Cluster support activities in the German biotechnology sector

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Abstract

Many governments have established cluster policies to foster innovation and support high-tech industries through agglomeration economies. They attempt to boost networks through providing clusters with resources to organise heterogeneous support activities. A key question is which support activities are the most important for firms. In this study, we investigate the German biotechnology industry based on a survey of dedicated German biotechnology firms ($n = 92$). We find that i) members of biotechnology clusters primarily take part in events related to network development and fundraising, ii) they do so by a much greater extent than firms outside of clusters. We then show that firms in clusters are more likely to engage in R&D collaborations, to attract public R&D grants or private investments, and to be innovators.

Keywords: Cluster policy, Agglomeration, Biotechnology

JEL Codes: O38

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1 Introduction

Cluster policies have been implemented in an increasing number of countries targeting a wide range of high tech sectors (Cantner *et al.*, 2019). Their popularity stems from different arguments related to the benefits of co-location. First, co-location increases knowledge spillovers (Allen, 1983; Thursby & Thursby, 2002) by fostering formal and informal exchange (Porter, 2000). Second, co-location enhances complementarities between the activities of different actors and sustains co-learning between customers and suppliers (Lundvall, 2016; Freeman, 1991; Saxenian, 1991). Third, co-location creates dense resource networks, fostering, for instance, the access to local infrastructure and skilled staff (Cooke *et al.*, 2011).

While the theoretical arguments linked to agglomeration economics are known since Marshall (1988), the empirical literature is still investigating the individual importance of each factors (Duranton & Overman, 2005, 2008; Ellison & Glaeser, 1997; Ellison *et al.*, 2010). At the same time, innovation policies aim to develop industrial clusters, and to increase the length and intensity of local micro-interactions to maximize the benefits from co-locations within specific industries (see the subsection 3.1, or Nishimura & Okamuro (2011) for material sciences in Japan). Despite their popularity, assessments of cluster policies have yielded ambiguous results across countries (Martin & Sunley, 2003; Martin *et al.*, 2011; Huber *et al.*, 2012).

Our study contributes to this discussion by assessing how clusters support innovation in the German biotechnology industry. The German biotech industry is a relevant lens to study the impact of cluster policies on innovation. The importance of concentrating R&D activities near universities and benefiting from complementary inputs from a large innovative ecosystem are key reasons to integrate a local innovation network. This effect is likely to be all the stronger in the German biotech case considering that the industry is mostly composed of SMEs. Those are more likely to benefit from entering the R&D value chains of large firms and specializing in one specific research areas. Cluster support is also likely to increase SMEs visibility in terms of attracting skilled-labour and investments that larger firms do not necessarily need. Our measure of cluster support relies on the firm's cluster membership and the related means of cluster support collected in a firm survey.

Our results show that firms in German biotechnology clusters make intensive use of networking opportunities. They are also more likely to collaborate with upstream and downstream firms and scientific institutes. Furthermore, they attract financing from public and private sources more often. Finally, in line with previous studies, we document a positive link between innovation activities and cluster membership. Our results contribute to the literature by documenting the different channels through which cluster organisations affect the innovative performance of their membership firms. These findings can inform policy making by contrasting the relative importance of the individual channels of cluster polices.

The remainder of this paper is structured as follows: section 2 develops the theoretical framework underpinning the effect of clusters, section 3 reviews the institutional background. Section 4 introduces the methodology and data, section 5 presents the results and a discussion of alternative data sources. Section 6 concludes and covers policy implications.

2 Literature review

2.1 Delineating clusters

In this part of the literature review, we discuss the difficulties in defining clusters, and argue that heterogeneity in these definitions might explain part of the heterogeneity in results found across countries and industries. While geographical proximity has been mainly used as cluster definition, spatial clustering might also be the result of other dimensions (e.g. regional access to research infrastructure, skilled labor, technological or economical complementarities) (Cooke *et al.*, 2011). Consequently, conducting an empirical evaluation of cluster policies requires to distinguish agglomeration effects coming from cluster policies from other local or industrial peculiarities.

