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Another cluster premium: Innovation subsidies and R&D collaboration networks

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Abstract:

This paper investigates the allocation of R&D subsidies with a focus on the granting success of firms located in clusters. On this basis it is evaluated whether firms in these clusters are differently embedded into networks of subsidized R&D collaboration than firms located elsewhere. The theoretical arguments are empirically tested using the example of the German biotechnology firms' participation in the 6th EU-Framework Programmes and national R&D subsidization schemes in the early 2000s.

We show that clusters grant firms *another premium* to their location, as they are more likely to receive funds from the EU-Framework Programmes and hold more favourable positions in national knowledge networks based on subsidies for joint R&D.

Keywords: Innovation policy, R&D subsidy, collaboration networks, embeddedness, technology cluster
JEL codes: R11, O33, O83, R58, D85

1 Introduction

A rich literature argues theoretically and shows empirically that innovation activities cluster in space (Baptista, 2000; Breschi and Beaudry, 2001; Maskell and Lorenzen, 2004; Asheim et al., 2006). Such clusters are regarded as loci of innovation due to their ability to endogenously generate and diffuse knowledge (Saxenian, 1994; Audretsch and Feldman, 1996; Baptista and Swann, 1998; Maskell and Malmberg, 2002). Due to favorable knowledge generation, production, and demand conditions being located in clusters yields a "premium" (Spencer et al., 2010).

In addition to the above, we claim that clusters also profit from public R&D subsidization policies in two ways. Firstly, they are more likely to receive R&D subsidies. Secondly, they are better embedded into networks of subsidized R&D collaboration. With the first point, the study contributes to the stream of literature investigating the allocation of R&D subsidies (cf. Busom, 2000; Czarnitzki and Fier, 2003; Czarnitzki et al., 2007; Zúñiga-Vicente et al., 2012), which is however rarely looking at geographic aspects. With the second point, the work adds to the growing literature on modeling and analyzing the embeddedness of organizations into networks of subsidized R&D collaboration (Maggioni et al., 2007; Scherngell and Barber, 2009; 2011; Broekel and Graf, 2012). While this literature has a strong geographical background, it has paid less attention to the allocation dimension of R&D subsidies and how this relates to clusters. Accordingly, the present paper brings together different literature streams that have rarely crossed each other and have not been investigated within the same framework.

The theoretical arguments are empirically tested using the example of the German biotechnology industry in the early 2000s and by comparing firms in and outside (technology) clusters. We consider funds from the 6th EU-Framework Programmes (EU-FP) and national R&D subsidization schemes. On this basis, we investigate the allocation of funds and the embeddedness of firms into networks of R&D collaboration emerging from these. By comparing subsidization schemes provided by two different administrative levels the study contributes to the literature on networks of subsidized R&D collaboration, which for the most parts evaluates R&D subsidization programs in isolation of other schemes.

Our empirical results support the existence of an additional premium to being located in a cluster: Firms in clusters are more likely to be supported by policies aiming at excellence and international collaborative R&D. They also hold more prominent positions in national networks of subsidized R&D collaboration granting better and easier access to knowledge diffusing therein.

The paper is structured as follows. In the subsequent section, we briefly review the literature on cluster and innovation policies, which is related to the discussion on networks of subsidized R&D collaboration. On this basis hypotheses are derived. Section 3 presents the empirical approach, the data on the German biotechnology industry, and information on R&D subsidies. The results are presented and discussed in Section 4. Section 5 concludes the paper.

2 Theory and research questions

2.1 Cluster premium

There are numerous definitions and theories of clusters. In the present paper, we understand a cluster being a “*non-random geographical agglomeration of firms with similar or highly complementary capabilities*” (Maskell and Lorenzen, 2004; p. 1002), whereby, „*…similar and related firms […] form the basis of a local milieu that may facilitate knowledge spill-overs and stimulate various forms of adaptation, learning, and innovation*” (Malmberg and Maskell, 2002, p. 433).

It is shown that firms in clusters experience stronger growth and higher innovation (diffusion) rates (Audretsch and Feldman, 1996; Baptista and Swann, 1998; Baptista, 2000) than those outside clusters. These positive effects of cluster emerge from advantageous regional conditions such as Marshallian localization externalities (Asheim et al., 2006), local competition (Porter, 2000), socio-cultural or institutional embeddedness (Amin and Thrift, 1994), or favourable conditions for localized learning processes (Malmberg and Maskell, 2002).[1] However, firms inside clusters do not benefit equally because relations and exchange processes are not uniform within clusters (Boschma and Ter Wal, 2007).

The specific conditions within clusters may however also induce negative externalities, which reduce cluster firms' performance. First, there are negative effects caused by local competition. High demand for scarce resources lowers profit rates (Stuart and Sorenson, 2003), which in turn increases the failure rates of cluster firms and decreases their growth rates (Glenn and Hannan, 2000). In addition, firms are subject to an inherent danger of "*knowledge drain*" when competent employees leave the firm to join local competitors. Secondly, regional concentration (as it is the case in clusters) may cause a negative technological or economic lock-in, as it decreases the probability of radical innovations (Grabher, 1993). Firms will stick to apparently successful routines, specializations and collaboration, while changes and opportunities emerging in new markets and technologies remain unnoticed (Martin and Sunley, 2007).

Hence, while being located in a cluster may not be beneficial in all instances (see, e.g., Stuart and Sorenson, 2003; Brixy and Grotz, 2004) the notion "cluster" is generally related to yielding a premium on sales and profit growth of firms (Spencer et al., 2010).

It is worth noting that the importance of clustering in the form of traditional Marshallian externalities and for innovation has been found robust across different sectors and geographical contexts, such high-tech in Silicon Valley (Saxenian, 1994) and Cambridge (Keeble et al., 1999); biotech in Boston (Porter et al., 2005); ICT in Sophia Antipolis (Longhi, 1999); as well as in mid/low-tech traditional supplier-based clusters in Europe (see Pyke and Senberger, 1992; Becattini, 1990; 1984; Brusco, 1982), and the new industrial clusters emerging in developing economies (see among others Schmitz and Nadvi, 1999; Caniels and Romijn, 2003; Lorenzen and Mudambi, 2012).

In addition, we argue that there exist additional benefits of being located in a cluster, which relate to today's R&D subsidization policies that are presented in the following.

2.2 Innovation policies and scientific evaluation

2.2.1 Effects of R&D subsidies

The justification for public support to R&D is based on the argument that private investments in R&D are below a social optimum. A sub-optimal level of R&D is realized since the individual marginal returns of investments in R&D are not aligned with the social marginal return. Uncertainty, high risk involved in research, and the impossibility of fully appropriating the benefits of these investments, are argued to discourage private investments (Nelson, 1959; Arrow, 1962). These arguments are backed by rich empirical evidence, whereby most empirical studies focus on input and output additionalities that is, they assess the impact of subsidies on R&D efforts (input) or economic performance (output). For instance, Girma et al. (2008) show that subsidies induce additional employment and Czarnitzki and Hussinger (2004) report positive effects on firms' patenting (output

[1] Note that the cluster-related advantages are not static in nature and vary in strength along cluster life cycles (Audretsch and Feldman, 1996; Pouder and St. John, 1996).

additionalities). Zúñiga-Vicente et al. (2012) review the literature with respect to input additionality. They conclude that most empirical evidence suggests a stimulation of R&D efforts by subsidies, which implies that the market failure can be (at least partly) corrected by subsidization. However, these authors also point out that more recent studies rather find no or only weak effects of R&D subsidies.

2.2.2 Allocation of R&D subsidies

The literature also addresses the allocation of R&D subsidies meaning who applies and who is granted R&D subsidies, whereby the most decisive factor for the allocation is naturally the design of R&D subsidization programs. For instance, the EU-Framework Programmes (FP) explicitly aim at building excellence in research (Luukkonen, 2000). This translates into the type of firms that (in addition to universities and research organizations) are most likely to receive grants, which are primarily large firms from R&D intensive sectors (Marín and Siotis, 2008). R&D subsidization schemes are however very diverse in their objectives: some are targeted to support specific groups of organizations (SMEs, innovators, non-R&D intensive firms, etc.). Others are restricted to participants from specific regions. It matters who is initiating such programs in this respect. For instance, national policies frequently apply more inclusive approaches, as most (federally organized) countries seek to stimulate a convergence in regional development.

