuliani, 2005; Graf, 2007) and that they are often research organisations that belong to the public sector (Graf, 2007; Steiner and Ploder, 2008). These results hint towards gatekeepers as providers of a club good. This is the starting point for our study. Our main research question is whether actors benefit from interacting with internal and external actors of the respective innovation system, i.e. by acting as a gatekeeper.

To answer this question (and related questions) we employ methods of social network analysis based on German patent applications between 1995 and 2001 to generate network measures on an individual level. The analysis is applied to the innovator networks of four regions in Germany: Aachen and Karlsruhe in western part and Jena, and Dresden in the eastern part. We assume linkages, and therefore knowledge transfer, between two innovators (patent applicants) if they jointly apply for a patent ('co-operation') or if one inventor is observed as having worked for both innovators on distinct patents ('scientist mobility') (Cantner and Graf, 2006; Graf and Henning, 2008). Innovators are qualified as external actors if they have applied for at least one patent with an inventor living in the region but are not located in the region themselves. Based on these networks, we characterise actors according to their role and/or position within the network and test their influence on the innovative performance in terms of applied patents in subsequent periods.

Our analysis unfolds as follows. In section 2 we review the body of existing theoretical work on the relevance of the network position on innovative success. This is followed by a brief descriptions of the regions, the method of social network analysis and the treatment of the data in section 3. Section 4 then proceeds with an outline of the count data regression methods we apply and in section 5 we present and discuss the regression results. Section 6 concludes.

2 Network Position and Innovation

2.1 Linkages in Innovation

Cooperation and mobility: Since the sources of innovation are often found between firms, universities, research laboratories, suppliers, and customers (Powell, 1990), firms commit resources to grasp these sources of innovation. Subsequent to Penrose's (1959) work on a resource-based view of the firm, the development of organisational routines (Nelson and Winter, 1982; Shane, 1996) and access to capital (Martin and Justis, 1993) have been shown to exert positive growth effects. To overcome resource scarcities and to benefit from partner's resources, firms engage in interfirm cooperation (Combs and Ketchen, 1999). Since cooperation opens up possibilities to perform activities which a single firm could not perform on its own, resource sharing is considered a primary explanation for interfirm cooperation (Borys and Jemison, 1989; Hamel, 1991). Besides this cost-economising argument, i.e. sharing the costs of research activities, risk sharing, obtaining access to new markets and technologies, and pooling of complementary skills are more strategic rationales for collaboration in research and development (Kogut, 1989; Hagedoorn, 1993; Eisenhardt and Schoonhoven, 1996; Mowery et al., 1998).

Another important channel for the transfer of knowledge is labor mobility. As a major example, a higher level of mobility is held responsible for the success of Silicon Valley in comparison to other regions as knowledge is transmitted faster and more efficiently through scientists and engineers who frequently change their jobs (Saxenian, 1994; Almeida and Kogut, 1999). In a more comprehensive analysis Breschi and Lissoni (2003, 2006) find the mobility of inventors to be the main source of localised knowledge spillovers.

Relevance of network position on innovative success: The network perspective not only accounts for the frequency and intensity of the bilateral relations (relational embeddedness), but in combining them, makes it possible to analyse the structure of such a network and of individual positions therein (structural embeddedness) (Gulati, 1998). If we allow for the possibility that knowledge can flow not just between two actors, but through several nodes of a network, the position in the network becomes of major importance for the acquisition of external knowledge. Ahuja (2000) shows the relevance of indirect linkages in addition to direct forms of interaction. While Ahuja (2000) finds a significant impact of direct ties (degree) on subsequent innovation output, Powell et al. (1996) obtain rather ambiguous results concerning the influence of a central position in the network on firm growth. In their study, degree centrality is predicts employment growth, though no significant effects were found for closeness centrality or firms in the main component. The fact that the influence of centrality on innovation still seems to be unclear motivates our first two research questions.

Research Question 1 *What is the influence of a central network position of an actor on its innovation output in the subsequent period?*

Research Question 2 *To which extent is this influence dependent on the centrality concept applied?*

2.2 Gatekeepers and Innovation

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 (Morrison, 2008). In the context of a regional innovation system, gatekeepers link the system to outside knowledge sources (Giuliani and Bell, 2005; Graf, 2007).

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 the power to push the new knowledge into the local system (Lazerson and Lorenzoni, 1999; Giuliani and Bell, 2005). Universities and public research institutes are primary candidates for such a position as they not only have the absorptive capacity to absorb external knowledge but also have incentives to spread knowledge as a part of their public mission (Graf, 2007). Knowledge might also be channeled through multinational firms originating from outside the regional system, seeking to exploit special local resources (Giuliani et al., 2005).