Spatial clustering in high tech sectors has many reasons. One of them is that clusters form around universities, where highly innovative firms can hire skilled staff and maintain ties with science to access knowledge (Thursby & Thursby, 2002). Consequently, the literature on high tech clusters depicts a strong polarization of firms around highly populated areas, and its spatial clustering is stronger than in broader manufacturing (Ellison *et al.*, 2010). Firms also co-locate to access infrastructure (Agrawal *et al.*, 2017). Like the presence of universities, the quantity and quality of infrastructure is more concentrated in urban areas, which enhances the spatial clustering of high tech activities. These facts generate empirical challenges. The first challenge is to quantify the density of agglomeration in which clusters can be seen as a specific case of agglomeration. The second challenge is to isolate the effect of agglomeration from the effect of belonging to a cluster and other competing explanations.

Different approaches have been used to measure agglomeration economies. A first stream of literature relies on regional evidence by evaluating to what extent an industry is agglomerated within given spatial units (i.e. counties, cities, states) (Rosenthal & Strange, 2001, 2004; Duranton & Overman, 2005, 2008; Ellison & Glaeser, 1997). A second strand of the literature looks at the productivity gains at the establishment level based on firms' co-location characteristics. In this framework, the context of co-location is defined by the amount of plants located in a given radius around a firm (i.e. miles, commuting times, counties, cities, states). In line with this framework, patenting activities and commuting distance have for instance been used to study the impact of agglomeration on firms' innovativeness (Carlino *et al.*, 2007, find for example more patents per capita in higher urban density areas). However, the methodological diversity in defining the unit of analysis and proxies for measuring spatial clustering of R&D activities (e.g. geographical thresholds, industry classifications, patents) can lead to contrasting conclusions regarding the impact of agglomeration on innovation (see Pajunen & Järvinen, 2018). Clusters can be seen as a specific case of spatial agglomeration, but there is no clear definition, or threshold, delineating the borders of a cluster. In the context of the biotechnology industry, clusters have been mostly been delineated based on firm density and (Stuart & Sorenson, 2003) and regional patenting (Engel *et al.*, 2013).

2.2 Beyond agglomeration: non-financial support and quality signaling

Most of the literature studies the effect of clustering based on geographical proximity. However, several forms of proximity (i.e. social, institutional, geographical, and technological) can substitute and complement each other (Boschma, 2005). As mentioned above, some targeted initiatives showed different effects of clustering on firm performance depending on a firm's relatedness with a cluster's industry, or activity. Furthermore, the effect of geographical distance on knowledge exchange is reduced if social proximity increases: trust or common goals can substitute to some extent a close geographical distance on knowledge exchange (Agrawal *et al.*, 2008). Surveys and patent data have been used to proxy joint projects, and hence, social proximity. However, doing so limits the set of relevant interactions to formal collaborations. We argue that interactions between members of a given cluster go beyond the latter: the establishment of common goals and a cluster identity might also participate in enhancing firms' innovation activities. The view on social proximity should therefore be broadened to include the overall management of a cluster that supports and coordinates cluster activities.

Few studies look at the quality of the cluster management as a determinant to sustain and coordinate innovation activities, explaining why firms located in clusters perform better (Cantner *et al.*, 2019). Nevertheless, there is some indicative evidence. Evaluations of Swedish cluster policies have documented positive impacts of providing support with innovation processes and mentoring (Cooke, 2010). An evaluation of cluster policy in Great Britain reported a positive response to providing businesses access to technology, machinery, and consulting (DTZ, 2008), and a study of Canadian cluster policies reported that support activities related to mentoring, business development, and networking were received well (NRC, 2012).

