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## Structural dynamics of innovation networks in German Leading-Edge Clusters

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**Abstract**

We study the effects of a German national cluster policy on the structure of collaboration networks. The empirical analysis is based on original data that was collected in fall 2011 and late summer 2013 with cluster actors (firms and public research organizations) who received government funding. Our results show that over time the program was effective in initiating new cooperation between cluster actors and in intensifying existing linkages. Newly formed linkages are to a substantial amount among actors who did not receive direct funding for a joint R&D project, which indicates an additional, mobilisation effect of the policy. Furthermore, we observe differential developments regarding clusters' spatial embeddedness. Some clusters tend to increase their localisation, whereas others increase their connectivity to international partners. The centrality of large firms increased over time, indicating their prominent role as preferred partners for R&D cooperation within the clusters while it is the opposite case for public actors.

**Keywords**: Cluster, Innovation Policy, Evaluation, Social Network Analysis

**JEL Codes**: O38, L14, R10

# 1 Introduction

Over the last decades a distinctive shift in innovation policy in Germany and many other countries towards an increased funding of cooperative R&D was observable (Fier and Harhoff 2002). In the past years, competitive allocation of research funds to network and cluster initiatives pushed this trend even further by adding a regional perspective, by increasing the scope of funding, and by fostering interaction between a large number of actors. Prominent examples of these policies in Germany are the competitive programs BioRegio and InnoRegio (Dohse 2000; Eickelpasch and Fritsch 2005; Engel et al. 2013). In the context of its high-tech strategy the German ministry for education and research (BMBF) started the "Leading-Edge Cluster competition" (LECC) (Spitzencluster-Wettbewerb) in 2007. The conceptual foundation of this and related policies is mainly to be found in the literature on clusters, but also on regional innovation systems and innovation networks. At the core of the LECC is the funding of R&D cooperation within concrete projects and pools of joint R&D projects on a specific topic or problem with high innovation opportunities. From a network perspective, this policy approach aims at establishing new linkages (initiated linkages) or strengthening existing ones (intensified linkages) of R&D-cooperation networks.

As yet, empirical validations of the benefits of the policy impact on the process of cluster formation, development, and success are (more than) sparse (Martin and Sunley 2003; Duranton 2011). Since evaluations, especially of innovative funding schemes, are crucial for learning of the adaptive policy maker (Metcalfe 1995) there is obviously a need for such kind of an empirical analysis. Following the suggestions of Giuliani and Pietrobelli (2011) and building on the previous analysis by Cantner et al. (2013), we employ social network analysis to study the influence of the LECC on interaction structures. Our goal is to identify to which extent the LECC influences the structure of the network of the most important R&D-cooperation partners within the funded clusters. This impact can appear directly through the funding of joint research projects or indirectly through a mobilisation effect of the policy representing an additional value besides the research grants. Therefore we focus especially on R&D-cooperation and the corresponding networks covering various kinds of actors engaged in R&D and innovation processes such as firms, research institutes and universities within and outside of the funded cluster. Our analysis does not explicitly consider the specifics of bilateral cooperation but focusses on the general embeddedness of network actors into the network to identify especially the structural effects of the policy.

The paper is structured as follows: section 2 covers the theoretical background for our analysis as well as some general description of the LECC. In section 3 we introduce our data and research setup and in section 4 we present our results concerning the impact of the LECC on the structure of R&D cooperation networks. In section 5 we move to the micro level and study changes of network positions due to the LECC. Section 6 concludes.

# 2 R&D cooperation and the "Leading-Edge Cluster Competition"

## 2.1 Rationale for cluster policies

Due to the increasing complexity of new knowledge, outsourcing of specialized tasks within the knowledge creation process has become more and more important (Chatterji 1996). Therefore, the level of openness and the distribution of tasks within the knowledge and innovation generation process have increased over the last years (Coombs et al. 2003). The positive effect of cooperation, networking and interconnectedness on the innovative success of innovation oriented actors has been shown by many authors (Freeman 1991; Lundvall 1992; Cantner and Graf 2006; Schilling, Phelps 2007; Breschi and Lissoni 2009; Cantner et al. 2010; Graf and Krüger 2011). Such cooperation can be bilateral – between two partners – or multilateral – between a group of actors trying to solve a general or concrete (technological) problem together as a kind of formal or informal research consortium or simply as joint research project. An active participation in innovation related networks can be an important mechanism for firms as well as for research institutes and universities to gain access to external knowledge sources. On the one hand it fosters the creation of new knowledge via the exchange of knowledge and information and by combining complementary capabilities (Granovetter 1973; Ahuja, 2000) and on the other hand it provides a possibility for monitoring and controlling actual developed knowledge (Powell et al. 1996). The diffusion of knowledge is accomplished via different transmission channels, such as joint activities within formal industrial networks or clusters, through joint R&D projects or simply through informal contacts between employees/researchers of different firms, universities or research institutes (Cowan and Jonard 2009).

There is a positive correlation between the centrality of an actor inside a network and its innovative success by the fact of a better direct and indirect access to different sources of knowledge within the whole network (Ahuja 2000; Schilling and Phelps 2007). Furthermore the structure of a network influences the communication and the knowledge flows within all involved actors and has an effect on the general availability of knowledge and thereby on the innovative success (Cowan and Jonard 2004;

Fleming et al. 2007). However it is very difficult to state which structure of a network fosters especially innovation because the correlation between network structure and innovation depends strongly on the innovative environment (Rowley et al. 2000; Verspagen and Duysters 2004). Nevertheless, Fleming et al. (2007) and by Schilling and Phelps (2007) suggest that network connectedness – characterized by high density or few components – and a medium centralization affect the performance of networks positively. While centralization fosters communication and the speed of knowledge diffusion, it can also indicate a high dependence on single actors and leads to an unequal knowledge distribution.

Becker and Dietz (2004) amongst others show that joint R&D enhances the realization of innovation. A lack of cooperation could therefore be interpreted as a system failure in which possibilities for improving innovative performance of an industry or a cluster remain unexploited. In case of such a system failure, policy interventions in the form of promoting joint R&D activities can help to overcome this problem and increase innovative activities. The success of such policies depends last but not least on actor characteristics. In the literature on absorptive capacity the role of the own knowledge stock to be able to understand and to implement external knowledge has been widely discussed (Boschma and Wal 2007). The same holds also for R&D cooperations, which are according to Gomes-Casseres et al. (2006) the most important source for accessing external knowledge. Miotti and Sachwald (2003) argue that for successful cooperation in general firm's characteristics are more important than a specific cooperation that is publicly promoted and Boschma (2005) rules out the importance of (social) proximity between actors to create a "climate of trust" that foster collaboration. Consequently it is not sufficient for a policy that tries to stimulate cooperation within a cluster or a region to promote joint R&D activities but it also needs some mechanism to help actors to find the right and fitting partners. Duranton (2011) points out that cluster policies need to solve coordination problems among the involved actors and therefore create safety in a highly uncertain world without being captured by any group of interests. If policies fail in this respect, expected productivity gains will not occur as observed in the case of the French cluster policy "Systèmes Productifs Locaux" (Martin et al. 2011).