In addition to the design of initiatives and awarding policies, the willingness and capability of organizations to participate in these programs impacts the likelihood of applying for subsidies. Other factors that matter in this respect are the presence in foreign markets, their absorptive capacities, number of business units, the intensity of linkages to universities, reviewer ratings, and previous experience, whereby significant heterogeneity exists between industries (Busom, 2000; Blanes and Busom, 2004; Barajas and Huergo, 2010).

2.2.3 Collaborative R&D as additional dimension to R&D subsidies

The above brief review summarizes the traditional and most prominent view on R&D subsidies in the literature, which is based on the idea that R&D subsidies are granted to a single organization conducting R&D. However, the justification for public subsidization of R&D has been recently extended by the argument to also overcome market failures in the context of knowledge access and exchange (Lundvall, 1992; Nelson, 1993; Malerba, 2004). Newer policies therefore subsidize the production of knowledge and seek to enhance its diffusion by supporting the formation of inter-organizational collaboration in R&D in order to reduce system failures (Woolthuis et al., 2005). The underlying rational is the same as for subsidizing knowledge production: the diffusion of knowledge is perceived to be below a social optimum and is therefore stimulated by monetary incentives (Buisseret et al., 1995).

Frequently, this is done by means of subsidizing joint R&D projects. Figure 1 illustrates this shift from the subsidization of individual to supporting joint R&D projects for the case of German R&D subsidization programs initiated by the federal government. At the European level, the equivalent to this are the Framework Programmes that exclusively grant support to joint R&D projects.

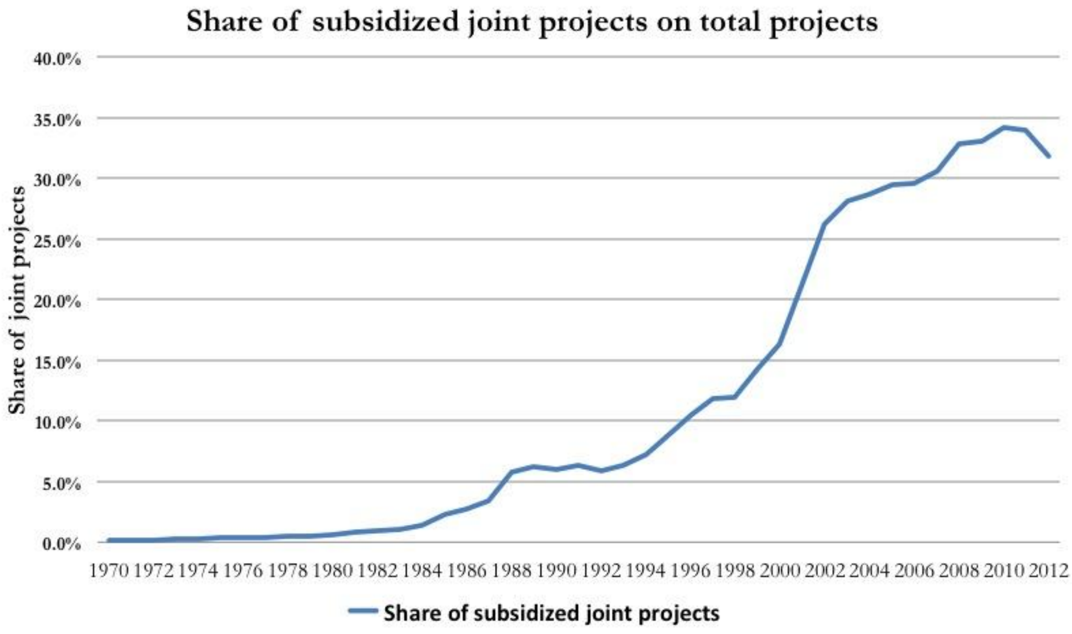

Figure 1: Share of joint R&D projects on total projects subsidized by the German federal government

This shift in R&D policy design triggered a new research stream focusing on whether subsidization of joint R&D impacts organizations' collaboration behavior such that they collaborate more or that their subsidized collaboration are structurally different from those they would have realized without subsidies. This is also denoted as cooperation additionality (Wanzenböck et al., 2014).

However, this is not the only impact of subsidies for joint R&D. It is well accepted that R&D collaboration integrate organizations into knowledge networks through which knowledge disseminates and diffuses through direct and indirect linkages (Powell et al., 1999). This applies to subsidized R&D collaboration as well, which embed organizations into knowledge networks of subsidized R&D collaboration (Broekel and Graf, 2012). Researchers therefore investigate inter-organizational and cross-regional collaboration networks generated by the R&D subsidies from a network perspective, whereby most studies concentrated on the EU-Framework Programmes (Breschi and Cusmano, 2004; Cassi et al., 2008; Hoekman et al., 2010; Scherngell and Barber, 2009; 2011). Focal issues of this literature are the determinants of collaboration, the typologies of contacts, the structure of the collaboration network, and organizations' positions in the network.

2.3 Research hypotheses: linking cluster and subsidies for joint R&D

2.3.1 The other cluster 'premium'

So how does the subsidization of R&D in general and support for joint R&D in particular relate to clusters and which benefits may organizations gain from being located therein? Firstly, we argue that in many instances the allocation of R&D subsidies is biased in favor of firms being located within clusters. Secondly, we put forward that firms in clusters hold more advantageous positions in networks of subsidized R&D collaboration than firms located outside.

Concerning the first issue, in light of the literature review in Section 2.1 it can be expected that firms in clusters benefit from localized learning processes, regionalized knowledge spillover, and access to well-fitting labor markets. Moreover, these advantages tend to be larger than potential negative effects related to being located in a cluster. Firms in clusters are therefore more likely to conduct state-of-the-art and possibly *excellent* research (see Section 2.1). Consequently, they are more likely to meet the high standards subsidization schemes aiming at research excellence, which not least depends on writing good proposals. Hence, policy can be expected to be more likely awarding these organizations with grants. It can further be hypothesized that organizations in clusters are aware of their excellence. If this is the case, they are more probable to apply for such funds in the first place, as they will rate their chances of success higher.

Another reason for firms in clusters to receive more R&D subsidies is their superior access to information, which is primarily induced by their stronger exposure to cluster internal knowledge spillover and knowledge networks (Malmberg and Maskell, 2002), which can be further enforced by active cluster managements organizations. It seems reasonable to assume that these also include information on subsidization schemes. If this is the case, it can be expected that firms in clusters are more likely to learn about subsidization programs, which is probable to translate into higher application rates.

We also argue that firms in clusters are potentially stronger motivated to participate in subsidization schemes promoting international collaboration. First, this is because for these firms it is essential to complement their cluster-internal relations with cross-regional collaboration in order to avoid too much embeddedness into cluster networks and potential cognitive lock-ins. Usually, establishing external knowledge linkages will reduce this danger (Bathelt et al., 2004). Given the growing importance of joint research in R&D subsidization programs, we can therefore expect these to be highly attractive for firms in clusters. Second, under the assumption of greater research excellence, firms in clusters are likely to be more demanding in terms of their collaboration partners' quality than firms outside clusters. It seems plausible that in many instances, few organizations and regions within a single country are able to offer such complementary (excellence) research within a specific research field. Hence, international collaboration might be a necessity in many instances. In consequence, it can even be expected that firms located in clusters that engage in international subsidized joint R&D will more frequently collaborate with organizations also located in clusters giving rise to global networks of excellent clusters (Moodysson et al., 2008). In biotechnology and other high technology industries, which rely mainly on an *analytic* form of knowledge (Asheim and Gertler, 2005), it is also likely that firms in clusters are stronger engaged in (subsidized) collaboration with public research organizations. These organizations generate large portions of the state-of-the-art knowledge in these young industries making collaboration a necessity to conduct research excellence.

It is worth pointing out that clusters might not always host organizations that carry out research at-the-frontier. For instance, cluster in transition phases or at initial stages of development are unlikely to provide superior research. However, we argue that even in these cases their firms are more likely to attract R&D subsidies than firms outside clusters. Possible reasons are that policy makers strongly believing in such clusters becoming powerful generators of regional growth (OECD, 1999; 2009). Accordingly, policy makers are likely to regard projects submitted by organizations in clusters to be more rewarding because they thereby (indirectly) support the clusters in which the applicants are located, and which are expected to generate future economic growth. Such an argument also applies to the biotech sector that is frequently seen as a future growth engine (OECD, 1999). In many instance, policies are therefore explicitly designed to support clusters. A remarkable example in this respect is the German technological policy, which has become more and more cluster-oriented, with a whole set of measures supporting either the emergence (e.g., *BioRegio*) or the renewal of high-tech clusters (e.g., *InnoRegio*) (Dohse, 2000). We therefore argue that the presence of cluster-based policies and the participation in existing policy schemes makes firms in clusters more aware of the existence of R&D subsidies and more probable to receive these subsidies.