3 Institutional background

The year 2019 marked the 100th anniversary of the term "biotechnology" first coined by Karl Ereky, director of the livestock assessment cooperative of Hungary's large landowners. He popularized the word biotechnology in his book Biotechnology of Meat, Fat and Milk Production in Large Agricultural Enterprises published in 1919. Historically, biotechnologies have been defined as "the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services" (OECD, 2007, p 140). The German Association of Biotechnology Industries specifies biotechnology companies as companies using "modern biological, rather than conventional, techniques to develop commercial products for human or animal healthcare, agricultural production, food, processing and the environmental services sector" (Young, 1998, p 2).

Since the inception of biotechnology in 1919, the scope of industries relying on biotechnologies keeps expanding (Englbrecht, 2019). More than ever, the biotechnology industry plays an important role in finding innovative answers to health and sustainability issues in which resource management, access to food, and water are key. The ongoing COVID crisis is a prime example. It puts the biotechnology industry at the forefront of counteracting the pandemic by producing new tests, and identifying therapeutics and vaccine candidates (Englbrecht, 2019). The strong willingness to establish the German biotech industry as a key international competitor made Germany a precursor in implementing cluster-based policies through the BioRegio iniatiative (Champenois, 2012). In contrast to other countries, the German biotech industry is mostly composed of SMEs (670 dedicated biotech firms in 2018), representing 1.04bn euros in research and development and 3.28bn euros of turnover in 2015 (Wirsching *et al.*, 2016). Ensuring the growth of these SMEs paved the ground to innovation policies that could boost their productivity and innovation capabilites by fostering local innovative networks (Hantsch *et al.*, 2013). In the next subsections, we will describe the key cluster-based initiative in the German biotech industry. Figure 1 presents an overview.