## 2.2 Leading-Edge Cluster Competition

As a follow up to competitive policy programs in Germany, such as BioRegio and InnoRegio, the German ministry for education and research (BMBF) started the LECC in 2007 as one prominent instrument within its high-tech strategy. The aim of this program is to strengthen innovative capabilities and to support highly productive and efficient regional clusters to achieve or to maintain international leadership. Hence, regional innovative capacities should be exploited via innovations leading in the end to economic growth. To address these targets, different opportunities had been established to create an innovative environment or to increase innovative performance inside a region due to intensified R&D cooperation between different actors like firms, research institutes and universities.

Within this program, 15 clusters were selected in three waves (in 2008, 2010 and 2012) and received a funding up to 40million Euro each for a five-year period. The funding was split into two phases – 20million Euro each – where the allocation of the second one depends on a positive evaluation of the achievements of the cluster and the success of the realised projects herein after two years. The initiative was open to all kinds of technologies and the selection of successful clusters was consigned to an independent jury of renowned experts from industry and academia. In order to foster the innovative success of the clusters the BMBF formulated different requirements. The following two are in our opinion the most important ones: First, the applying clusters needed to have a central cluster management coordinating to some extend the activities within the cluster. This management also serves as intermediary between cluster actors, linking those with complementary competencies. As such, the LECC implements the function of local coordination among cluster actors as required by Duranton (2011). The stimulation of an additional goal of the LECC – to link scientific and economic actors – could be increased through this institution. To increase the quality of the project portfolio the cluster applied for funding with, these cluster managements organised together with a committee of actors a preselection of projects. Furthermore in most of the funded clusters these managements offer also additional services to the cluster partners. Second, a common strategy linking the different R&D projects of the cluster – that applied for funding – to one vision for the whole cluster and cluster region has been required. A broad commitment to this strategy could be achieved by establishing a formal cluster organisation in which all potentially funded actors participate. At the same time social proximity among the cluster actors increased through this shared membership and commitment to the strategy. Therefore an increased probability for cooperation and also innovative success could be expected (Boschma 2005). The abandonment of the LECC to strict regimentation regarding cluster organisation and composition of actors led to a large heterogeneity between the clusters in terms of technological focus, formal structure and existing boards, as well as the set of activities within the clusters and their managements. But also the size of their geographical areas and distances within cluster boundaries differ substantially due to the open interpretation of the cluster concept.

# 3 Data, Methodology and Variables

Our analyses are based on primary data collected with members (firms, universities and research organizations) of the five successful clusters of the first wave of the LECC (in 2008) which all also received funding for the second period. We study the networks of most important cooperation partners and focus on their actor composition as well as their geographic reach. Structural changes of these networks are considered and the presumed policy influence is investigated. Since the LECC initiative was open to all kinds of technologies our sample clusters differ quite recently. The first cluster – "BioRN" – belongs to the field of red biotechnology – and therefore many actors can be assigned to the pharmaceutical industry supplemented by knowledge intensive services from life science and software development. Due to this composition small-or-medium-sized enterprises (SMEs) are the majority of cluster actors in BioRN. However large pharma companies play still an important role because innovative SMEs mainly focus on them as costumers. The reason for that is the difficulty to emerge from a SEBCO (Small Emerging Biopharmaceutical Company) to an FIBCO (Fully Integrated Biopharmaceutical Company) coming from heavily increasing cost during later stages of R&D projects. That's why large firms often take over these projects via licencing or even take over the whole SME. The second one – "Cool Silicon" – focuses on an increased energy efficiency in microelectronics. Consequently the cluster actors are related to electronic semiconductors and electronic devices as well as medical technology and industrial process and control technology. Additional knowledge intensive services are related to engineering and software development. In contrast to other large IT-clusters like the Silicon Valley in the USA, R&D activities and productive activities are not decoupled from each other. The technological core area of the third cluster – the "Solarvalley" – is silicon based photovoltaic but also the thin film technology is present. Its value creation chain is closely related to the semiconductor industry, that's why cluster actors focus, like in Cool Silicon, on electronic semiconductors and electronic devices but also on fine mechanical optical devices, mechanical testing machinery and production of optical instruments. The joint aspect of this cluster at its origin was the vision to achieve grid parity in 2015. That's why the R&D activities within this cluster are in comparison to the others more application-oriented helping also to increase the accuracy of fit among different steps of the value creation chain. "Hamburg Aviation", the fourth cluster of our sample, covers two aspects. On the one hand there are aerospace technology and engineering, especially development, construction and production of cabin systems together with innovative applications for fuel cells and on the other hand a lot of actors with broader spectrum of services related to aeronautical technics and air traffic. Beside a few large anchor companies as well as several research institutes and universities the cluster includes a reasonable amount of SMEs The technological focus of the cluster actors is much broader than the actual cluster concept and covers a heterogeneous field of knowledge intensive services from natural science to software development. The main focus within the last cluster in our sample – "Forum Organic Electronics" (FOE) – is the quite new cross-section technology organic electronic, which offers a lot of potential applications for the processing industry. The actors mainly focus on more advanced or even high tech applications of this young technology. Due to the novelty of the technology and a strong focus on basic research the composition of cluster actors is dominated by large companies as well as renowned research institutes and universities. The number of small-or-medium-sized enterprises in comparison to the other four clusters is relative low. Within "FOE" the cluster actors concentrate their R&D activities on organic LED, organic photovoltaic, organic sensors and organic memories and circuits.

The data for our empirical analysis was collected in fall 2011 and late summer 2013 from actors of the clusters who received a government grant within the cluster initiative. For the reconstruction of the networks, these actors were asked to provide the names and addresses of up to ten of their most important R&D-partners. In addition, we asked the respondents to provide supplementary information regarding the properties of these linkages. Most importantly, we asked if the partnership was initiated by the LECC, if it existed before the contest was started in September 2007 and if in that case the linkage was intensified through the LECC. Furthermore, we asked for typical actor characteristics. To complete our data, we conducted several interviews with different actors to obtain qualitative insights on the clusters.

For the questionnaire, we chose a free recall design for several reasons. First, we wanted to avoid a strict limitation in the size of the networks that would result if we had presented a list of potential partners, i.e. cluster actors. In addition, this list would have been based on information provided by the respective cluster management and the governmental project management. However, both apply different definitions of the respective clusters which would have led to biases in the geographical and technological demarcation of the clusters and associated problems in comparing the clusters. Second, with a predefined list of actors, we would not have been able to identify linkages with partners that are not members of the cluster. However, since these external linkages – often with more geographically distant partners – are highly relevant for innovative success (Bathelt et al. 2004), the information about partnerships with these external actors is crucial for evaluating the effects of the LECC on the network structures. Finally, a predefined list of actors filled with cluster members would have biased responses towards these actors, even if we would have allowed for adding important R&D-partners to this list.