The first three hypotheses summarize these arguments:

- **H1** Firms in clusters participate more frequently in R&D subsidization programs than firms located outside clusters. This is particularly the case when support schemes focus on research excellence.
- **H2** Firms in clusters are generally more prone to participate in subsidized joint R&D, when it involves international partners, than firms located outside clusters.
- **H3** Within subsidized R&D collaborations, firms in clusters are more likely to connect to organizations that offer research excellence and state-of-the-art knowledge than firms outside clusters. This particularly applies to the public research sector (**H3a**) and organizations located in (other) clusters (**H3b**).

2.3.2 Network position and collaboration partner premium

Higher R&D subsidization is however not the only *premium* firms may gain from being located in a cluster. They can also be expected to hold more prominent positions in networks of subsidized R&D collaboration, which we discuss in the following.

In network research the degree of embeddedness into a network is frequently related to the number of direct collaboration partners (Grewal, 1996). Accordingly, organizations are well embedded when having a large number of direct collaboration partners. Being well embedded grants a *premium* to firms' collaboration activities by providing easy access to knowledge located in their direct network neighborhood. Moreover, their network embeddedness is relatively robust to node and link failure. High embeddedness may however induce negative effects, as it leads to overexposure to information and cognitive overload. This in turn can cause poorer work performance (Rosa et al., 1999). These rationales also apply to networks of subsidized R&D collaboration. Crucially, this degree of embeddedness exclusively refers to the direct (network) neighborhood of a firm and is therefore referred to as *local centrality*. Positions that are globally central in the network are those that also account for indirect paths between actors. Such positions may also grant a *premium* because they imply higher exposure and access to knowledge circulating in the overall network without the risk of overexposure (Wasserman and Faust, 1994). It is referred to as *global centrality*. Firms in these positions usually act as gatekeepers by connecting peripheral parts of the network.

So, why should organizations in clusters show higher degrees of embeddedness and hold more globally central positions in networks of subsidized R&D collaboration than other firms? First of all, in the context of networks of subsidized R&D collaboration the likelihood of a firm to be well embedded depends on the number and size (in terms of participants) of subsidized R&D projects it is already active in. In line with the above argumentation, firms in clusters are more likely to be active in a higher number of R&D projects and potentially even in larger projects than firms outside clusters because they are more probable to apply for and receive collaborative R&D subsidies. Second, firms in clusters benefit from stronger exposure to local buzz and superior access to *know-who* and information about potential collaboration partners. For these reasons, they are also more likely being perceived as attractive collaboration partners by other organizations. Hence, they will be approached by a greater number of organizations to collaborate in subsidized joint R&D. Such processes are clearly self-reinforcing. For instance, firms that are well embedded into a network are more attractive collaboration partners than less embedded organizations because of their superior network access, which is also known as preferential attachment (cf. Barabasi and Albert, 1999).

In summary, we can put forward the following two hypotheses concerning the embeddedness of firms in clusters into networks of subsidized R&D collaboration.

H4 Firms within clusters are characterized by higher degrees of embeddedness into networks of subsidized R&D collaboration than firms outside clusters.

H5 Firms in clusters are also qualitatively better embedded into networks of subsidized R&D collaboration than firms outside clusters by holding globally more central positions.

The hypotheses are empirically tested using the case of the German Biotechnology industry.

3 Empirical approach and data

3.1 The biotechnology industry

The biotechnology industry has three characteristics that make it a well-chosen case for our investigation. First, biotechnology is a research-intensive business and patents are important for intellectual property right protection (Thumm, 2003). The largest German organizations patenting in biotechnology and their average patent numbers per year between 2003 and 2005 are shown in Table 1. The presence of a public research organization among the top ten, namely the Fraunhofer Society ("*FHG zur Förderung der angewandten Forschung e.V.")* underlines the relevance of public research in this rather young industry (cf. Powell et al, 1996). The latter also explains why R&D processes in this industry frequently involve integrating firm external knowledge (cf. Niosi and Banik, 2005; Ter Wal, 2011).

Second, the biotechnology industry provides informative and significant empirical data on subsidized R&D collaboration. The motivation for heavily subsidizing this industry is policy-maker's view of the industry as a future growth engine. For instance, the German federal government introduced a whole set of innovation policy programs in order to support this industry (e.g. the BioRegio, BioFuture, BioProfile and BioChance initiatives (Dohse, 2000)). The industry plays a similarly prominent role in R&D subsidization programs by the European Union, which also views biotechnology as a strategically important sector. It is therefore one of the priority thematic areas in its main R&D support scheme, namely the EU Framework Programmes.

Rang	Organization	Average number of patents applications per year (2003-2005)
1	Bayer Healthcare AG	38.4
2	Roche Diagnostics Gmbh	20.7
3	Basf Aktiengesellschaft	14.1
4	Basf Plant Science Gmbh	10.2
5	Epigenomics AG	7.8
6	Degussa Gmbh	6.8
7	Aventis Pharma Deutschland Gmbh	6.6
8	Eppendorf AG	5.6
9	Evotec Neurosciences Gmbh	5.2
10	Fhg zur Foerderung der Angewandten Forschung E.V.	5.1

Note: the organizations displayed in bold are public research institutes

Table : Top ranking of organizations by patent applications per year (2003-2005)

Third, biotechnology firms tend to concentrate in space and form clusters with intense local interaction (cf. Zeller, 2001; Niosi and Banik, 2005). Ter Wal (2011) therefore concludes that "[t]*his makes biotechnology an ideal case for studying spatial clustering*" (p. 5). It needs to be pointed out that by being a high technology industry, most clusters in biotechnology can be regarded as being so-called "technology clusters". The reason for this is that their firms are highly innovative and knowledge intensive with their product or process innovation incorporating either scientific discoveries or advanced know-how. Their knowledge base is prevalently *analytical*, i.e. it mainly relies on scientific discoveries, highly formalised and often codified inputs and output (Asheim and Gertler, 2005).

3.2 Data on German biotechnology firms and patents

For the identification of biotechnology firms in Germany we use the *German Biotechnology Year and Address Book* (versions 2002 and 2004), which covers firms and research organizations. We exclusively focus on firms for which we obtain the following information.

Using the information on a firm's founding date their age in 2004 is estimated (AGE). Firms' total employment (EMP) is also known with respect to the year 2004. To approximate firms' innovation activities, we collected information on their yearly patent activities from 1997 to 2005 The patent data is derived from the EPO Worldwide Statistical Patent Database version October 2007 (PATSTAT October 2007 database). Patents in biotechnology are identified on the basis of the International Patent Classification (IPC) and the OST2/INPI/ISI concordance in the version of 2000. They are considered when at least one IPC code falls into the category of the technological field 'biotechnology' in the concordance. Patents are divided with the number of applicants and the shares are summed for each firm giving the final weighted patent number per employee (PAT.EMP). We obtain complete information about employment, patenting, and age of 703 firms. 26.5 percent of these receive R&D subsidies from at least one of the two sources presented below. Lacking complete information on subunits, we treat all firms as single entities and assign all information to the location of their headquarters. Such an approach is justified by the fact that the majority of German biotech firms are comparatively small in size. In 2005 around 88% of all German biotech firms had below 50 employees (biotechnologie.de, 2006) and the average firm size in 2004 was 22 employees (Statistisches Bundesamt, 2005).