While the literature reviewed above provides arguments and some evidence for the necessity of internal and external relations on the level of the region, it is not quite clear what motivates actors to act as a gatekeeper if they would not benefit themselves from being in such a position. 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 (Giuliani, 2005; Wink, 2008). 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 is integrated within the local system via a sufficient number of internal relations (Giuliani and Bell, 2005). They argue that "a cluster does not absorb external knowledge uniformly through all its constituent firms, but selectively through only those firms with a low cognitive distance from the technological frontier. Interestingly enough, firms with high external openness could be potentially fruitful at local level if they contribute to the diffusion of acquired knowledge to other firms in the cluster, and perform as technological gatekeepers"(Giuliani and Bell, 2005, p. 49). Recent studies on the functions of gatekeepers show that the effective realisation of 'potential absorptive capacity' requires additional effort regarding the transfer of knowledge into the cluster

(Lazaric et al., 2008) and that gatekeepers have to put efforts in transcoding and filtering of external knowledge (Morrison, 2008).[1]

To summarise, if actors with (non-redundant) external contacts benefit from their non-local resources, they should show a higher level of innovation output. A high level of internal contacts, however, leads to a diffusion of this externally acquired knowledge. The benefits from non-local knowledge elements are therefore non exclusive and this second effect of being a gatekeeper should work in the opposite direction. As such, we cannot state a clear hypothesis regarding the effect of being a gatekeeper on innovation output. On a low level of technological sophistication, it might well be better to only have internal contacts, while for actors at the technological frontier it should be necessary to have both, internal and external relations.

This brings us to our main research questions:

Research Question 3 *Are gatekeepers able to reap benefits in terms of innovative success from their position within the network?*

Research Question 4 *Are there differences in the influence of the intensity of gatekeeping activity on innovative success?*

3 Method and Data

3.1 Social Network Analysis and Patent Data

With respect to our methodological approach we follow a literature that tries to gain deeper insights in the innovation process by applying social network analysis to study interaction structures in the process of innovation. This literature has made substantial advances in the development of theoretical models (e.g. Jackson and Wolinsky, 1996; Cowan et al., 2006; Goyal and Vega-Redondo, 2007; Carayol et al., 2008), and also in the empirical investigation of innovation networks over the last years (e.g. Powell et al., 1996; Cantner and Graf, 2006; Fleming and Frenken, 2007; Fleming et al., 2007). Social network analysis focuses on relations, i.e. 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 the appropriate methodology for identifying and studying gatekeepers as they are 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, we require relational data. Patent data meet this requirement: They provide information about the persons involved

[1]See also Wink (2008) for a nice elaboration of the functions of gatekeepers in relation to different forms of proximity.

in the underlying innovative activity and can therefore be used to uncover 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 individuals 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., 2007; 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, 2008). While the function of a gatekeeper could in principle be served by individuals as well as by organisations, we find it more appropriate to 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 means 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.[2]

We interpret the linkages (inventors) between the nodes (innovators) as possible channels of knowledge transmission (Fleming et al., 2007). In the case of co-operations, we do

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

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. 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 collaborators from both innovators. Having discussed these commonalities and differences between the two cases, we combine them to a single innovator network. For the subsequent analysis we use the dichotomised versions of these networks to account for the variety of external sources of knowledge irrespective of the intensity of relations.

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 would be 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 research lab of the firm or university holding the patent is located there. Unfortunately, we face the problem that several, especially large, organisations often have many and regionally dispersed subsidiaries, but apply for patents centrally, on behalf 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 (Jaffe et al., 1993; Breschi and Lissoni, 2006). Consequently, we base the regional networks on all patent applications with at least one inventor residing in the respective region.

The last step is to separate 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. 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).

3.2 Data

Regions: We selected two eastern regions with the highest innovation performance, Dresden and Jena, and compare them to the most efficient regions in the western part of Germany of comparable size, Aachen and Karlsruhe. We did not select the most efficient regions, Munich and Stuttgart, for this comparison because these two regions are substantially larger (for an analysis of the efficiency of German Regional Innovation Systems see Fritsch and Slavtchev, 2008). The geographical boundaries of the regions are defined as German planning regions ("Raumordnungsregionen"). Designed to represent socio-economic entities, they normally comprise several NUTS3 level districts, namely a core city and its surrounding area. We consider planning regions to be more suitable than districts. In the first place, the core city districts seem to be too small because local innovation systems may well include some R&D capacities located beyond the boundaries of the core city. The second reason is methodological: since patents are assigned to regions in accordance with the inventors' residence, this larger regional unit allows us to account for commuting inventors who work in the city but live in the surrounding areas. All four regions are of comparable size, ranging from 800.000 in Jena to 1.2 million inhabitants in Aachen. Each region contains a research university and a number of public research organisations such as institutes of the Fraunhofer-Gesellschaft, the Leibniz Association, and the Max Planck Society. All regions have a considerable tradition in manufacturing industries. From the perspective of patenting activity most important technologies are printing and instruments in Dresden, instruments and optics in Jena, electronics and instruments in Aachen, instruments and electronics in Karlsruhe. The fact that instruments are at a top position in all regions assures that the four regions are not overly diverse with respect to their technological orientation.