Table 1 delivers a summary of the data with respect to the total number of identified nodes within all networks, the composition of networks in terms of actor type (large company, small-or-medium-sized enterprise (SME), university, or research institute) and the geographical dimension of actors and linkages. The data for 2007 is based on our questionnaire in 2011 and covers all nodes and linkages that have been reported as existing already before the beginning of the LECC – if the cooperation already was established before September 2007. Therefore the response rate for 2007 and 2011 are identical and 2007 is to be viewed as a subset of the "true" 2011 network.

**Table 1: Description of the dataset**

| | total sample (all clusters) | | |
|---|---|---|---|
| | 2007 | 2011 | 2013 |
| Sample size (beneficiaries) | 136 | 136 | 178 |
| Number of Answers (related to network question) | 65 | 65 | 94 |
| …large companies | 16 | 16 | 21 |
| …SME | 29 | 29 | 29 |
| …Universities | 10 | 10 | 11 |
| …Research institutes | 10 | 10 | 18 |
| Response rate (item related) | 47.8% | 47.8% | 52.8% |
| Actors: no. of nodes | 188 | 285 | 319 |
| Cluster members: no. of nodes being member of the cluster association | 101 | 132 | 135 |
| Actor located in cluster region | 49.5% | 45.3% | 41.7% |
| ... in Germany | 39.4% | 38.6% | 39.5% |
| ... in Europe | 6.9% | 7.7% | 8.5% |
| ... outside Europe | 4.3% | 8.4% | 9.1% |
| Number of linkages | 171 | 380 | 463 |
| ... into cluster region | 49.7% | 55.5% | 55.5% |
| ... to Germany | 38.0% | 32.4% | 31.5% |
| ... to Europe | 7.6% | 5.8% | 5.8% |
| ... to outside Europe | 4.7% | 6.3% | 6.3% |

Our sample consists of two different types of actors, those that are part of the formal cluster organization/association and those without a formal membership. The former are defined as having received funding within the LECC. However, not all of them are respondents in our sample. If they chose not to provide answers to our questionnaire, they can still appear within the networks if named as an important partner for at least one of the respondents. While cluster members are typically but not exclusively located within the cluster region, the overall networks are geographically more dispersed.

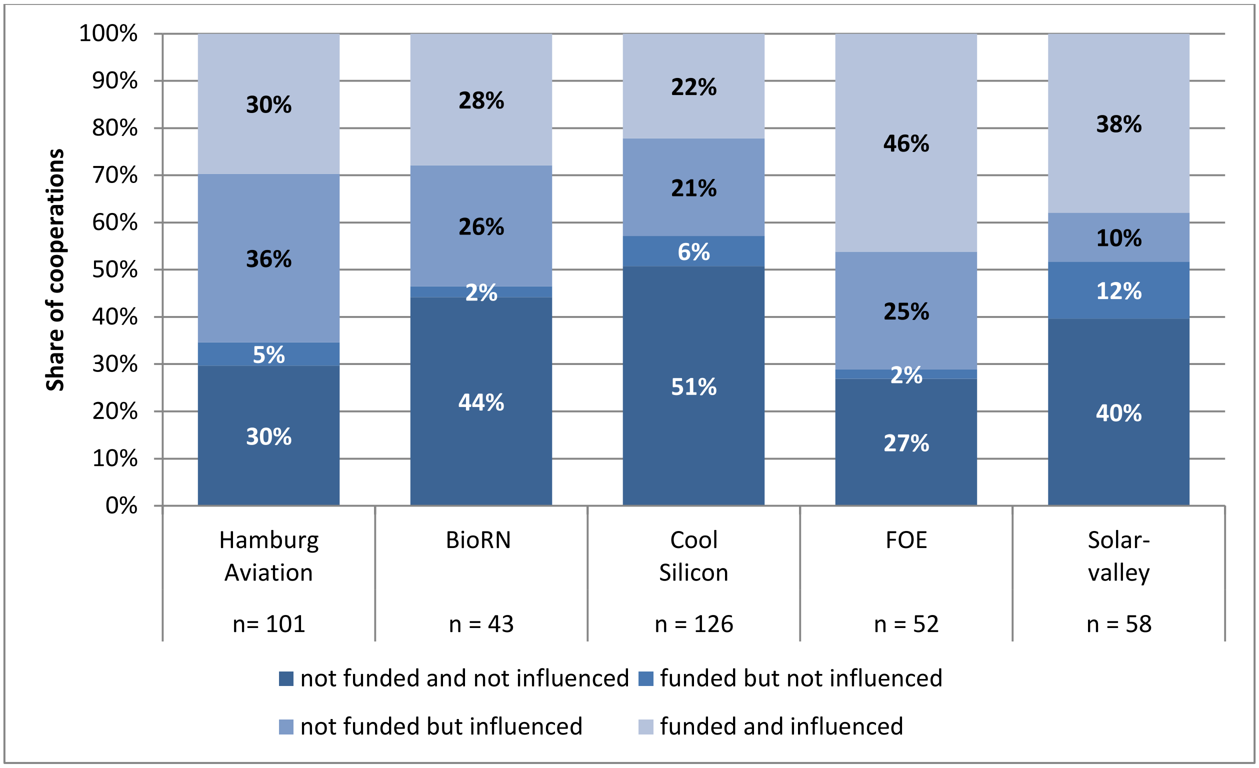
Still, the majority of all actors are located inside the cluster region or inside Germany and only 11.2% (in 2007) to 17.6% (in 2013) are international collaboration partners. R&D cooperation with partners inside the cluster region account for roughly half of all linkages, those with partners inside Germany make up one third, and only a small fraction is related to a region outside Germany. Since we collected our data from actors that are mostly located inside the cluster region this pattern of the geographical distribution of linkages is not surprising and the interviews with funded actors confirmed that they prefer geographically close partners. Also Feldman (1999) and Boschma (2005) rule out, that geographical closeness is an important determinant for successful cooperation that fosters the innovative and economic success of a cluster. Only if no competent partners reside within the cluster region, actors cooperate with external partners, and search rather national than international. Nevertheless roughly 50% of the strategically important R&D partners are not located inside the core region of the cluster. The linkages to these actors provide access to external knowledge hubs completing the available knowledge inside the cluster and as Bathelt et al. (2004) point out, beside the internal ones these external partners are important sources of knowledge fostering the innovative success of a cluster additionally. Without these external linkages a cluster would face a large danger of a regional Lock-in (Bathelt et al. 2004, Boschma 2005). Slight differences between the clusters regarding the geographical distribution of linkages, as shown by Cantner et al. (2013), are due to peculiarities of the technological systems the clusters belong to but are neglected at this point.