3.3 Data on R&D subsidies

3.3.1 National R&D subsidization schemes and EU-Framework Programmes

The first source on information about R&D subsidies is a comprehensive data set on R&D projects subsidized by the German Federal government, whereby the majority of funds is organized by the Federal Ministry of Education and Research (BMBF). A number of other federal ministries contribute as well but to smaller extents. The subsidization programs' objectives are the stimulation of individual and collaborative R&D activities by means of co-financing R&D projects. With respect to biotechnology, the database covers a wide range of initiatives with heterogeneous objectives and targeted recipients. Most biotechnology-related initiatives are designed to support specific biotech-technologies and do not tend to be focused on particular geographical regions (with the BioRegio contest being an important exception). In order to benefit from subsidies for joint R&D projects, participants agree to a number of regulations guaranteeing significant knowledge exchange potential. For this reason, information on subsidized joint R&D projects can be used to model (subsidized) knowledge networks (Broekel and Graf, 2012). Given the paper's focus on collaboration and networking, we consider the small number of biotechnology initiatives that are designed to simulate networking and collaboration among biotech organizations in addition to the general R&D-oriented grants. These initiatives' grants are also included in the database. The data is made publically available in the so-called "*Förderkatalog*" (subsidies catalog). It lists detailed information on more than 156,000 individual funds granted between 1960 and 2012. We refrain from further presenting the data as a detailed description can be found in Broekel and Graf (2012).

The second source of data on subsidized R&D are organizations' participations in the (6th) EU-Framework Programmes (FP6 in the following) running between 2002 and 2006. However, the start dates of supported projects in this study vary from 01.01.2003 until 30.09.2007, which we therefore consider as relevant time period. We choose the 6th FP because it is the most recent EU-Framework Programme being completed. To be funded through this program, organizations have to form research consortia with at least three organizations from at least two different countries. Accordingly, all research projects imply some kind of inter-organizational international collaboration, which have been frequently analyzed in the literature (cf. Scherngell and Barber, 2009; 2011; Barajas and Huergo, 2010).

While the two data sources are comparable in many respects there are also significant differences. First, information on German R&D subsidies for joint projects exclusively covers intra-German knowledge relations, while FP6 based relations primarily include international collaboration. Second, FP6 are R&D subsidization schemes focused on research *excellence*. In contrast, the German subsidization scheme includes much more heterogeneous sub-programs. They are generally more inclusive, as the government also aims at stimulating the participation of SMEs and firms located in more peripheral regions. Accordingly, it cannot be ruled out that the allocation of funds is subject to alternative political objectives such as supporting regional convergence and keeping a balanced fund allocation among German federal states. Third, in comparison to FP6, support initiatives by the German federal ministries are quite well consolidated, well known, and relatively easy accessible. Hence, smaller and less R&D intensive firms have fewer barriers to apply to such programs than in FP6. Fourth, FP6 exclusively support joint R&D, while this type of R&D projects only accounts for about one third of projects funded through the German subsidization schemes (Broekel and Graf, 2012).

We use these differences in FP6 and German subsidization programs to test the hypotheses concerning research excellence and the importance of subsidized collaboration.

3.3.2 Empirical variables bases on R&D subsidies data

All funds of the German domestic R&D subsidization schemes are classified by an internal hierarchical classification scheme called "*Leistungsplansystematik*". Its 16 main areas include category *K* ("*Biotechnology*"). We focus on all projects classified into this research area. In equivalence to the FP6, we consider all projects with at least one day of funding within the time period 01.01.2003 and 31.12.2007. 656 German organizations received support from 1,094 projects in this time period. 353 of the latter are joint projects ("*Verbundprojekte*") involving at least two organizations. In addition, there are 741 individual grants that do not include inter-organization collaboration. Of the 656 organizations, 81 are universities, 253 are research organizations (private and public), 314 are private firms, and 8 are miscellaneous organizations.

On the basis of this data the following variables are created. Firstly, we count the number of subsidized projects firms are involved (NAT.PROJ). The variable gives insights into firms' propensities to participate in R&D subsidization programs, which is in focus of hypothesis **H1**. The number of projects is split into the numbers of collaborative (NAT.COLL) and individual (NAT.IND) projects. These variables will be used to assess hypotheses **H2**. To answer if firms in clusters are more likely to connect to organizations located in (other) clusters (**H3**), we create the variable NAT.CLUSTER, which represents the share of links to organizations located in clusters. In case of firms being located in clusters, this also includes links to organizations in their own region. Hypothesis **H4** and **H5** are approached in different ways, as we have to evaluate firms' positions in the networks of subsidized R&D collaboration. The networks are constructed on the basis of co-appearance in subsidized joint projects considering all types of organizations (firms, universities, research organizations, etc.). Organizations exclusively receiving such individual grants will appear as isolates in the inter-organizational network. We focus on firms' degree and betweenness centrality in these networks as the first can be seen as a measure of local embeddedness and the second as global centrality (Freeman 1979, Wasserman and Faust 1994). Degree centrality is a simple count of firms' number of direct collaboration partners and gives a quantitative expression of its local network embeddedness, which is in focus of hypothesis **H4**. In contrast betweenness centralization refers to the extent to which shortest paths connections run through this node in the network. It approximates the degree of firms' exposure to knowledge diffusing in the network and their (indirect) access to distant areas of the network. It therefore allows for assessing hypothesis **H5**. The two variables are denoted by NAT.DEGREE (for degree) and NAT.BETWEEN (for betweenness). Hypothesis **H5** is further explored by looking at the type of collaboration partners. We calculate for each firm the share of universities (NAT.UNI) among its partners and the share of research organizations (NAT.RD).

We create the same variables for the FP6 data. Projects in FP6 are divided into seven priority thematic areas of which we consider projects classified into the area "*Life sciences, genomics and biotechnology for health*". In contrast to the national R&D subsidies data, in FP6 projects it can be differentiated between project leaders and partners. A recent study by Maggioni et al. (2011) shows that knowledge exchange between FP6 partners is hierarchically structured „*in which knowledge produced by network participants is exploited by the coordinator*" (Maggioni et al., 2011, p. 1). We therefore consider only FP6 projects with German organizations being project coordinators. On this basis, we identify 107 projects involving 803 organizations in 57 countries. 168 organizations are located in Germany with 49 being universities, 54 research organizations, 61 firms, and 4 being miscellaneous organizations. As for the German R&D subsidies data, inter-organizational networks are constructed on the basis of co-appearance in subsidized FP6 projects including all types of organizations (firms, universities, research organizations, etc.). The variables created are FP.PROJ (**H1**), FP.DEGREE (**H4**), FP.BETWEEN, FP.UNI, FP.RD, FP.FIRM (all **H5**).[2]

3.4 Identifying and describing biotechnology clusters in Germany

For the present study it is crucial to identify cluster of biotechnology in Germany. We rely on an established method namely the cluster index (CI), which is suggested by Sternberg and Litzenberger (2004). However, we pointed out above that in the biotechnology industry, clusters are foremost "technology clusters". We therefore modify the index. While the original index considers industrial employment, we adapt the index such that it reflects R&D density in biotechnology and hence allows for identifying technology clusters. More precise, the index is estimated on the basis of the number of patents generated by organizations located in a particular region (including public research). Using patents to empirically identify clusters of innovative activities (i.e. technology clusters) is well established in the innovation literature (Feldman and Lendel, 2010; Fornahl et al., 2011; Schiffauerova and Beaudry, 2011; Kogler et al. 2013). More in general, since the seminal work of Jaffe et al. (1993), a growing stream of literature uses patents to investigate the propensity of innovative activities to cluster in space (see among others Almedia and Kogut, 1999; Beaudry and Breschi, 2003; Breschi and Lissoni, 2009).

The CI index by Sternberg and Litzenberger (2004) adapted to patent data shows as:

$$CI_r = \frac{\frac{pat_r}{\sum_{r=1}^{n} pat_r}}{\frac{pop_r}{\sum_{r=1}^{n} pop_r}} * \frac{\frac{pat.org_r}{\sum_{r=1}^{n} pat.org_r}}{\frac{area_r}{\sum_{r=1}^{n} area_r}}$$

pat_r being the number of patents in biotechnology in region r and $pat.org_r$ is the number of organizations with biotechnology patents in r. pop_r represents the regional population and $area_r$ is the area of region r. In accordance to Sternberg and Litzenberger (2004), we use the 97 German planning regions. These planning regions ("*Raumordnungsregionen*") are constructed on the basis of administrative regions (districts). They represent functional

[2] Note that hypothesis H2 cannot be tested using FP6 data, as all supported projects are collaborative in nature.

regions based on commuting behavior. The final index is estimated for three consecutive years at the beginning of the considered time period, namely: 2003, 2004, and 2005. In order to reduce random fluctuations and variations, the annual numbers are averaged for each region.