Variables: For our econometric analysis in section 5, we employ the following variables on the level of the individual innovator. We only include the internal actors since we know about both their internal and external relations while for external actors we only know about their relations to actors within the focal region. Thus, our units of observation are patent applicants located within the respective region. We end up with 974 innovators located in Aachen, 600 from Dresden, 390 from Jena, and 879 from Karlsruhe. We measure innovative output as the number of patent applications. Our dependent variable is the sum of all patent applications in the current period ($\textit{No. of Patents}_t$). The explanatory variables can be divided into three groups. First, to control for persistence in the innovation process, we include the lagged innovation output ($\textit{No. of Patents}_{t-1}$). In addition we control for size by the number of inventors in the same period ($\textit{No. of Inventors}_t$).

The second group of variables consists of those characterising the actors according to their position in the regional network in period $t-1$. The networks are generated for two non-overlapping periods: 1995–1997 and 1999-2001. These periods are sufficiently long to allow for the observation of mobility between the innovators and at the same time short enough to allow for the detachment of relations. $\textit{Degree}_{t-1}$ is the number of direct linkages irrespective of the location of the partner. $\textit{Betweenness}_{t-1}$ is another measure of centrality that accounts for the position in the whole network (whereas degree is only based on the egonetwork). It is calculated as the frequency with which an actor is positioned between pairs of other actors on the shortest path connecting them. If knowledge

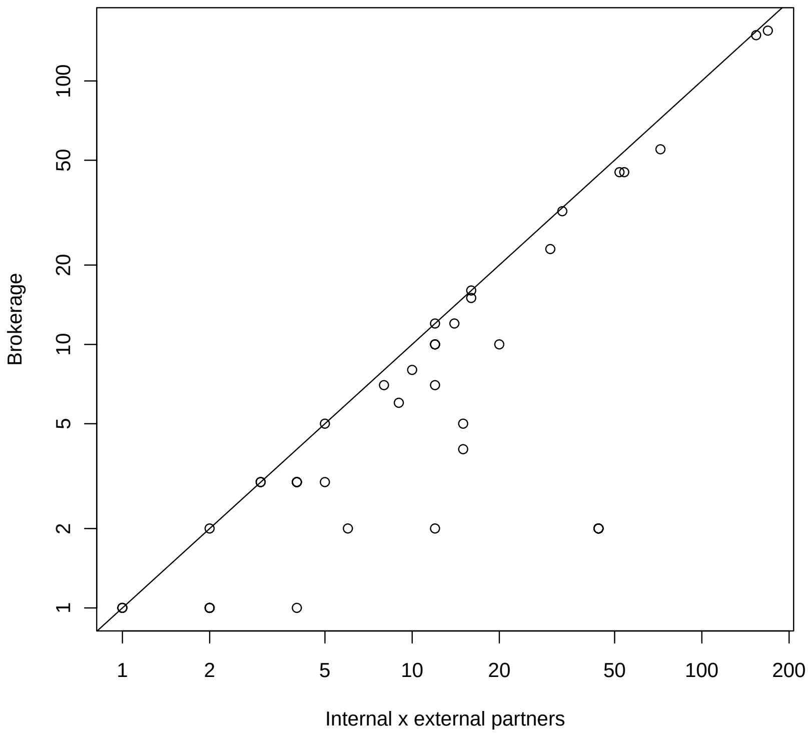

Figure 1: Relation between gatekeeper measures

can only ‘flow’ through the connected part of a network, it should make a difference for an actor to be a member of the main component, meaning the largest connected part of the network. Therefore, we include the dummy variable $MainComp_{t-1}$ to account for a position within the largest component of the respective regional network. The last two network related variables are the ones that represent the actors’ position as a gatekeeper. Our first index ($Gatekeeper1_{t-1}$) merely distinguishes between internal and external partners and is calculated as the product of both (Graf, 2007). The second index is slightly more sophisticated. This brokerage measure is described by Gould and Fernandez (1989) as the role played by an actor who mediates contact between two alters who belong to different groups. In our setting gatekeepers are local actors that have non-redundant contacts to internal and external nodes in the regional network. $Gatekeeper2_{t-1}$ of an actor is then given as the number of brokering positions held by this actor.[3] Figure 1 compares the two gatekeeper indices showing that they are highly correlated and that the brokerage score ($Gatekeeper2$) serves as an upper bound for the first index ($Gatekeeper1$).

Finally, in the third group we include dummies for actors located in the eastern part of Germany (i.e. Dresden and Jena), for individual applicants, and for public research institutes. Descriptive statistics are shown in table 1.

[3]For a detailed description of the calculation of brokerage scores, see the documentation for `brokerage` in Butts (2007).

Table 1: Descriptive Statistics

Name	Min.	Max.	Mean	SD
No. of Patents$_t$ — applications from 1999–2001	0	448	3.046	19.692
No. of Patents$_{t-1}$ — applications from 1995–1997	1	181	3.210	11.039
No. of Inventors$_t$	0	410	3.990	23.908
Degree$_{t-1}$ — no. of distinct partners	0	29	1.026	2.157
Gatekeeper1$_{t-1}$: internal × external partners	0	169	0.954	7.610
Gatekeeper2$_{t-1}$: broker (gatekeeper)	0	155	0.505	6.507
Betweenness$_{t-1}$	0	0.25	0.001	0.011
MainComp$_{t-1}$ — member of main component	0	1	0.068	0.252
East	0	1	0.340	0.474
Public	0	1	0.023	0.149
Individual	0	1	0.618	0.486

4 Regression Model

The regression analyses reported in this section take account of the discrete nature of our dependent variable (number of patents) and therefore are based on two different methods for count data regression. These are the ordinary Poisson model and the zero-inflated generalised Poisson model which are briefly explained in the following.