# 4 Influence of the LECC on R&D networks

To identify the general impact of the LECC on R&D networks of the clusters, we rely on two attributes of the linkages. We know if reported linkages are also funded by the LECC and if they are perceived to be influenced by the LEEC. These two dimensions lead to four classes of linkages, namely “not funded and not influenced”, “funded but not influenced”, “not funded but influenced”, and “funded and influenced”. We draw the information on funded versus not funded partnerships from data provided for our evaluation project by the BMBF and partially from the publicly available database “foerderkatalog.de” about project funding of the German government. The information on LECC influence is based on a self-assessment within our survey, where we asked the respondents to provide us with additional information for each of their strategic R&D cooperations. A cooperation is influenced, if it was reported to be either intensified or initiated through the LECC.

Figure 1 illustrates for 2011 that the establishment of new linkages and the intensification of existing ones occurs not only via funded joint research projects. A mobilisation effect of the LECC can be assumed for those linkages that are either intensified or initiated but did not receive public funds for a collaborative project. The share of these partnerships ranges between 10% and 36%, which shows that beside the direct effects of the policy – the funding of concrete joint R&D projects – a non-negligible indirect impact exists. One reason for these indirect effects could be the common membership in a funded cluster and the related commitment to a joint strategy of the whole cluster – which is one of the specific attributes of the LECC. Through this membership the visibility of actors and their expertise increased and new potential partnerships among cluster actors are exploited. At the same time the accessibility of prominent actors increased, allowing other actors more easily to cooperate with these prominent ones. This was for Hamburg Aviation – the cluster with the largest mobilisation effect – the case, where through the cluster formation process the openness for new cooperations of the established large companies such as “Airbus” or “Lufthansa Technik” increased. During our interviews representatives of SMEs confirmed that thanks to the cluster creation process it was much easier to meet these large companies at eye level that fostered the formation of new cooperations with them. Simultaneously with the development of the joint cluster strategy missing competences among the cluster actors could be identified and as a result of the following search process for partners providing these competences, new partnerships could be established to remedy this shortage. Nevertheless, we also observe the opposite case of free-riding – funded but not intensified linkages – but on a lower level (2% to 12%). The largest share of free-riding (12%) was reported from Solarvalley. This fact is not surprising for the photovoltaic industry since secrecy was reported during our interviews as the main strategy to protect newly gained knowledge. Consequently trust among partners was a dominant precondition for cooperation – especially in the field of R&D. Therefore a reasonable share of LECC funded joint projects was between actors that had already established partnerships through former cooperations. The prosperous establishment of a new partnership happened mostly through a third, well-known cooperation partner, who already experience cooperated successful with the unknown partner. The net effect of mobilisation and free-riding for the R&D cooperation networks remains positive in all clusters except one (Solarvalley) of the first wave of the LECC.

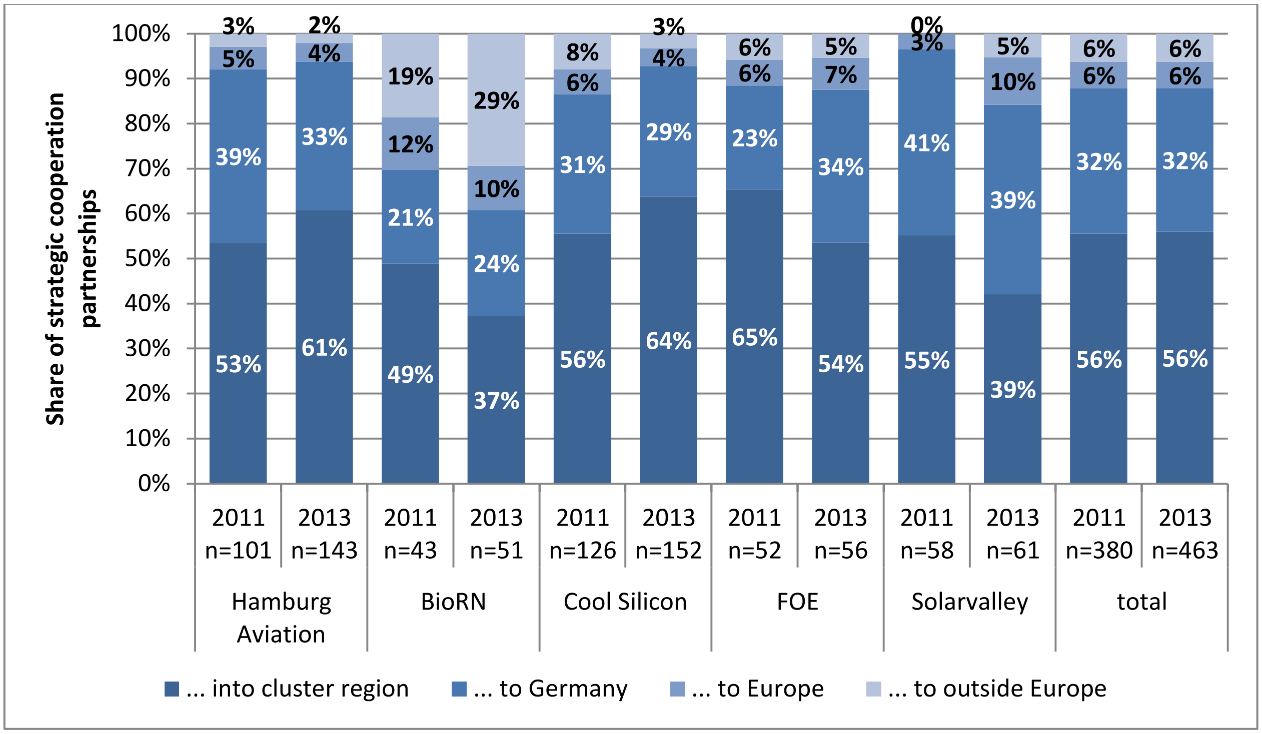
**Figure 1 Impact of the Leading-Edge Cluster competition on strategic cooperation in 2011**




n: number of linkages

The geographical range of the networks differs among the observed clusters and we also observe different trends during the time of funding through the LECC (figure 2). First there are Hamburg Aviation and Cool Silicon that tend to localize with an increased share of linkages into the cluster region. The LECC helped both clusters to discover and exploit additional regional capacities. Second, BioRN and Solarvalley become more international orientated. For Solarvalley this trend can be explained by the fundamental changes of the market environment and the corresponding strategy change of the cluster during this process. At least there is FOE, where the local linkages decrease in favor of a stronger national focus. Interestingly, the geographical composition within the whole sample of observed network nodes does not change from 2011 to 2013 even if the total amount of actors increased. This means that an assessment based on aggregate statistics, ignoring cluster specific developments, might well lead to wrong conclusions regarding the effects of cluster policies.