The distribution of this index's values is presented in Figure . It reveals the existence of a small number of regions with very large values. Two regions show extremely high cluster values and another group of five regions have somewhat lower values that are nevertheless considerably larger than the values for all other regions. The latter group can be further divided into two subgroups of regions of two and three regions respectively. We derive two scenarios on this basis. The first considers the 7 regions with the largest cluster index value being clusters.[3] This includes the two top regions and the complete group of 5 follower regions (Scenario **C7**). The second exclusively perceives of the top 5 regions (Scenario **C5**) being clusters.

Figure plots the cluster values to the map of German planning regions. The top seven (**C7**) cluster regions are: Munich, Hamburg, Berlin, Lower Neckar, Cologne, Duesseldorf, and Rhenish Palatinate. The latter two are excluded in the C5 scenario.

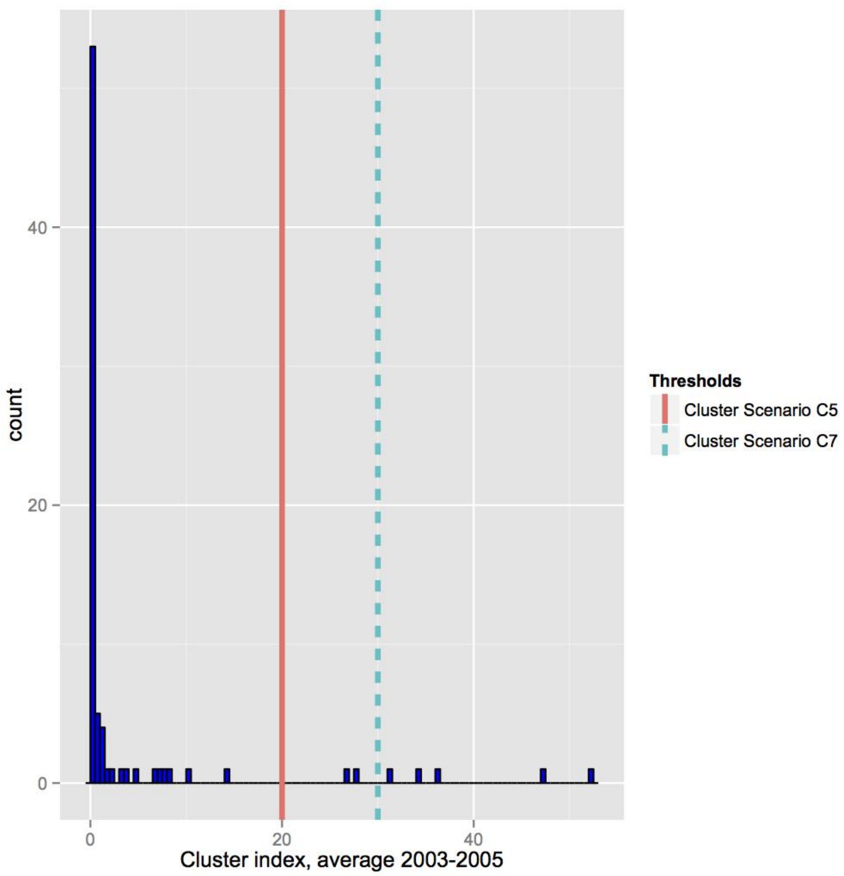

Figure 2: Distribution of cluster index

These definitions are used to identify German clusters of biotechnology. However, in order to investigate if firms linked to organizations in biotech clusters outside Germany, an alternative approach has been used. For identifying international Biotechnology clusters we

[3] While our clusters are not to be mistaken for "industrial clusters", we will continue using the notion of "clusters" instead of "technology clusters" in the following to increase the readability of the paper.

use the map provided by Rinaldi (2006) that lists 62 international clusters in biotechnology. The map is based on information by the Harvard Cluster Mapping Project (http:// http://clustermapping.us) and by W. Hoffman exploiting the MBB-net (http://www.mbbnet.umn.edu). The top three German biotechnology clusters identified in this paper also appear in this list.

Two variables are defined on this basis: The first represents a firm’s share of links in the EU-FP6 network to organizations located in international biotechnology clusters. It is denoted as FP.CLUSTER. In contrast, the share of links to (national) German biotechnology clusters (NAT.CLUSTER) is based on the German subsidies network and the 7 clusters (**C7**) or 5 clusters (**C5**) identified above.

We match the three datasets described above (biotech firms data, domestic R&D subsidies, and FP6) and obtain the final data set including 703 firms active in biotechnology. 253 (**C7**: 282) are located within those regions identified as clusters in Scenario **C5** and 450 (**C7**: 421) outside cluster regions.

Table summarizes the relevant information on patenting, firm numbers, and subsidization in the two scenarios.

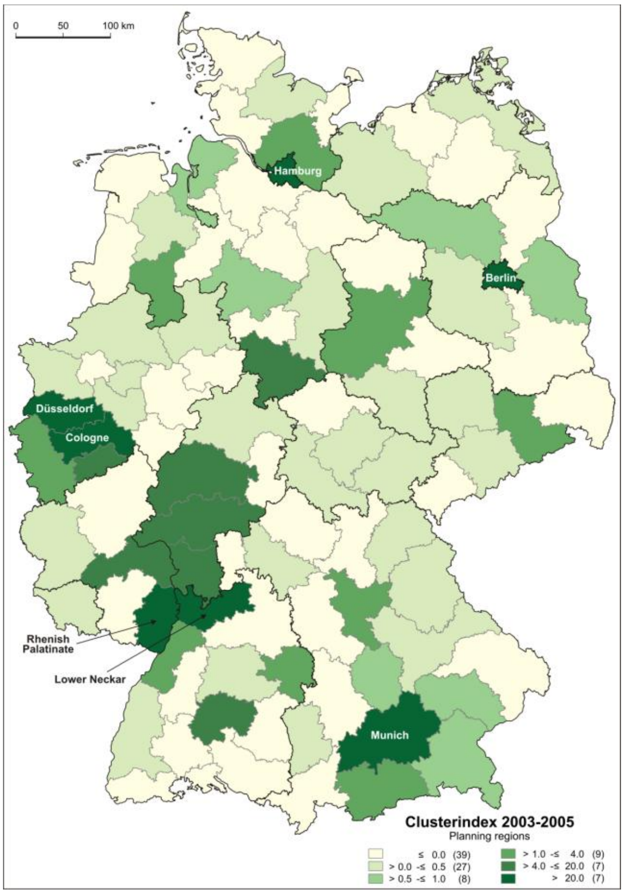

Figure 3: Biotechnological clusters in Germany (cluster index) – 2003-2005

	Scenario **C7**		Scenario **C5**	
	Top-7 CI Cluster	Regions with biotechnology firms lacking a cluster	Top-5 CI Cluster	Regions with biotechnology firms lacking a cluster
Regions	7	73	5	75
Biotechnology firms	282	421	253	450
Subsidized firms (FP6 or national)	77	119	61	128
Share of subsidized firms	0.273	0.283	0.269	0.284
Total number of weighted patents	949.81	514.52	327.21	1137.12

Table : Descriptives of clusters

4 Empirical results

4.1 The participation of biotech organizations in R&D support programs

In order to compare firms in clusters with other firms we use a regression with the cluster membership as dependent variable and firm characteristics, engagement in domestic subsidization programs as well as EU-FP programs as independent variables. A generalized estimation equations (GEE) approach is employed to fit the model using joint location in regions as grouping variable because we have to control for the fact that multiple firms are located within the same region. The results are shown in

Table (Scenario **C5**) and

Table (Scenario **C7**).

Model	**1**	**2**	**3**	**4**
(Intercept)	-1.024* (0.59)	-1.011* (0.588)	-1.005* (0.592)	-0.992* (0.592)
log(EMP)	0.222** (0.106)	0.233** (0.112)	0.232** (0.112)	0.234** (0.115)
PAT.EMP	0.984 (0.6)	1.075* (0.613)	1.098 (0.691)	1.233* (0.635)
AGE	-0.021*** (0.005)	-0.022*** (0.006)	-0.022*** (0.006)	-0.021*** (0.006)
NAT.IND	-	-0.251 (0.265)	-0.252 (0.272)	-0.410* (0.234)
NAT.COLL	-	-	-0.050 (0.277)	-0.286 (0.217)
FP.PROJ	-	-	-	0.402** (0.17)
Scale parameter	0.993 (0.16)	0.993 (0.156)	0.993 (0.156)	0.988 (0.153)
Maximum VIF	1.345	1.371	1.381	1.375
Firms in cluster	253	253	253	253
Firms outside cluster	450	450	450	450

Table : National R&D subsidization and EU-FP6 participation (Scenario **C5**)

The significant positive coefficients of log(EMP) and AGE indicate that firms in clusters are on average larger and younger. In most models also the coefficient for PAT.EMP is significantly positive implying that firms in clusters tend to be more innovative as well. This is in line with previous findings in the literature (Beaudry and Breschi, 2003).