Ordinary Poisson Regression Model: Let $y_i \in \{0, 1, 2, ...\}$ denote the number of patents that an actor i applied for at the German Patent Office. The ordinary Poisson regression model treats the dependent variable of the model as following a Poisson distribution with mean λ, i.e. $\Pr(y_i) = \exp(-\lambda) \cdot \lambda^{y_i}/y_i!$. Letting the mean of the dependent variable depend on explanatory variables collected in the vector $\boldsymbol{x}_i$ via the relation $\lambda(\boldsymbol{x}_i) = \exp(\boldsymbol{x}_i'\boldsymbol{\beta})$, where $\boldsymbol{\beta}$ denotes the vector of regression parameters to be estimated, the conditional distribution of y_i given $\boldsymbol{x}_i$ can be stated as

$$\Pr(y_i|\boldsymbol{x}_i) = \exp(-\lambda(\boldsymbol{x}_i)) \cdot \lambda(\boldsymbol{x}_i)^{y_i}/y_i!.$$

Cameron and Trivedi (1998, ch. 3) provide a comprehensive treatment of the Poisson regression model. The estimates reported in this paper are computed using the function `poisson` of the "Zelig" package for R (see Imai et al., 2007).

One main deficiency of the ordinary Poisson regression is the so-called equidispersion property of the Poisson distribution, meaning the equality of mean and variance. In real data situations the variance is frequently larger than the mean, leading to the overdispersion phenomenon. For that case a count data regression based on the negative binomial distribution has been developed. This NegBin regression is, however, difficult to estimate which manifests in the frequent non-convergence of numerical optimisation procedures. Even when applying the NegBin regression the number of zeros in the data may be substantially larger than what is consistent with the negative binomial distribution. To deal with this case of zero-inflation other count data models have been developed (see again Cameron and Trivedi, 1998, ch. 3).

Zero-Inflated Generalised Poisson Regression Model: In recent years the literature developed towards regression models based on the generalised Poisson distribution as an alternative to the negative binomial distribution. The generalised Poisson distribution is constructed as a mixture of simple Poisson distributions, analogous to the derivation of the negative binomial distribution as a particular gamma mixture of simple Poisson distributions. Fits of both models are often quite similar as pointed out by Joe and Zhu (2005) but generalised Poisson regression estimation appears to be more stable from a computational point of view (see Famoye and Singh, 2006). Since we suspect overdispersion as well as zero-inflation in our data we choose the more numerically stable zero-inflated variant of the generalised Poisson regression model (ZIGP) originally developed by Famoye and Singh (2003) in the form described in Czado et al. (2007). Experiments with the NegBin regression in fact demonstrated the convergence problems for the case of our dataset.

In its most general form the density function of the ZIGP model can be stated as

$$\Pr(y_i) = \begin{cases} \omega + (1-\omega)\cdot \exp(-\mu/\phi) & \text{for } y_i = 0 \\ (1-\omega)\,[\mu(\mu+(\phi-1)y_i)^{y_i-1}/y_i!]\cdot \phi^{-y_i}\cdot \exp(-(\mu+(\phi-1)y_i)/\phi) & \text{for } y_i > 0 \end{cases}$$

(see Czado et al., 2007, p. 127) together with some restrictions on the parameters. This distribution contains the ordinary Poisson distribution as a special case for $\phi = 1$ and $\omega = 0$. Mean and variance are given by

$$\mathrm{E}(y_i) = (1-\omega)\mu \quad \text{and} \quad \mathrm{V}ar(y_i) = (1-\omega)\mu\cdot(\phi^2+\mu\omega).$$

Since the computation of our `mle.zigp` estimates is performed using the "ZIGP" package for R, we rely on the particular parametrisation of the model given in the documentation of Czado et al. (2007) accompanying the package. Thus we specify the influence of the explanatory variables on the mean by letting μ depend on $\boldsymbol{x}_i$ in the form $\mu(\boldsymbol{x}_i) = \exp(\boldsymbol{x}_i'\boldsymbol{\beta})$. The overdispersion level is parameterised by $\phi = 1 + \exp(\alpha)$, where α is the parameter that is actually computed. Note that with this parametrisation the overdispersion level is guaranteed to be larger than one, irrespective of the level of α. Finally, the zero-inflation level is parameterized by $\omega = \exp(\gamma)/(1+\exp(\gamma))$, where γ is the parameter that is actually computed. Here the logistic transform bounds the zero-inflation level in the interval $(0, 1)$, irrespective of the value for γ. In principle ϕ and ω could also be made dependent on explanatory variables which may or may not overlap with those in $\boldsymbol{x}_i$. In our estimates we treat them as constant and simply report the estimates for a and γ as the levels of overdisperison and zero-inflation, respectively.