**Figure 2: Geographical distribution of most important R&D partnerships**




n: number of linkages

For an additional analysis, we distinguish the influenced linkages as intensified or initiated. The former are defined as linkages that already existed before the LECC and are influenced by the LEEC; the latter are linkages that were reported to have been established because of participating in the LECC. The first three rows of table 2 show for each cluster that a substantial share of the identified linkages has been influenced by the LECC, either as being intensified or being initiated. Especially in Hamburg Aviation and FOE more than the 50% of all linkages, which existed already before the introduction of the LECC in 2007, were intensified by the policy. In the other three clusters one third of the existing links in 2007 were intensified by the LECC. This high share of strategic R&D cooperation that was intensified by the cluster policy reflects a first, short run impact of the policy. In these cases, already existing structures of the network of strategic important R&D cooperation were strengthened due to the introduction of the policy. The influence of the LECC on the network changes over time. In 2011, the influence is mainly through new partnerships (initiated) whereas the strengthening of existing linkages (intensified) is relatively more frequent in 2013. In addition to that, we report in table 2 the network density among respondents, the indegree centralization based on the whole sample of linkages and the indegree centralization without the initiated linkages. For the period 2007 to 2011 we also observe an increase in network density (realized linkages divided by all possible linkages). This fact shows the increasing interconnectedness between the funded actors. Considering the observations in 2013, an increasing network density seems to be sustained at least for the Hamburg Aviation, Cool Silicon and FOE. Here the increase in interconnectedness remains stable over the time of governmental funding.

All five case study clusters are centred around one or more prominent global players and/or an excellent research institute or university. As such, observing a moderate or high degree of network centralization is no surprise. However, ex ante it is unclear in which way the LECC influences the network structure in terms of centralization. If peripheral actors grab the opportunity to connect with the more prominent central actors, we would observe an increase in centralization, whereas if peripheral actors learn about each other and become aware of their complementary capabilities, centralization should decrease. We decided to calculate network centralization based on actors' indegree which is independent of own responses to avoid noise from the fact that not all actors answered to our questionnaire. We observe an increasing centralization in all but one network during the funding period from 2011 to 2013. This result also holds if we calculate centralization without links that were initiated by the LECC. That means that each network, with exception Solarvalley, tends to focus more on single core actors. These actors mostly play a prominent role inside the technological field of the cluster but also inside the associated cluster organization.

**Table 2: Influence of the "Leading-Edge Cluster Competition" (cluster wise)**

| | Hamburg Aviation | | | BioRN | | | Cool Silicon | | | FOE | | | Solarvalley | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 | 2011 | 2013 | 2007 | 2011 | 2013 | 2007 | 2011 | 2013 | 2007 | 2011 | 2013 | 2007 | 2011 | 2013 |
| Initiated linkages by LECC | - | 45.5% | 25.9% | - | 41.9% | 27.5% | - | 20.6% | 27.6% | - | 53.8% | 35.7% | - | 34.5% | 19.7% |
| Intensified linkages by LECC | 55.6% | 19.8% | 35.0% | 29.4% | 11.6% | 17.6% | 37.3% | 22.2% | 36.8% | 52.9% | 17.3% | 17.9% | 30.8% | 13.8% | 42.6% |
| Initiated or intensified linkages by LECC | 55.6% | 65.3% | 60.8% | 29.4% | 53.5% | 45.1% | 37.3% | 42.9% | 64.5% | 52.9% | 71.2% | 53.6% | 30.8% | 48.3% | 62.3% |
| Density (related to respondent) | 0.04 | 0.154 | 0.132 | 0.023 | 0.068 | 0.038 | 0.07 | 0.132 | 0.155 | 0 | 0.167 | 0.133 | 0.015 | 0.106 | 0.027 |
| Centralization (indegree) | 0.056 | 0.141 | 0.173 | 0.057 | 0.024 | 0.082 | 0.058 | 0.081 | 0.153 | 0.115 | 0.106 | 0.163 | 0.073 | 0.104 | 0.052 |
| dito without initiated linkages | - | 0.053 | 0.13 | - | 0.034 | 0.046 | - | 0.042 | 0.124 | - | 0.07 | 0.09 | - | 0.048 | 0.056 |

## 5 The development of the R&D networks during the LECC

Since we observe an increasing centralization of the networks a logical next step is to ask how actors that become more central inside the networks are characterized. Considering that almost all policies – and especially those that are picking winners – create distortions, it is important to understand the structural changes on a micro-level. Therefore we proceed to analyze the structural specificities and changes of the R&D networks of the clusters during the LECC, based on a balanced panel of actors that are observed in 2011 and 2013. This restricted dataset leaves us with observations for 142 actors. On this basis we analyze changes in their indegree centrality between 2011 and 2013, with a special focus on the policy influence.

In our econometric analysis, we employ the following variables (table 3): The dependent variable is the change of an actor's indegree centrality; we calculated this change for each single observation from 2011 to 2013 (d.deg). Our main explanatory variables that measure a direct policy impact refer explicitly to funding within the LECC. We use information on the number of funded projects in 2013 (num.proj) and the total amount of funding for the second period of the LECC (2013) (log.fin) in log. To control for non-linearity in the funding variable we also use the squared term (log.fin^2). To control for additional actor characteristics, we distinguish between types of actors, namely whether they are formal members of the respective cluster (cluster.actor) and whether they are private or public organizations (public). Size is taken into account by a dummy variable (actor.large) which indicates firms with more than 500 employees. Furthermore, location is taken into account (region) where we distinguish between "inside the Cluster", "Germany", "Europe" or "World". In order to control for persistence of network positions, we include indegree centrality of 2011 (Indegree.2011). Table 3 shows the list of variables included in the regressions. Since we observed heteroskedasticity according to a Breush-Pagan test we use robust regressions for the analysis. Table 4 in the appendix reports the correlations between all independent variables.

As to the dependent variable, for 26 of our observations we recorded a decrease of their indegree implying a decline of their importance within the R&D network. Contrariwise for 42 actors the indegree centrality and therefore their importance in the network (slightly) increased. For the remaining 74 actors, the majority, we observe no change of their indegree.