Model	**1**	**2**	**3**	**4**
(Intercept)	-1.051* (0.580)	-1.043* (0.579)	-1.055* (0.584)	-1.051* (0.586)
log(EMP)	0.253** (0.102)	0.260** (0.106)	0.261** (0.106)	0.261** (0.108)
PAT.EMP	1.591** (0.695)	1.661** (0.714)	1.607** (0.728)	1.691** (0.729)
AGE	-0.012* (0.007)	-0.013* (0.007)	-0.013** (0.007)	-0.013* (0.007)
NAT.IND	-	-0.163 (0.254)	-0.165 (0.244)	-0.260 (0.237)
NAT.COLL	-	-	0.115 (0.213)	-0.015 (0.235)
FP.PROJ	-	-	-	0.264* (0.153)
Scale parameter	1.002 (0.099)	1.002 (0.097)	1.001 (0.097)	1.001 (0.098)
Maximum VIF	1.451	1.481	1.519	1.521
Firms in cluster	282	282	282	282
Firms outside cluster	421	421	421	421

Table : National R&D subsidization and EU-FP6 participation (Scenario **C7**)

The empirical results for the variables based on subsidies by and large confirm hypothesis **H1**. We find a positive significant coefficient for FP.PROJ, i.e. the number of FP6 projects in which firms participate. Accordingly, firms in clusters are more frequently engaged in this kind of subsidization program. Given that we control for firms' age, size, and patent intensity, it suggests that firms in clusters either apply for more FP6 grants or that their applications are more frequently granted compared to those by firms not located within a cluster. In other words, firms located in clusters are more likely to receive FP6 grants than firms with identical R&D activities, age, and size but located outside clusters. The finding becomes even more interesting when benchmarked against the coefficients of variables approximating participation in national subsidization programs (NAT.IND, NAT.COLL). The coefficient for NAT.IND becomes negative significant implying that organizations in clusters acquire less subsidized individual projects than firms outside clusters. Even more insightful is the insignificance of NAT.COLL, i.e. participation in nationally subsidized joint projects. It suggests that it is not the subsidization of collaborative R&D in general that makes FP6 more attractive to firms in clusters. It is either the subsidization of international collaboration or FP6's focus on research excellence that matters in this respect. Accordingly, we cannot clearly confirm hypothesis **H2**, as firms in clusters are more active in specific subsidized R&D collaboration but are not more actively collaborating in general.

The insignificance of NAT.COLL moreover highlights that cluster-oriented policy initiatives, such as the BioRegio contest in Germany, do not bias our results. While such collaborative funds are included in our data and clearly favor organizations in clusters, they account for a tiny fraction of projects.

In addition to the question of differences in application and/or grating rates between firms in clusters and other firms, this issue has to be investigated in more detail in future research.

4.2 Firms' embeddedness into networks of subsidized R&D collaboration

We now approach the question whether firms in clusters show different network embeddedness profiles than other firms. For the empirical analysis we restrict the sample to include only firms that are actually engaged in subsidized R&D collaboration. Accordingly, we concentrate on firms that either receive support from FP6 or national programs subsidizing joint R&D. Of the 703 firms in the sample, this applies to just 108 firms, which serve as units of observation in the following. We drop NAT.IND from the analysis, as it is of no interest here. Unfortunately, the network embeddedness measures based on FP6 data (FP.DEGREE and FP.BETWEEN) are strongly correlated among each other and with FP.PROJ (number of FP6 projects) (see Appendix: Table in the Appendix), which prevents their joint inclusion in the regression. It also needs to be pointed out that FP.PROJ and NAT.COLL capture all differences in terms of subsidization intensities, which therefore do not impact the other findings. The results for the scenario **C5** are presented in

Table and those for the scenario **C7** in

Table .

The first thing to notice is that the coefficients of the control variables are similar to those in the previous model implying that the fundamental differences between firms in clusters and outside also exist between subsidized firms. Another interesting observation is the negative coefficient of NAT.COLL, which becomes significant in a number of models in scenario **C5**. It means that on average firms in clusters do not show higher numbers of nationally subsidized joint R&D projects than their counterparts outside clusters. This adds weight to the observation of a continuously significant negative coefficient of NAT.DEGREE representing the count of direct collaboration partners in nationally networks of subsidized R&D collaboration. Accordingly, firms in clusters (participating in at least one subsidized joint project) are not engaged in more subsidized joint projects; they are not more intensely embedded into national networks, and they are not more locally central in these networks. Hence, with respect to nationally subsidized networks we can clearly reject hypothesis **H4**. Amongst the reason for this finding might be the underlying policy's focus on convergence and comparatively stronger support for firms lacking research excellence. It may reduce the chances of firms in clusters being awarded and lowers the program's attraction for firms in clusters. The reason for the latter is that firms in clusters are likely to search for complementary research excellence, which is less likely to exist in national networks of subsidized R&D collaboration. Accordingly, being strongly embedded into national networks is of much smaller importance to them. The latter argument is supported by the significantly positive coefficient of FP.PROJ.[4] Firms in clusters rely on FP6 collaboration to a larger extent than their counterparts outside of clusters. It might therefore be the case that firms see FP6 and national subsidization programs as substitutes. Given that the former provides easier access to state-of-the-art knowledge and rewards research excellence, they are more frequently and more intensively used to access complementary knowledge and resources. Due to the strong correlations between the centrality measures and the number of subsidized projects, Hypothesis **H4** (local embeddedness) can only be tested for national networks. For these networks the hypothesis has to be rejected, as the negative coefficient of NAT.DEGREE

[4] Note once more that this variable correlates strongly with firms' local and global centrality in the FP6 based networks.

clearly indicates a lower number of direct collaboration partners. Hence, firms in clusters are less well embedded into national networks and hold locally less central positions in these.

Model	1	2	3	4	5	6
(Intercept)	-1.401 (0.892)	-1.911** (0.951)	-1.224 (1.111)	-1.217 (0.921)	-2.165** (0.907)	-1.402 (1.063)
log(EMP)	0.465** (0.231)	0.515* (0.264)	0.58* (0.309)	0.58* (0.323)	0.537* (0.289)	0.622* (0.328)
PAT.EMP	2.209* (1.185)	0.801 (1.1)	1.141 (1.047)	0.918 (1.245)	0.994 (1.19)	1.088 (1.287)
AGE	-0.033** (0.014)	-0.03** (0.014)	-0.028* (0.017)	-0.03* (0.016)	-0.035** (0.017)	-0.032* (0.017)
NAT.IND	-	-	-	-	-	-
NAT.COLL	-0.192 (0.601)	-0.856 (0.75)	-1.466** (0.703)	-1.301* (0.753)	-	-1.406* (0.771)
NAT.DEGREE	-0.114* (0.067)	-0.151 (0.098)	-0.189** (0.093)	-0.168* (0.087)	-0.185** (0.082)	-0.175** (0.089)
NAT.BETWEEN	0.003** (0.002)	0.004* (0.002)	0.005* (0.002)	0.004* (0.002)	0.004** (0.002)	0.004* (0.003)
NAT.UNI	-	0.872 (0.578)	0.833 (0.562)	-	-	0.826 (0.562)
NAT.RD	-	1.776** (0.839)	1.727* (0.925)	1.343* (0.687)	1.236** (0.602)	1.735* (0.94)
NAT.REG	-	1.166* (0.666)	1.118* (0.652)	1.378** (0.588)	1.191** (0.563)	1.096* (0.631)
NAT.CLUSTER	-	-0.411 (1.122)	-0.504 (1.058)	-	-	-0.528 (1.081)
FP.PROJ	0.291** (0.139)	0.505*** (0.193)	1.074** (0.541)	1.015 (0.618)	1.45** (0.642)	1.068 (0.67)
FP.DEGREE	-	-	-	-	-	-
FP.BETWEEN	-	-	-	-	-	-
FP.UNI	-	-	-2.152 (1.978)	-3.187* (1.832)	-2.474 (1.63)	-3.202* (1.872)
FP.RD	-	-	2.801 (2.801)	-	-	-
FP.REG	-	-	-7.655 (9.05)	-	-	-
FP.CLUSTER	-	-	-3.385 (3.104)	-	-	-
Est. scale parameter	0.919 (0.352)	0.92 (0.834)	0.88 (0.793)	0.924 (1.619)	0.876 (0.286)	0.897 (1.001)
max VIF	2.583	2.799	6.878	5.928	5.367	5.95
Firms in cluster	38	38	38	38	38	38
Firms not in cluster	70	70	70	70	70	70