The asymptotic theory associated with the ZIGP model is not the standard one for generalized linear models since the ZIGP distribution does not belong to the exponential family of distributions. A brief discussion of consistency and asymptotic normality of the maximum likelihood estimates appears in Czado et al. (2007). The standard errors on which the t-statistics reported in this paper rely on an estimate of the covariance matrix based on the Fisher information.

Construction of the R^2 Measure: The R^2 measure we report in the tables below is simply the squared correlation of the value of the dependent variable with the predicted values of the respective model. This measure can be more intuitively interpreted for intermediate values compared to log-likelihood ratio indices.

5 Results

Table 2 presents the regression results obtained with the ordinary Poisson and the zero-inflated generalized Poisson (ZIGP) estimation methods and the two variants of the gatekeeper index. In all cases the dependent variable is the number of patent applications of the agents (private firms, public institutions or individual innovators) during the period 1999-2001.

Focusing first on the Poisson regressions we observe the usual finding of persistence in innovative success. This becomes evident for the coefficient associated with the lagged number of patent applications (here during the period 1995-1997) which is statistically significant with a very large value of the t-statistic. Agents that were successful innovators in the past are very likely to be so in the future.

Also significantly positive is the number of inventors involved in generating the inventions and therefore in the patenting process. We interpret this result as the effect of the variety of different experiences that inventors are able to contribute in the research process. This interpretation is also related to the notion of absorptive capacity (Cohen and Levinthal, 1990) since more inventors involved generate a greater variety of ideas out of a larger range of different experiences accumulated in the course of their past research endeavors.

The next variable is concerned with the degree of an innovator in his respective network. This variable is significant throughout and reveals that a larger number of different research partners leading to a greater variety of relations in the network promotes innovative success.

The effect of the intensity of a gatekeeper position on innovative success is here investigated with a quadratic specification. One central result is that being in a gatekeeper position is not unequivocally beneficial for innovative success. The significantly negative coefficient for the linear term together with the significantly positive coefficient for the quadratic term together imply a U-shaped form of the relation of the gatekeeper position

Table 2: Baseline Regression Results

Dependent Variable: No. of Patents (1999–2001), $t-1$ = 1995–1997				
	Poisson		ZIGP	
Intercept	0.8970	0.8855	0.9236	0.8978
	(27.2696)	(27.4552)	(7.9156)	(7.0710)
No. of Patents$_{t-1}$	0.0222	0.0222	−0.0078	0.0238
	(28.0800)	(28.6973)	(−1.3623)	(7.8109)
No. of Inventors$_t$	0.0042	0.0050	0.0201	0.0087
	(9.7987)	(12.0621)	(8.6225)	(5.3765)
Degree$_{t-1}$	0.1928	0.1785	0.1109	0.1048
	(12.1827)	(15.9154)	(2.6132)	(3.1108)
Gatekeeper1$_{t-1}$	−0.0441		−0.0241	
	(−8.6368)		(−1.6325)	
Gatekeeper1$^2_{t-1}$	0.0003		0.0003	
	(14.9055)		(4.0774)	
Gatekeeper2$_{t-1}$		−0.0507		−0.0528
		(−11.4769)		(−3.0745)
Gatekeeper2$^2_{t-1}$		0.0004		0.0006
		(18.4906)		(6.3067)
Betweenness$_{t-1}$	−31.3043	−33.7571	−39.8423	−49.3087
	(−24.6883)	(−26.1495)	(−7.1805)	(−8.9339)
MainComp$_{t-1}$	0.6184	0.6167	0.2396	0.2659
	(9.9017)	(9.9217)	(1.2235)	(1.3200)
East	0.0426	0.0373	−0.2480	−0.2584
	(1.0354)	(0.9080)	(−2.2613)	(−2.3310)
Public	0.4768	0.6159	1.1752	1.5073
	(8.2795)	(11.1949)	(6.0520)	(7.7846)
Individual	−2.1053	−2.1374	−1.0661	−1.0751
	(−34.7251)	(−34.6934)	(−9.5952)	(−9.4936)
Overdispersion			1.3204	1.2574
			(11.9376)	(11.4115)
Zero-Inflation			−9.4083	−2.8368
			(−0.2289)	(−3.0673)
R^2	0.779	0.792	0.761	0.815
$\ln L$	-3,058.7	-3,019.5	-1,560.0	-1,559.7
n	1,322	1,322	1,322	1,322

Note: t-statistics in parentheses

and innovative success. Only innovators with a gatekeeper index above a certain threshold are able to reap the benefits from their gatekeeper position. In the case of the first regression this threshold is at a gatekeeper index of about 70, implying that beyond this value innovative success increases whereas all innovators with a gatekeeper index below 70 may generate benefits for their regional innovation system as a whole but are not able to benefit individually from their position. These interpretations hold irrespective of the gatekeeper index variant used, just the threshold level drops to about 60 for ($Gatekeeper2$).