**Table 3: List of dependent and independent variables**

| Variable | Explanation | Mean | Min | Max |
|---|---|---|---|---|
| d.deg | change of the (indegree) centrality of the actor from 2011 to 2013 | 0.296 | -2 | 8 |
| log.fin | total funding in second period (2013) (in log scale) | 6.972 | 0 | 15.961 |
| log.fin^2 | squared term of total funding (in log scale) | 94.223 | 0 | 254.762 |
| num.proj | number of funded projects in second period | 1.204 | 0 | 15 |
| Indegree.2011 | (indegree-) centrality of the actor in 2011 | 1.641 | 0 | 10 |
| region | location of the actor (ordered: inside the Cluster = 1, Germany = 2, Europe = 3, World = 4) | 1.620 | 1 | 4 |
| public | public actor (yes = 1/no = 0) | 0.373 | 0 | 1 |
| actor.large | large enterprise (more than 500 employees) (yes/no) | 0.331 | 0 | 1 |
| cluster.actor | formal member of the leading edge cluster organisation in 2013 | 0.662 | 0 | 1 |
| cluster | cluster dummy for each leading edge cluster | | | |

These changes inside the Leading-Edge Clusters can either be caused by the LECC or simply appear as regular economic developments and the formation and breakup of R&D cooperations within the innovation processes. To distinguish between these two different effects – policy induced and regular changes – we test a first set of models (model 1a/1b/1c) including only variables that are not directly related to LECC funding. The following independent variables are included: First, we expect the geographical location of an actor (region) or in other words the geographical distance to the cluster to be negatively related to the change in indegree; this is due to the observation that in high-tech research intraregional innovation linkages are typically of high importance (Koschatzky and Sternberg, 2000; Lublinski, 2003; Torre, 2008). Secondly, high-tech clusters are oriented towards more advanced innovation and therefore cooperation with universities and (public) research institutes should be considered relevant (Tödtling et al. 2009); hence the indegree centrality of a public actors should increase more than the one for a firm. Third, since large companies cooperate more often than small ones they also tend to change their partners more often and consequently changes of their indegree seem to be more likely. Finally, being more embedded into the whole network can make a change of the indegree more likely due to a more exposed position or more experience with R&D cooperations. Therefore the initial position inside the network should influence the change in centrality. At last we added a cluster dummy accounting for specific technology and innovation related factors inside the clusters.

Our estimation results show that for three specifications the initial indegree centrality has a significant impact on observed changes of the indegree. The positive coefficient indicates that those actors which were considered important in 2011 increased their importance until 2013 – the networks as a whole tend to become more centralized with a few increasingly important actors at their respective core. During the short period 2011 to 2013, public actors become significantly less central whereas large firms tend to be able to increase their centrality compared to other private actors. In model 1c we include all non-policy variables[1]. In this overall model without policy variables only the significant effect for the indegree remains.

In a second model we include cluster membership as a rather indirect measure for the policy impact of the LECC. Because of the high correlation we excluded the region (model 2a) in one specification while we include both in model 2b because of the low variance inflation factors. Interestingly, indegree in 2011 loses some significance while cluster membership and sharing the commitment on the general strategy of the cluster has no influence on the change in importance of an actor for the network. To identify the direct impact of the LECC on the structure of the R&D cooperation network we added the following direct policy measures to our model: log.fin, (log.fin)^2 and num.proj. In view of the high correlation between these variables we tested them separately in different models. We found a significant effect of the number of funded projects (model 3a – 3c) and of the total amount of received funding in its non-linear specification during the second period of the policy on the change of indegree centrality (model 4a – 4c). Looking at the coefficient of the financial volume of the subsidies (log.fin) and the related quadratic term delivers a significantly negative sign for the volume and a significantly positive sign for the quadratic term. This on a first view suggests a u-shaped relationship. However, a further analysis of the support of the variable log.fin.2013 delivers a monotonically increasing non-linear relationship between the financial volume of subsidies and the change in the indegree centrality.

Since one of the funded clusters reacts significantly different to the others (Solarvalley), we include interaction terms between the cluster dummy and the policy variables (model 3c and 4c). The number of granted projects as policy measure remains significant but no interaction term turns out to be significant. When we test for interaction between the cluster dummy and financial volume the significance of the quadratic term increases and for BioRN the change of the indegree centrality reacts significantly different compared to the other clusters. Furthermore we test our models 1c, 2b, 3a and 4a also for each cluster separately. The results are reported in table 6. For BioRN we cannot report any results because the regressions did not converge. Compared with our regressions for the whole sample we observe different results for some clusters. While Hamburg Aviation, Cool Silicon and FOE are mostly in line with

[1] Because of their high correlation we calculated variance inflation factors which are in all cases lower than 4.

our overall results for the effect of their embeddedness into the network, Solarvalley shows the opposite effect. Nevertheless for Hamburg Aviation non of our explanatories turns out to be significant on any level and therefore the development within this cluster differ quite recently from our assumptions. In contrast to that Cool Silicon shows at for 3 of our 4 tested models a high significance for the indegree.2011. In this cluster the initial position determines the change of importance of an actor while these strong influences can't be observed for the other clusters. Furthermore not all clusters react significantly positive onto our measure for the direct policy impact.

## Table 5: Robust linear regression of the change of indegree centrality

| | Model 1a | Model 1b | Model 1c | Model 2a | Model 2b | Model 3a | Model 3b | Model 3c | Model 4a | Model 4b | Model 4c |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **(Intercept)** | 0.1959 | 0.0926 | 0.1521 | -0.1200 | -0.1815 | -0.2347 | -0.2225 | -0.1967 | -0.0831 | -0.1914 | -0.2708 |
| **region** | -0.0475 | -0.0788 | -0.0676 | | 0.0250 | 0.0578 | 0.0589 | 0.0471 | 0.0426 | 0.0754 | 0.0420 |
| **public** | -0.2768* | | -0.1524 | -0.1098 | -0.1125 | -0.0406 | -0.0219 | 0.0243 | -0.0526 | -0.0442 | -0.0181 |
| **actor.large** | | 0.3076+ | 0.2294 | 0.2975 | 0.3116 | 0.2895 | 0.2991 | 0.0908+ | 0.2195 | 0.2498 | 0.2423 |
| **Indegree.2011** | 0.1293** | 0.1040** | 0.1123* | 0.0989+ | 0.0998+ | | -0.0264 | -0.1072 | 0.0283 | 0.0266 | -0.0171 |
| **cluster.actor** | | | | 0.2807 | 0.3003 | 0.1152 | 0.1042 | 0.3555+ | | 0.1553 | 0.0918 |
| **no.proj** | | | | | | 0.1943*** | 0.2123*** | 0.2961* | | | |
| **Log.fin** | | | | | | | | | -0.2315** | -0.2355*** | -0.2387* |
| **log.fin^2** | | | | | | | | | 0.0193*** | 0.0193*** | 0.0222*** |
| **BioRN** | -0.1182 | -0.0307 | -0.0697 | -0.0651 | -0.0771 | -0.1050 | -0.1082 | 0.0349 | -0.2430 | -0.2606 | 0.1154 |
| **Cool Silicon** | 0.2269 | 0.2175 | 0.2017 | 0.1551 | 0.1539 | 0.2784 | 0.2860 | 0.2239 | 0.2139 | 0.1775 | 0.3755 |
| **FOE** | -0.1809 | -0.2094 | -0.2152 | -0.2448 | -0.2496 | -0.1978 | -0.1972 | -0.2521 | -0.2709 | -0.2833 | -0.2016 |
| **Solarvalley** | -0.3089 | -0.3801 | -0.3557 | -0.4160 | -0.4130 | -0.4797+ | -0.4978+ | -0.0624 | -0.4916+ | -0.5182+ | -0.1473 |
| **BioRN x no.proj** | | | | | | | | -0.2235 | | | |
| **Cool Silicon x no.proj** | | | | | | | | 0.1250 | | | |
| **FOE x no.proj** | | | | | | | | 0.0421 | | | |
| **Solarvalley x no.proj** | | | | | | | | -0.3517* | | | |
| **BioRN x log.fin** | | | | | | | | | | | -0.0701+ |
| **Cool Silicon x log.fin** | | | | | | | | | | | -0.0298 |
| **FOE x log.fin** | | | | | | | | | | | -0.0140 |
| **Solarvalley x log.fin** | | | | | | | | | | | -0.0585 |
| **Observations** | 142 | 142 | 142 | 142 | 142 | 142 | 142 | 142 | 142 | 142 | 142 |
| **Degrees of freedom** | 134 | 134 | 133 | 133 | 132 | 132 | 131 | 127 | 131 | 130 | 126 |
| **Residual standard error** | 0.7267 | 0.6462 | 0.6419 | 0.6397 | 0.6433 | 0.655 | 0.673 | 0.6842 | 0.6875 | 0.6427 | 0.6536 |