Table : Empirical results for network embeddedness C5

However, firms in clusters hold positions that are globally more central than their counterparts outside clusters: The coefficient of NAT.BETWEEN is significantly positive in all models implying that firms' betweenness centrality is larger when they are located in clusters. In addition to confirming hypothesis **H5**, it means that firms get a *premium* to their subsidized collaboration, which shows in better access and stronger exposure to knowledge diffusing in the whole national network. The results for NAT.DEGREE and NAT.BETWEEN can be interpreted such that firms in clusters do not need to engage in many (domestic) collaborations because they are collaborating with few but strategically valuable partners, which provide (indirectly) sufficient access to the network. This is a very interesting observation that points to the possible gatekeeping role played by firms in clusters. By linking otherwise disconnected parts of the networks they shorten distances between organizations and increase overall efficiency of knowledge transmission.

Model	1	2	3	4	5	6
(Intercept)	-2.616** (1.175)	-3.4*** (1.222)	-3.445*** (1.261)	-3.137*** (1.178)	-2.929*** (0.927)	-3.335*** (1.264)
log(EMP)	0.629** (0.25)	0.669** (0.286)	0.721** (0.321)	0.727** (0.317)	0.713** (0.316)	0.749** (0.328)
PAT.EMP	4.149** (1.863)	4.883 (4.141)	5.935 (5.259)	5.822 (4.918)	6.19 (4.967)	6.064 (5.101)
AGE	-0.024* (0.013)	-0.022 (0.015)	-0.022 (0.016)	-0.024 (0.016)	-0.023 (0.016)	-0.024 (0.016)
IND.PROJ.SUBS	-	-	-	-	-	-
COOP.PROJ.SUBS	0.522 (0.621)	0.27 (0.653)	0.222 (0.653)	0.209 (0.709)	-	0.124 (0.7)
DEGREE.SUBS	-0.132*** (0.046)	-0.161*** (0.049)	-0.187*** (0.044)	-0.18*** (0.042)	-0.179*** (0.042)	-0.188*** (0.045)
BETWEEN.SUBS	0.007*** (0.001)	0.008*** (0.002)	0.009*** (0.002)	0.009*** (0.002)	0.009*** (0.001)	0.009*** (0.002)
NAT.UNI	-	0.688 (0.564)	0.704 (0.535)	-	-	0.672 (0.524)
NAT.RD	-	1.342* (0.727)	1.337* (0.762)	1.069 (0.665)	1.092* (0.642)	1.341* (0.779)
NAT.REG	-	1.105* (0.596)	1.152* (0.6)	1.249* (0.644)	1.274** (0.598)	1.102* (0.589)
NAT.CLUSTER	-	-0.093 (0.752)	-0.027 (0.75)	-	-	-0.101 (0.753)
FP.PROJ	0.503 (0.525)	0.904* (0.549)	1.546** (0.783)	1.684** (0.739)	1.611** (0.779)	1.765** (0.799)
FP.DEGREE	-	-	-	-	-	-
FP.BETWEEN	-	-	-	-	-	-
FP.UNI	-	-	-1.837 (2.215)	-3.058 (2.111)	-3.149 (2.058)	-3.059 (2.163)
FP.RD	-	-	4.204 (3.169)	-	-	-
FP.REG	-	-	-4.368 (10.531)	-	-	-
FP.CLUSTER	-	-	-3.577 (4.121)	-	-	-
Est. scale parameter	0.967 (0.478)	0.962 (0.612)	0.941 (0.532)	0.949 (0.594)	0.942 (0.518)	0.949 (0.61)
max VIF	3.031	3.37	7.25	6.204	5.688	6.458
Firms in cluster	43	43	43	43	43	43
Firms not in cluster	65	65	65	65	65	65

Table : Empirical results for network embeddedness C5

The above findings are also in line with evidence from in-depth case studies on Biotech clusters (see among other Moodysson et al., 2008). These studies show that biotech firms strongly rely on analytical knowledge, which exchange is less sensitive to spatial distances. Indeed biotech firms have to build long distance collaborations in search of complementary knowledge, often provided by public research organizations.

We argued that firms in clusters are more likely to engage in subsidized joint projects with the public research sector than firms located outside clusters (**H3a**). Our findings in both scenarios confirm this at least with respect to public research organizations in national R&D networks: The coefficient of NAT.RD is significantly positive in almost all models. Accordingly, on the national level, these institutions are crucial knowledge hotspots, which cluster firms more frequently interact with than other firms. We do not observe a significant coefficient for links to national universities (NAT.UNI). Interestingly, in the **C5** scenario, the share of links to universities through FP6 subsidized collaboration even obtains a significant negative coefficient (FP.UNI). Given that FP.UNI and FP.RD are strongly negatively correlated (see Appendix: Table in Appendix) it might be the case that collaborating with universities reduces or even "crowds out" interactions with extramural research organizations.

By and large, we have to reject hypothesis **H3b,** as the coefficients of NAT.CLUSTER and FP.CLUSTER do not gain significance in any of the models. However, NAT.REG is positive significant in all specifications suggesting that firms in clusters engage more frequently in regional collaboration than firms not located in clusters. This may be interpreted in three ways. First, it can be seen as a manifestation of the cluster being a cluster. Clusters are not just agglomerations of organizations. They are also characterized by intense regional interaction. Moreover, clusters offer larger potentials for regional collaboration than regions with few organizations. In this view, the positive coefficient of NAT.REG confirms that this also holds for subsidized collaboration. Second, one could also argue that it is the research excellence of organizations in clusters directing more (subsidized) collaboration of firms in clusters to other organizations in their cluster. Third, some (national) policies are explicitly designed to support collaboration among organizations in clusters, as for instance the BioRegio contest in Germany (Dohse, 2000). Although its effect appears to be negligible, we cannot disentangle this with the current research design and have to leave this to future research.

5 Conclusion

The present paper argued and tested empirically whether firms in clusters obtain an additional premium because of their location that shows in (1) a higher likelihood of being granted support by public R&D subsidization programs and (2) in being quantitatively and qualitatively better embedded into knowledge networks of subsidized R&D collaboration. Our empirical findings based on the German biotechnology industry confirm these hypotheses to some extent. It was shown that biotechnology firms in (technology) clusters as compared to outside firms are particularly prone to receive support from the 6th EU-Framework Programmes, which can be explained by the initiatives' focus on research excellence and cluster firms' demand for international collaboration with state-of-the-arte knowledge sources. In contrast, national R&D subsidization schemes, in particular those that do not support collaborative R&D, are utilized to smaller extents by biotechnology firms in clusters. The funding probabilities for national support of collaborative R&D projects are not significantly different. Notably, firms' in clusters nevertheless tend to be less intensively embedded into nationally subsidized networks of R&D collaboration but maintain more globally central positions. Moreover, firms in clusters make particular use of national subsidization schemes to engage with public research organizations (not universities). In summary, firms in clusters are clearly subject to “another *cluster premium*”. This does not mean, though that this automatically result in better growth or economic performance: Lee (2011) shows that R&D subsidies stimulate the R&D intensities of firms located outside clusters stronger than that of firms in clusters.

The analysis has some shortcomings, which need to be pointed out. First, the empirical analysis is restricted to German firms active in biotechnology. It still has to be shown that our findings can be replicated in other industries and countries as well. This holds especially since the composition of the network (e.g. share of internal and external linkages) is depend on the stage of the cluster life cycle. Menzel and Fornahl (2010) and ter Wal and Boschma (2011) discuss these changes from a conceptual perspective and Giuliani (2013) compares the development of networks in clusters over time in a case study design. Future research should therefore analyse such changes in network structures in the biotech industry and in other industries. Second, the paper exclusively relies on information about granted subsidies, which does not allow for disentangling policy design, application behaviour, and granting probabilities. Such, surely interesting endeavour, requires additional information on rejected applications. Third, in the present paper, we only look at the isolated behaviour of firms ignoring that collaboration is a bilateral process in which the collaboration partners’ behaviour and characteristics play equally important roles. While there is a fast growing literature on analysing the drivers of collaboration and network evolution (see, e.g., Cantner and Graf, 2006; Balland, 2011) little attention has been paid to the impact of organizations’ actual locations so far.