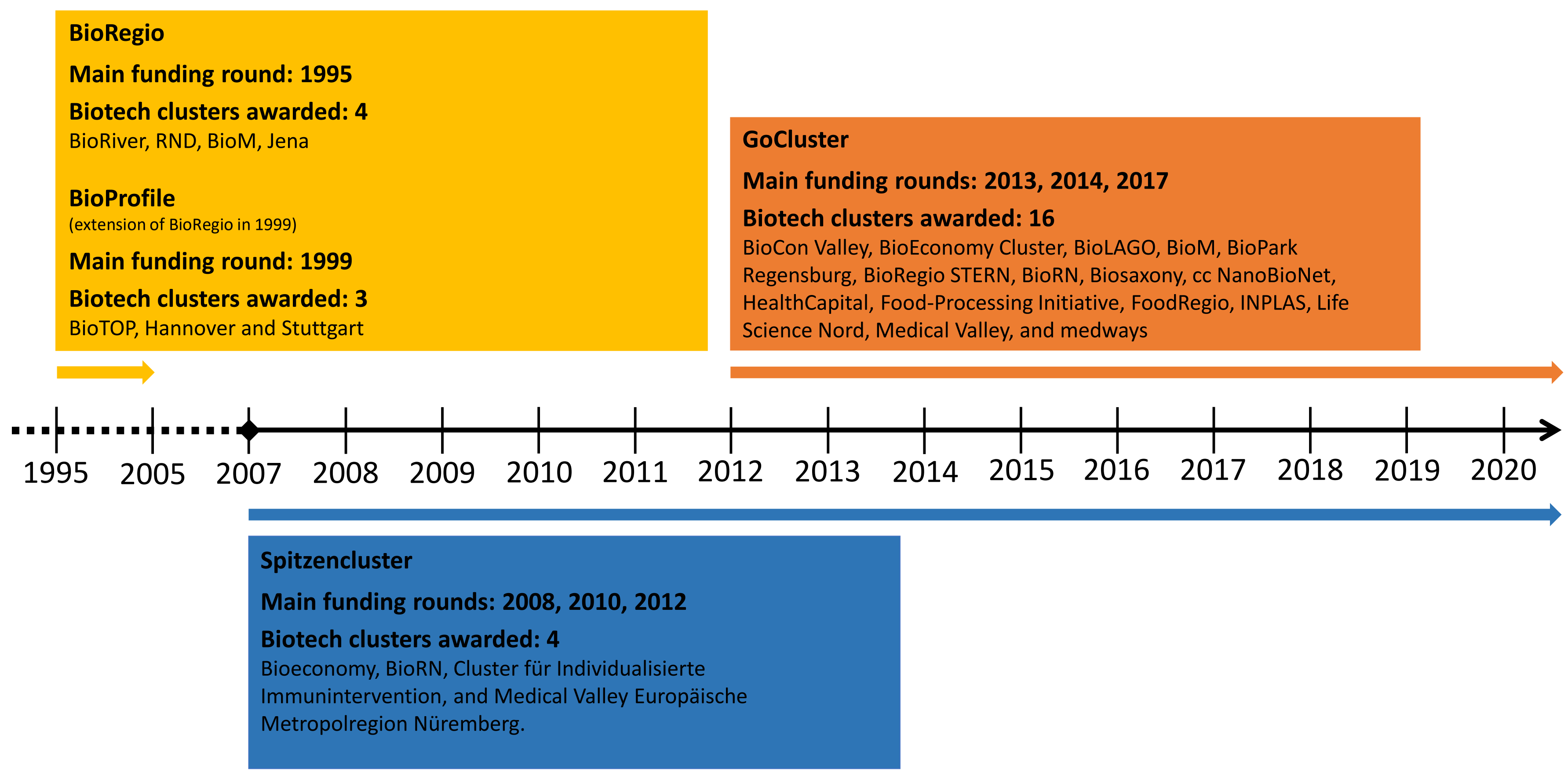

Figure 1: Overview of the main cluster initiatives related to biotech industries

3.1 BioRegio and BioProfile

The BioRegio contest emerged in the 1990s to accelerate the development of the biotechnology industry in Germany. Despite a strong competitive advantage in chemical and pharmaceutical industries, Germany developed its biotechnology industry at a slower pace than in the USA and the UK (Dohse, 2000). This different pace is explained by more risk aversion coming from, on the one hand, banks and venture capitalists, and on the other hand, the limited acceptance of the German society in consuming genetically modified products (Young, 1998). The German Federal Ministry of Research and Education established the BioRegio contest with the aim of making Germany the leading European country in the field. The contest officially started in 1995 with simple rules: any locality (e.g. cities, states, network of cities) could present its current strength in biotech (e.g. research and commercialization) and its strategy to enhance the latter in the region. These proposals were evaluated by an independent panel composed of a representative sample of the industry stakeholders (e.g. scientists, industry, and trade unions). The jury elected three winners based on a set of 9 main criteria related to the growth and consistency of the regional biotech innovation ecosystem[1]. Overall, 17 regions participated in the competition from which 3 were elected as winners (BioRiver, RND, BioM) and one special vote of the jury made a fourth winner (Jena). The latter was aiming at rewarding a positive and dynamic development of the biotech industry in a post-reunification context (Dohse, 2000). These regions were mainly financially rewarded: first, by receiving a share of 150 million DM directly provided by BioRegio, and second, by benefiting from the larger share of the "Biotechnology 2000 program" launched by the Federal Ministry of Research and Education. The latter consist of funding over 5 years (1996-2001) and represent an overall public investment of 1.5 billion DM split across all German Biotech Clusters (see Table 2 in Dohse, 2000, for more details).