**Signif. Codes: + p<0.1 ; * p<0.05 ; ** p<0.01 ; *** p<0.001**

**Table 6: Robust linear regression of the change of indegree centrality per cluster**

| | Hamburg Aviation | | | | Cool Silicon | | | |
|---|---|---|---|---|---|---|---|---|
| | Model 1c | Model 2b | Model 3a | Model 4a | Model 1c | Model 2b | Model 3a | Model 4a |
| (Intercept) | 0.6738 | -0.4480 | 0.8711 | 0.5945 | -0.3820 | -0.4288 | -0.1204 | -0.0553 |
| region | -0.1513 | 0.0304 | -0.2281 | -0.0835 | -0.1833 | -0.1716 | -0.1776 | -0.1445 |
| public | -1.0989 | -0.5014 | -1.1740 | -0.9222 | 0.3175 | 0.3254 | 0.4245 | 0.1205 |
| actor.large | 0.1053 | 0.8834 | 0.0400 | -0.0118 | 0.724+ | 0.7388 | 0.8935* | 0.4878 |
| Indegree.2011 | 0.1680 | 0.0883 | 0.2295 | 0.0427 | 0.5644*** | 0.5578*** | 0.1332 | 0.3889** |
| cluster.actor | | 0.8928 | | | | 0.0415 | | |
| no.proj | | | -0.0903 | | | | 0.2886* | |
| Log.fin | | | | -0.3462 | | | | -0.6224** |
| log.fin^2 | | | | 0.0279 | | | | 0.0467** |
| Observations | 31 | 31 | 31 | 31 | 49 | 49 | 49 | 49 |
| Degrees of freedom | 26 | 25 | 25 | 24 | 44 | 43 | 43 | 42 |
| Residual standard error | 0.9017 | 0.9117 | 1.001 | 0.9616 | 0.8 | 0.778 | 0.6655 | 0.6934 |

| | FOE | | | | Solarvalley | | | |
|---|---|---|---|---|---|---|---|---|
| | Model 1c | Model 2b | Model 3a | Model 4a | Model 1c | Model 2b | Model 3a | Model 4a |
| (Intercept) | -0.7530 | -0.7013 | -0.4239 | -1.9409+ | 0.4724 | 0.7676 | 0.2424 | 0.3498 |
| region | 0.1882 | 0.1698 | 0.2750+ | 0.5776+ | 0.0807 | -0.0598 | 0.2482 | 0.0883 |
| public | 0.0414 | 0.0549 | -0.0128 | -0.0514 | -0.6129+ | -0.4700 | -0.6973+ | -0.6197 |
| actor.large | -0.3141 | -0.3089 | -0.3319 | -0.6605 | -0.4478 | -0.3340 | -0.5359 | -0.3565 |
| Indegree.2011 | 0.3766* | 0.3814+ | -0.3501* | 0.3078 | -0.2911** | -0.3187*** | -0.3443* | -0.2539* |
| cluster.actor | | -0.0590 | | | | -0.2460 | | |
| no.proj | | | 0.6721*** | | | | 0.0746 | |
| Log.fin | | | | 0.2108 | | | | 0.1360 |
| log.fin^2 | | | | -0.0075 | | | | -0.0095 |
| Observations | 24 | 24 | 24 | 24 | 18 | 18 | 18 | 18 |
| Degrees of freedom | 19 | 18 | 18 | 17 | 13 | 12 | 12 | 11 |
| Residual standard error | 0.7447 | 0.7243 | 0.4077 | 0.8563 | 0.3892 | 0.2124 | 0.4389 | 0.3519 |

**Signif. Codes: + p<0.1 ; * p<0.05 ; ** p<0.01 ; *** p<0.001**

# 6 Summary

Our preliminary results show that over time the LECC program was effective in initiating R&D cooperation between cluster actors and in intensifying existing partnerships. A substantial share of the newly formed linkages is among actors who did not receive direct funding for a joint R&D project, which indicates a mobilisation effect of the policy that goes beyond government sponsored collaboration. The vast majority of linkages which are influenced by the LECC are located in the cluster region. During the early phase of the policy we identify mainly a local policy impact with some actors even reporting a decline in international activities in favour of new local partnerships. Following this policy influence common to all clusters, we observe differential developments regarding clusters' spatial embeddedness during the later stage. Some clusters tend increase their localisation, whereas others increase their connectivity to international partners. All five case study clusters are centred around one or more global players and/or an excellent research institute or university and we find an increase in network centralization caused by the policy induced linkages. We employ standard regression techniques to characterise actors that benefit most – in terms of increased centrality – from the policy. If we do not control for funding, it shows that actors who were already central in the previous period and large firms benefit most, whereas universities and public research institutes become less central within the R&D networks. If direct policy measures such as the number of funded projects and the total amount of funding are included, all other variables turn insignificant and a positive effect of funding. Apparently, the policy induced cluster development beyond direct funding does not favour any specific type of actor. Analyses for each cluster separately, lead to heterogeneous and inconclusive results. Apparently, evaluations of cluster policies should not rely on aggregated statistics that ignore cluster specific impacts. We suspect that such differential impacts are especially prevalent if clusters are as diverse and heterogeneous as within the LECC.

## References


Ahuja, G. (2000), "Collaboration networks, structural holes, and innovation: A longitudinal study." *Administrative science quarterly,* 45(3), 425-455.

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

Becker, W. and Dietz, J. (2004), "R&D cooperation and innovation activities of firms—evidence for the German manufacturing industry." *Research policy,* 33(2), 209-223.

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

Boschma, R. A., and Ter Wal, A.L. (2007), "Knowledge networks and innovative performance in an industrial district: the case of a footwear district in the South of Italy." *Industry and Innovation,* 14(2), 177-199.