A large degree of betweenness, accruing when an innovator assumes a central position within the network, always has a significantly negative effect in these regressions. This appears to be puzzling and is difficult to reconcile with theoretical considerations. In the case of the dummy variable indicating membership in the main component (the largest connected part) of the network we observe significance only in the case of the Poisson regressions with a substantially (two- to three-fold) larger coefficient than in the ZIGP case. Membership in the main component is, however, in no case detrimental to innovative success as indicated by the positive sign of the respective coefficients.

Turning to the other variables, we find the dummy variable for innovators hosted in the former eastern part of Germany not to be significant statistically in the ordinary Poisson regressions. By contrast, the dummy variable for public institutions is associated with a significantly positive coefficient whereas the dummy variable for individual innovators acts significantly negative. Since the reference group against which these results have to be interpreted consists of private firms hosted in the western part of Germany this implies that individual innovators have a worse and innovators associated with public institutions have a better innovative performance compared to this reference group, holding the other variables constant.

Overall, the explanatory power is considerable as measured by the simple analog of R^2, which is computed by the squared correlation coefficient of the actual values of the dependent variable with the predicted values from the respective regression model. A slightly better fit is obtained for the second variant of the gatekeeper index.

From the ZIGP regression results we can infer that overdispersion is indeed present (the corresponding parameter is significantly positive) and that there also is some indication of zero-inflation, albeit statistically significant in just one case (the last regression reported in the table). Overall, the main conclusions from the ordinary Poisson regression not accounting for overdispersion and zero-inflation appear to be quite robust. Generally, it can be observed that the absolute magnitude of the t-statistics is reduced somewhat in the ZIGP case. The R^2 measure is about the same as before, again with the second index variant fitting slightly better.

Several differences of the ordinary Poisson and the ZIGP regressions have to be noted, however. First, the lagged number of patents is significantly positive in the ZIGP regressions only when the second variant of the gatekeeper index is used. This is quite surprising since the two index variants are highly correlated with each other. Related to that is the second notable difference, concerning the agreement of the results for the two gatekeeper indices. We obtain differing results for the lagged number of patents and the linear term of the gatekeeper variable. The linear term is not significant in the ZIGP regression with the first index variant but the coefficient estimate has the same sign. Most important for the interpretation of the influence of this variable is the quadratic term which is significantly positive in all cases. The threshold estimates, however, are reduced to values of about 43 and 45 for the two index variants. Third, the loss of significance and the substantial drop of the coefficient magnitude in the case of the main component variable has already been discussed above. Fourth, differences also show up in the case of the dummy variables. Here, the coefficient for innovators in the east turns significantly negative in the case of the ZIGP regressions. The coefficients of the dummies for public institutions and individual innovators become larger and smaller, respectively, in an absolute sense, while retaining sign and significance.

Overall, the main conclusions derived from the regressions, especially concerning the gatekeeper position appear to be robust across the different specifications.

6 Conclusions

We investigate the impact of actors' positions within four regional innovator networks on their innovative performance. Concerning the influence of a central network position on innovation output we find clear evidence on the positive role of the number of linkages on innovation. A larger number of linkages can be associated with a greater diversity of the knowledge bases which opens up opportunities for further advancements of knowledge. The positive effect of being in the main component of the respective network not only shows that direct relations determine the accessible knowledge pool but that also indirect contacts play an important role. However, we do not observe a positive effect of a central position as measured by the betweenness centrality. On the contrary, we are facing the puzzling result of a significant negative effect of this measure.

Motivated by the literature on regional innovation systems we pursue a further refinement of the analysis. Bathelt et al. (2004); Graf (2007) suggest that a blend of local and external relations is beneficial for the development of the entire innovation system, therefore we distinguish relations according to the location of partners. This leads us to our main research question which is concerned with the influence of gatekeepers on innovative performance. On the individual level we find that being a gatekeeper – characterised by multiple internal and external contacts – matters for innovative success. Our results suggest a U-shaped relation between the intensity of a gatekeeper position and innovation performance. Accordingly, it might be better to not be a gatekeeper at all than to just have few internal and external relations. It also implies that being a large gatekeeper is a particularly attractive position. This reflects a trade-off between two opposing effects: On the one hand, gatekeepers have privileged access to valuable external knowledge while on the other hand this knowledge leaks out in the process of diffusion which counteracts the exclusive usage of that knowledge. Overall, our findings suggest that gatekeepers provide some sort of public or club good to the innovation system as they are not able to reap all the benefits accruing from their brokering position. This finding is consistent with the observation of (Graf, 2007) that public research fulfills its function to collect and disseminate external knowledge.

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.

References

Ahuja, G. (2000). Collaboration networks, strucutral holes, and innovation: a longitudinal study. *Administrative Science Quarterly*, 45:425–455.

Allen, T. J. (1977). *Managing the Flow of Technology. Technology Transfer and the Dissemination of Technological Information within the R&D Organization*. MIT Press, Cambridge.

Almeida, P. and Kogut, B. (1999). Localization of knowledge and the mobility of engineers in regional networks. *Management Science*, 45(7):905–917.