The BioRegio initiative created a shift in biotechnology innovation policy design by shifting the focus of the competition for funds from the firm level towards innovative networks (Eickelpasch & Fritsch, 2005). Doing so, it aimed to stimulate a local division of innovative labour between private firms, universities and non-university research institutes (Eickelpasch & Fritsch, 2005). This initiative created an institutional competition between regions to attract funds to develop innovation (Dohse, 2000; Eickelpasch & Fritsch, 2005) and scientific third party funding (Koenig *et al.*, 2017). While positive effects of this competition on innovation have been stressed, adverse effects have been less discussed (Audretsch *et al.*, 2019; Dohse, 2000). Dohse (2000) emphasizes that concentrating biotech know-how in winning regions deepens inequalities in high tech sectors between regions. Being located in a well-known biotech region acts as a signal mechanism in attracting funding but does not ensure that the allocation of funds targets innovative firms Dohse (2000). Firms located in less known biotech clusters are ceteris paribus less likely to benefit from BioRegio funds, deepening the already existing inequalities across leading and lagging biotech regions (Dohse, 2000). While the development of high-tech sectors has been described as a clustering phenomenon (Porter, 2000), BioRegio amplified spatial clustering by serving as a quality signal. To take into account the differences between leading and lagging regions, a new competition, BioProfile, was created. As an extension of BioRegio, it targeted "second bests", e.g. strong specialized biotech regions with less capabilities than BioRegio winners. 3 clusters were awarded (i.e. BioTOP, Hannover and Stuttgart) and shared 50 million euros from the German Federal Ministry of Research and Education over 5 years (1999-2004). The positive effect associated to BioRegio and BioProfile in terms of firms creation and innovation efforts spurred the extension of such cluster-based policies to several high tech domains (Young, 1998; Dohse, 2000; Champenois, 2012).

[1]Number and scale of biotech firms in the region, number and productivity of biotech research facilities and universities in the region, networking of different branches in biotech research in the region, supporting technological transfer facilities, strategies to translate biotech research ideas into new products and processes, a regional concept to enhance regional biotech entrepreneurship, provision of financial resources (banks and private equity to support regional biotech companies), cooperation among biotech regional research institutes and clinical units, local authorities approval practices related to biotech facilities and field experiments.

3.2 Spitzenclusters

The Spitzencluster (Leading Edge Cluster) competition is a large-scale German policy program, that was established in 2007 by the Federal Ministry for Education and Research (BMBF) as a prominent part of the country's High-Tech Strategy. It follows the competition launched by the BioRegio initiative but enlarged the number of relevant technological areas (Töpfer *et al.*, 2019). The general aim of the Spitzencluster competition is to improve Germany's innovation potential by supporting highly performing regional innovation clusters to reach or maintain international leadership (Rothgang, 2014). The program has gone through three funding rounds (2008, 2010, and 2012) and awarded 15 clusters (only 5 in biotechnologies[2]). Overall, 600 million EUR have been distributed between 2009 and 2017, representing a cluster investment of 40 million EUR over five years.

The selection procedure consists of two main stages. In a first stage, applicants submitted proposal sketches that were evaluated by a jury composed of 15 representatives from science and industry. Based on these sketches, a dozen clusters were then invited to submit a full application. Overall, 5 clusters were chosen as winners of the competition. The initiative's funding was divided in two parts, whereas the first part was unconditional, but the second part was depending on a positive interim evaluation after two years of funding (Rothgang, 2014). The main evaluation criterion was that the clusters should have the potential to reach the ambitious goals of achieving (or maintaining) international competitiveness and visibility, and to achieve that in a sustainable way, that is likely to last after public support has ended. The interim evaluation was hence focused on the strategy proposed by the cluster, which was supposed to draw on the cluster's existing strengths, and developed those strengths in such a way that it was likely to lead to innovative products, processes and services (Rothgang, 2014). Sustaining innovation efforts was supposed to be fostered by another requirement regarding the composition of a cluster's innovation network. Cluster strategies should show sufficient financial involvement from private actors measured by economic restrictions on R&D funding: each euro of public subsidy should be matched in private R&D funding (Rothgang, 2014). More than impacting the composition of clusters, Spitzencluster enhanced the importance of the network governance through the evaluation and monitoring of cluster strategies. Over the funding time-span, cluster progress was tracked by a governing board, which assessed the role of cluster management organisations (i.e. organising meetings, managing contacts with internal and external partners, and to provide infrastructure).