The paper has a number of policy implications that especially concern the relationship between subsidization schemes by different administrative levels. Firms are confronted with a wide range of international, national, and regional programs offering R&D subsidies and promoting collaboration in R&D. This raises the question to what extent similar policies, which are however initiated at different administrative levels (EU, national, and regional), complement, substitute, or even conflict with each other. Few empirical studies have addressed this issue. For instance, Hoekman et al. (2009) investigate scientific collaboration within the European Research Area policy and find that coordination among EU countries is relatively weak. Nevertheless, the effects of European and national funding on innovation tend to be additive and crowding out effects do not seem to be present (Czarnitzky and Lopes-Bento, 2011). Morrison and Rabellotti (2007), looking at regionally subsidized R&D projects in the agro-food industry, also report that policy initiatives at regional level are crucial, as they create hubs that increase the connectivity of the local network and in turn facilitate knowledge dissemination. The present study adds to this by showing that biotech firms in (technology) clusters are more likely to receive R&D subsidies from international programs than those outside. While the latter finding might be peculiar to the biotech industry with its knowledge base being less sensitive to spatial distance (Moodysson et al., 2008), we still believe that it has interesting implications for policy makers and firms. Concerning the latter, firms have additional reasons (i.e. easier access to R&D subsidy) to relocate or set up a business in a cluster. On the other side, policy makers have to consider the potential allocation biases of their policy measures, which might increase the innovation gap between regions: as core regions become even more excellent and periphery regions continue to fall behind. These latter implications can be informative also for the EU policy agenda on cohesion and *smart specialization*. This study's findings suggest that national and inter-national R&D support policies are rather complementary. The study also revealed that firms in clusters make different and *better* use of such subsidization programs for joint research than firms located elsewhere. For policy it means that firms in clusters might be targeted by specific R&D policies, as they excel in research, which eventually is shared with or diffuses to peripheral organizations in the network. The latter do not have to be located within the cluster, i.e. in geographic vicinity. It is sufficient to be connected to the network in which the cluster firms hold central (betweenness) positions.

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	log(EMP)	PAT.EMP	AGE	NAT.IND	NAT.COLL	FP.PROJ	NAT.DEGREE	NAT.BETWEEN	NAT.UNI	NAT.RD
PAT.EMP	-0.09	-	-	-	-	-	-	-	-	-
AGE	0.71 ***	-0.06	-	-	-	-	-	-	-	-
NAT.IND	0.15	0	0.09	-	-	-	-	-	-	-
NAT.COLL	0.1	0.03	0.28 ***	-0.02	-	-	-	-	-	-
FP.PROJ	-0.05	-0.03	-0.1	0.57 ***	0.3 ***	-	-	-	-	-
NAT.DEGREE	0.11	0.01	0.17 *	0.24 **	0.49 ***	0.32 ***	-	-	-	-
NAT.BETWEEN	0.17 *	-0.02	0.16 *	0.26 ***	0.52 ***	0.38 ***	0.75 ***	-	-	-
NAT.UNI	-0.1	-0.07	-0.01	-0.15	0.27 ***	-0.16	0.13	0.06	-	-
NAT.RD	-0.02	0.15	0.04	-0.2 **	0.33 ***	-0.04	0.28 ***	0.21 **	-0.1	-
NAT.REG	-0.18 *	0.14	-0.18 *	-0.11	0.16 *	-0.07	-0.05	-0.07	0.31 ***	0.06
NAT.CLUSTER (C5)	0.04	0	0.05	-0.19 *	0.22 **	-0.06	0.17 *	0.06	0.08	0.26 ***
NAT.CLUSTER (C7)	0.09	-0.03	0.11	-0.22 **	0.25 ***	-0.07	0.14	0.04	0.13	0.19 *
FP.DEGREE	-0.04	-0.03	-0.07	0.54 ***	0.39 ***	0.97 ***	0.35 ***	0.41 ***	-0.13	0.02
FP.BETWEEN	-0.08	-0.03	-0.05	0.44 ***	0.56 ***	0.93 ***	0.43 ***	0.49 ***	-0.02	0.11
FP.UNI	0.03	-0.01	-0.13	0.43 ***	-0.48 ***	0.45 ***	-0.2 **	-0.13	-0.36 ***	-0.36 ***
FP.RD	0	0	-0.15	0.47 ***	-0.39 ***	0.52 ***	-0.13	-0.05	-0.34 ***	-0.3 ***
FP.REG	0.02	-0.07	-0.08	0.15	-0.36 ***	0.23 **	-0.2 **	-0.1	-0.25 ***	-0.25 ***
FP.CLUSTER (C5)	0.01	0.03	-0.13	0.49 ***	-0.42 ***	0.5 ***	-0.17 *	-0.08	-0.34 ***	-0.34 ***
FP.CLUSTER (C7)	0.01	0.03	-0.13	0.5 ***	-0.42 ***	0.5 ***	-0.17 *	-0.09	-0.35 ***	-0.34 ***

	NAT.REG	NAT.CLUSTER (C5)	NAT.CLUSTER (C7)	FP.DEGREE	FP.BETWEEN	FP.UNI	FP.RD	FP.REG	FP.CLUSTER (C5)
NAT.CLUSTER (C5)	-0.22 **	-	-	-	-	-	-	-	-
NAT.CLUSTER (C7)	-0.25 **	0.88 ***	-	-	-	-	-	-	-
FP.DEGREE	-0.02	-0.02	-0.01	-	-	-	-	-	-
FP.BETWEEN	0.03	0.05	0.04	0.95 ***	-	-	-	-	-
FP.UNI	-0.23 **	-0.28 ***	-0.25 ***	0.38 ***	0.14	-	-	-	-
FP.RD	-0.21 **	-0.24 **	-0.27 ***	0.45 ***	0.27 ***	0.67 ***	-	-	-
FP.REG	-0.16	-0.19 **	-0.18 *	0.14	0.07	0.46 ***	0.45 ***	-	-
FP.CLUSTER (C5)	-0.22 **	-0.27 ***	-0.24 **	0.43 ***	0.22 **	0.83 ***	0.82 ***	0.43 ***	-
FP.CLUSTER (C7)	-0.23 **	-0.27 ***	-0.24 **	0.43 ***	0.22 **	0.82 ***	0.83 ***	0.43 ***	1 ***

Appendix: Table : Correlation table for data on firms with subsidies for joint R&D

	mean	sd	median	min	max	skew
EMP	245.58	2414.55	15.00	0.00	56300.00	19.62
PAT.EMP	0.46	2.26	0.00	0.00	32.67	9.58
AGE	13.33	24.24	6.00	1.00	177.00	4.18
NAT.IND	0.16	0.38	0.00	0.00	2.00	2.21
NAT.COLL	0.14	0.41	0.00	0.00	5.00	4.63
FP.PROJ	0.07	0.63	0.00	0.00	15.00	19.48
NAT.DEGREE	0.97	3.74	0.00	0.00	40.00	6.02
NAT.BETWEEN	14.31	91.68	0.00	0.00	1190.74	8.09
FP.DEGREE	1.02	10.20	0.00	0.00	252.00	21.55
PF.BETWEEN	12.65	275.28	0.00	0.00	7263.76	26.01
NAT.REG	0.03	0.16	0.00	0.00	1.00	5.42
NAT.UNI	0.04	0.16	0.00	0.00	1.00	4.68
NAT.RD	0.04	0.16	0.00	0.00	1.00	4.40
NAT.CLUSTER (C5)	0.03	0.13	0.00	0.00	1.00	5.63
NAT.CLUSTER (C7)	0.03	0.15	0.00	0.00	1.00	5.02
FP.REG	0.00	0.01	0.00	0.00	0.17	9.42
FP.UNI	0.02	0.10	0.00	0.00	0.86	5.41
FP.RD	0.01	0.07	0.00	0.00	0.64	6.02
FP.CLUSTER (C5)	0.01	0.07	0.00	0.00	0.67	5.52
FP.CLUSTER (C7)	0.01	0.07	0.00	0.00	0.67	5.44

Appendix: Table 8: Descriptives of data