Arundel, A. and Kabla, I. (1998). What percentage of innovations are patented? empirical estimates for european firms. *Research Policy*, 27(2):127–141.

Balconi, M., Breschi, S., and Lissoni, F. (2004). Networks of inventors and the role of academia: An exploration of italian patent data. *Research Policy*, 33:127–145.

Bathelt, H. (2003). In good faith? the "distanced neighbor" paradox: "overembedded" and "under-socialized" economic relations in leipzig's media industry. presented at the DRUID Summer Conference 2003, Copenhagen/Elsinore June 12-14, 2003.

Bathelt, H., Malmberg, A., and Maskell, P. (2004). Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography*, 28(1):31–56.

Borys, B. and Jemison, D. B. (1989). Hybrid arrangements as strategic alliances: Theoretical issues in organizational combinations. *Academy of Management Review*, 14:234–249.

Boschma, R. (2005). Proximity and innovation: A critical assessment. *Regional Studies*, 39(1):61–74.

Braczyk, H.-J., Cooke, P., and Heidenreich, M. (1998). *Regional Innovation Systems: The Role of Governances in a Globalized World*. UCL Press, London.

Breschi, S. and Lissoni, F. (2003). Mobility and social networks: Localised knowledge spillovers revisited. Working Paper 142, Cespri.

Breschi, S. and Lissoni, F. (2006). Mobility of inventors and the geography of knowledge spillovers: New evidence on us data. CESPRI Working Papers 184, CESPRI, Centre for Research on Innovation and Internationalisation, Universita' Bocconi, Milano, Italy.

Broekel, T. and Meder, A. (2008). The bright and dark side of cooperation for regional innovation performance. Jena Economic Research Papers in Economics 2008-053, Friedrich-Schiller-University Jena, Max-Planck-Institute of Economics, Thueringer Universitaets- und Landesbibliothek.

Butts, C. T. (2007). Software manual for the r sna package. Technical report, R package version 1.5.

Cameron, A. C. and Trivedi, P. K. (1998). *Regression Analysis of Count Data*. Cambridge University Press, Cambridge, Mass.

Cantner, U. and Graf, H. (2006). The network of innovators in jena: An application of social network analysis. *Research Policy*, 35(4):463–480.

Carayol, N., Roux, P., and Yildizoglu, M. (2008). Inefficiencies in a model of spatial networks formation with positive externalities. *Journal of Economic Behavior and Organization*, 67(2):495–511.

Carlsson, B. and Stankiewicz, R. (1991). On the nature, function and composition of technological systems. *Journal of Evolutionary Economics*, 1(2):93–118.

Cohen, W. M. and Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35(1):128–152.

Cohen, W. M., Nelson, R. R., and Walsh, J. P. (2000). Protecting their intellectual assets: Appropriability conditions and why u.s. manufacturing firms patent (or not). Technical report, NBER Working Paper No. W7552.

Combs, J. G. and Ketchen, D. J. (1999). Explaining inter-firm co-operation and performance: Toward a reconciliation of predictions from the resource-based view and organizational economics. *Strategic Management Journal*, 20:867–888.

Cowan, R., Jonard, N., and Zimmermann, J.-B. (2006). Evolving networks of inventors. *Journal of Evolutionary Economics*, 16(1-2):155–174.

Czado, C., Erhardt, V., Min, A., and Wagner, S. (2007). Zero-inflated generalized poisson models with regression effects on the mean, dispersion and zero-inflation level applied to patent outsourcing rates. *Statistical Modelling*, 7:125–153.

Eisenhardt, K. M. and Schoonhoven, C. B. (1996). Resource-based view of strategic alliance formation: strategic and social effects in entrepreneurial firms. *Organization Science*, 7(2):136–150.

Famoye, F. and Singh, K. P. (2003). On inflated generalized poisson regression models. *Advances and Applications in Statistics*, 3:145–158.

Famoye, F. and Singh, K. P. (2006). Zero-inflated generalized poisson regression model with an application to domestic violence data. *Journal of Data Science*, 4:117–130.

Fleming, L. and Frenken, K. (2007). The evolution of inventor networks in the silicon valley and boston regions. *Advances in Complex Systems*, 10(1):53–71.

Fleming, L., King, Charles, I., and Juda, A. I. (2007). Small worlds and regional innovation. *Organization Science*, 18(6):938–954.

Fritsch, M. and Slavtchev, V. (2008). Determinants of the efficiency of regional innovation systems. *Regional Studies*, 99999(1):1–1.

Gertler, M. (1997). The invention of regional culture. In Lee, R. and Wills, J., editors, *Geographies of Economies*, pages 47–58. Edward Arnold, London.

Giuliani, E. (2005). Cluster absorptive capacity: Why do some clusters forge ahead and others lag behind? *European Urban and Regional Studies*, 12(3):269–288.

Giuliani, E. and Bell, M. (2005). The micro-determinants of meso-level learning and innovation: evidence from a chilean wine cluster. *Research Policy*, 34(1):47–68.