Cantner, U., Graf, H. and Hinzmann, S. (2013), "Policy induced innovation networks: the case of the German "Leading-Edge Cluster competition" *Jena Economic Research Papers* 2013-008, Friedrich-Schiller-University Jena, Max-Planck-Institute of Economics

Cantner, U. and Graf, H. (2006), "The Network of Innovators in Jena: An Application of Social Network Analysis." *Research Policy,* 35(4), 463-480

Cantner U., Conti, E. and Meder, A. (2010), "Networks and innovation: the role of social assets in explaining firms' innovative capacity." *European Planning Studies,* 18(12), 1937-1956

Chatterji, D. (1996), "Accessing external sources of technology." *Research-Technology Management,* 39(2), 48

Coombs, R., Harvey, M. and Tether, B. S. (2003), "Analysing distributed processes of provision and innovation." *Industrial and Corporate Change,* 12(6), 1125-1155.

Cowan, R. and Jonard, N. (2004), "Network structure and the diffusion of knowledge." *Journal of Economic Dynamics and Control*, 28(8), 1557-1575

Cowan, R. & Jonard, N. (2009), "Knowledge portfolios and the organization of innovation networks." *Academy of Management Review,* 34(2), 320-342.

Dohse, D. (2000), "Technology Policy and the Regions - the Case of the BioRegio Contest." *Research Policy*, 29 (9), 1111-1133.

Duranton, G. (2011), “California Dreamin': The Feeble Case for Cluster Policies.” *Review of Economic Analysis*, 3(1), 3-45

Eickelpasch, A. and Fritsch, M., (2005), "Contests for cooperation-A new approach in German innovation policy." *Research Policy*, 34(8), 1269-1282

Engel, D.; Mitze, T.; Patuelli, R. and Reinkowski, J. (2013), “Does Cluster Policy Trigger R&D Activity? Evidence from German Biotech Contests.” *European Planning Studies*, 21 (11), 1735-1759

Feldman, M. P. (1999), “The new economics of innovation, spillovers and agglomeration: A review of empirical studies”, *Economics of Innovation and New Technology*, 8, (1-2), 5-25

Fleming, L., King III, C. and Juda, A.I. (2007), "Small worlds and regional innovation." *Organization Science,* 18(6), 938-954.

Fier, A. and Harhoff, D. (2002), „Die Evolution der bundesdeutschen Forschungs- und Technologiepolitik: Rückblick und Bestandsaufnahme.“ *Perspektiven der Wirtschaftspolitik,* 3(3), 279-301.

Freeman, C. (1991), “Networks of innovators: A synthesis of research issues.” *Research Policy*, 20(5), 499-514

Giuliani, E. and Pietrobelli, C. (2011), "Social network analysis methodologies for the evaluation of cluster development programs." *Inter-American Development Bank*, 1-46.

Gomes-Casseres, B., Hagedoorn, J., and Jaffe, A. B. (2006).” Do alliances promote knowledge flows?”. *Journal of Financial Economics*, 80(1), 5-33.

Graf, H. and Krüger J. (2011), ”The Performance of Gatekeepers in Innovator Networks” *Industry and Innovation*, 18(1), 69-88.

Granovetter, M. (1973). “The strength of weak ties.” *American Journal of Sociology*, 78, 1360-1380.

Koschatzky, K. and Sternberg, R. (2000), "R&D cooperation in innovation systems—some lessons from the European Regional Innovation Survey (ERIS)." *European Planning Studies,* 8(4), 487-501.

Lublinski, A. E. (2003), “Does geographic proximity matter? Evidence from clustered and non-clustered aeronautic firms in Germany.” *Regional Studies*, 37(5), 453-467.

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

Martin, R. and Sunley, P. (2003), "Deconstructing clusters: chaotic concept or policy panacea?," *Journal of Economic Geography*, 3(1), 5-35.

Martin, P.; Mayer, T. and Mayneris, F. (2011), "Public support to clusters: A firm level study of French “Local Productive Systems”." *Regional Science and Urban Economics* 41(2) 108-123.

Metcalfe, S. (1995), "The economic foundations of technology policy: equilibrium and evolutionary perspectives." *Handbook of the economics of innovation and technological change* 446

Miotti, L. and Sachwald F. (2003) "Co-operative R&D: why and with whom?: An integrated framework of analysis." *Research Policy,* 32(8), 1481-1499.

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*, 116-145.

Rowley, T.J., Behrens, D. and Krackhardt, D. (2000), “Redundant governance structures: an analysis of structural and relational embeddedness in the steel and semiconductor industries.” *Strategic Management Journal*, 21 (3), 369–86.

Schilling, M. A. and Phelps, C. C. (2007), “Interfirm Collaboration Networks: The Impact of Large-Scale Network Structure on Firm Innovation”, *Management Science*, 53(7), 1113-1126

Tödtling, F., Lehner, P. and Kaufmann, A. (2009), “Do different types of innovation rely on specific kinds of knowledge interactions?” *Technovation,* 29(1), 59-71.

Torre, A. (2008). “On the role played by temporary geographical proximity in knowledge transmission.” *Regional Studies*, 42(6), 869-889.

Verspagen, B. and Duysters, G. (2004), “The small worlds of strategic technology alliances.” *Technovation*, 24, 563–71.

Wasserman S. & Faust K. (1994) *Social network analysis: Methods and applications.* Cambridge University Press, Cambridge Massachusetts.

# Appendix

**Table 4: Correlation between independent variables**

| | region | public | cluster.actor | Indegree.2011 | actor.large | num.proj | log.fin | (log.fin)^2 | Cluster |
|---|---|---|---|---|---|---|---|---|---|
| region | **** | 0.051 | -0.662 | -0.229 | -0.002 | -0.358 | -0.504 | -0.503 | 0.104 |
| public | 0.551 | **** | -0.052 | 0.134 | -0.512 | 0.016 | -0.134 | -0.13 | 0.009 |
| cluster.actor | <0.001 | 0.536 | **** | 0.212 | -0.119 | 0.423 | 0.667 | 0.653 | 0.119 |
| Indegree.2011 | 0.006 | 0.112 | 0.011 | **** | 0.136 | 0.708 | 0.331 | 0.384 | -0.117 |
| actor.large | 0.98 | <0.001 | 0.158 | 0.106 | **** | 0.042 | 0.038 | 0.059 | 0.142 |
| num.proj | <0.001 | 0.846 | <0.001 | <0.001 | 0.62 | **** | 0.659 | 0.706 | 0.027 |
| log.fin | <0.001 | 0.112 | <0.001 | <0.001 | 0.657 | <0.001 | **** | 0.99 | 0.043 |
| log.fin^2 | <0.001 | 0.124 | <0.001 | <0.001 | 0.483 | <0.001 | <0.001 | **** | 0.045 |
| cluster | 0.217 | 0.916 | 0.157 | 0.167 | 0.091 | 0.751 | 0.609 | 0.594 | **** |

upper diagonal part contains correlation coefficient estimates / lower diagonal part contains corresponding p-values