Giuliani, E., Rabellotti, R., and Pietrobelli, C. (2005). Upgrading in global value chains: Lessons from latin american clusters. *World Development*, 33(4):549–573.

Gould, R. V. and Fernandez, R. M. (1989). Structures of mediation: A formal approach to brokerage in transaction networks. *Sociological Methodology*, 19:89–126.

Goyal, S. and Vega-Redondo, F. (2007). Structural holes in social networks. *Journal of Economic Theory*, 137(1):460–492.

Grabher, G. (1993). *The Embedded Firm: on the Socioeconomics of Industrial Networks*. Routledge, London and New York.

Graf, H. (2007). Gatekeepers in regional networks of innovators. Technical Report 2007-054, Jena Economic Research Papers.

Graf, H. and Henning, T. (2008). Public research in regional networks of innovators: A comparative study of four east german regions. *Regional Studies*, 99999(1):1–1.

Gulati, R. (1998). Alliances and networks. *Strategic Management Journal*, 19(4):293–317.

Hagedoorn, J. (1993). Understanding the rationale of strategic technology partnering: Inter-organizational modes of cooperation and sectoral differences. *Strategic Management Journal*, 14:371–385.

Hamel, G. (1991). Competition for competence and inter-partner learning within international strategic alliances. *Strategic Management Journal*, 12:83–103.

Imai, K., King, G., and Lau, O. (2007). *Zelig: Everyone's Statistical Software*.

Jackson, M. and Wolinsky, A. (1996). A strategic model of economic and social networks. *Journal of Economic Theory*, 71(1):44–74.

Jaffe, A. B., Trajtenberg, M., and Henderson, R. (1993). Geographic localization of knowledge spillovers as evidenced by patent citations. *Quarterly Journal of Economics*, 108(3):577–598.

Joe, H. and Zhu, R. (2005). Generalized poisson distribution: The property of mixture of poisson and comparison with negative binomial distribution. *Biometrical Journal*, 47:219–229.

Kim, S.-R. and von Tunzelmann, N. (1998). Aligning internal and external networks: Taiwan's specialization in it. SPRU Working Paper (SEWPS) 17, University of Sussex, Brighton.

Kogut, B. (1989). The stability of joint ventures: Reciprocity and competitive rivalry. *Journal of Industrial Economics*, 38(2):183–198.

Lazaric, N., Longhi, C., and Thomas, C. (2008). Gatekeepers of knowledge versus platforms of knowledge: From potential to realized absorptive capacity. *Regional Studies*, 42(6):837–852.

Lazerson, M. H. and Lorenzoni, G. (1999). The firms that feed industrial districts: A return to the italian source. *Industrial and Corporate Change*, 8(2):235–266.

Lundvall, B.-A., editor (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. Pinter Publishers, London.

Mairesse, J. and Mohnen, P. (2003). Intellectual property in services: What do we learn from innovation surveys? In *Patents, innovation and economic performance*, pages 227–245. OECD, Paris.

Malerba, F. (2002). Sectoral systems of innovation and production. *Research Policy*, 31:247–264.

Martin, R. E. and Justis, R. T. (1993). Franchising, liquidity constraints and entry. *Applied Economics*, 25:1269–1277.

Morrison, A. (2008). *Gatekeepers of Knowledge* within industrial districts: Who they are, how they interact. *Regional Studies*, 42(6):817–835.

Mowery, D. C., Oxley, J. E., and Silverman, B. S. (1998). Technology overlap and interfirm cooperation: Implications for the resource-based view of the firm. *Research Policy*, 27(5):507–523.

Munari, F., Malipiero, A., and Sobrero, M. (2005). Focal firms as technological gatekeepers within industrial districts: Evidence from the packaging machinery industry. *SSRN eLibrary*, page 717702.

Nelson, R. R., editor (1993). *National Innovation Systems: A Comparative Analysis*. Oxford University Press, New York.

Nelson, R. R. and Winter, S. G. (1982). *An Evolutionary Theory of Economic Change*. Belknap Press, Cambridge, Mass.

Penrose, E. T. (1959). *The Theory of the Growth of the Firm*. Wiley, New York.

Powell, W. W. (1990). Neither market nor hierarchy: Network forms of organization. *Research in Organizational Behavior*, 12:295–336.

Powell, W. W., Koput, K. W., and Smith-Doerr, L. (1996). Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. *Administrative Science Quarterly*, 41(1):116–145.

Saxenian, A. (1994). *Regional Advantage*. Harvard University Press, Cambridge.

Shane, S. A. (1996). Hybrid organizational arrangements and their implications for firm growth and survival: A study of new franchisors. *Academy of Management Journal*, 39:216–234.

Singh, J. (2005). Collaborative networks as determinants of knowledge diffusion patterns. *Management Science*, 51(5):756–770.

Steiner, M. and Ploder, M. (2008). Structure and strategy within heterogeneity: Multiple dimensions of regional networking. *Regional Studies*, 42(6):793–815.

Storper, M. and Venables, A. J. (2004). Buzz: Face-to-face contact and the urban economy. *Journal of Economic Geography*, 4(4):351–370.

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(6):777–791.