The Spitzencluster competition is generally seen as a successful policy instrument, stimulating regional innovation and entrepreneurship (Rothgang, 2014) and fostering new local collaborations (Töpfer *et al.*, 2019)[3]. At the same time, there appears to be room for improvement. The evaluation of Spitzenclusters at the German federal level in 2011 shed light on the uneven success rates across clusters and the importance of creating and sustaining innovation networks to be successful (Ekert *et al.*, 2016). The heterogeneous effects of Spitzenclusters put the importance of relying on cluster managements to the front. Furthermore, the limited positive impact of Spitzenclusters on local innovation is explained by regional lock-in. Rothgang (2014) recommend that future initiatives should not focus on local aspects too much. Therefore, the idea of supporting local innovation networks moved towards a new direction with an increasing internationalisation and the professionalisation of clusters activities. Both aspects paved the ground for a new initiative, GoCluster.

3.3 GoCluster initiative

The GoCluster program was initiated by the German Federal Ministry for Economic Affairs and Energy and aims at supporting cluster management organizations in strengthening their cluster's

[2] Bioeconomy, BioRN, Cluster für Individualisierte Immunintervention, and Medical Valley Europäische Metropolregion Nürmberg, BioM4.

[3] Rothgang (2014) reports that the policy relates to 300 patent applications, 600 innovations, and 2500 theses, dissertations, and scientific publications. Around 40 spinoffs stem from the program. Rothgang (2014) also reports that a counterfactual analysis shows that funding by the Spitzencluster competition led to higher R&D expenditures and personnel. The authors estimate a total effect of 1.36 EUR per 1 EUR in public support.

innovativeness. GoCluster has been heavily influenced by the trend initiated by the European Commission in supporting innovation and SME growth via cluster management. In 2009, the European Commission launched the European Cluster Excellence Initiative[4], supposed to signal the quality label for cluster management at the international level through different quality indicators (i.e. Gold, Silver, or Bronze labels). The GoCluster program comprises four different lines of support: i) Networking, ii) Momentum for excellence, iii) Clusterplattform Deutschland and iv) Support. We summarize the focus of each funding line based on the OECD (2019), Ekert *et al.* (2016) and the official program website Clusterplattform[5]. Applications for GoCluster memberships are possible at any time and monitored by the project organizer VDI—VDE Innovation+Technology. Additional funding possibilities for GoCluster members were designed to reward specific cluster characteristics: innovative cluster management services (2013/2014), inter-cluster projects (2014/2015), and a variety of topics related to internalization, education and digitization (2017/2018). The criteria to be eligible to the GoCluster initiative were influenced by the lessons learned from the Spitzencluster initiative.

The visibility of clusters is enhanced through the Momentum for Excellence, which provides cluster management consulting and seminars to promote their performance. Also, it supports quality hallmarks. All members of the GoCluster program are allowed to use the registered word and figurative mark "GoCluster – exzellent vernetzt" to promote their excellence and wave the cost of the European Silver Label Certification. Finally, Clusterplattform Deutschland aims at raising the profile of the program's cluster initiatives (location, technology field, industry and funding by the federal- or state-level). It exhibits newsletters, events, success stories and general information on cluster policies in Germany and the EU. Fostering the clusters visibility was also key to internationalize their R&D activities in order to avoid regional lock-in. For that reason, GoCluster members organize and participate in various national and international events, trade fairs, cluster policy meetings, generate printed and online publications, and supports match making.

GoClusters impose conditions to guarantee the sustainability of the developed networks. Clusters must consist of at least thirty permanent members. The cluster management must prove at least three years of activity since its official foundation, and provide a sufficient amount of employees per cluster member, solid finances as well as a cluster strategy codified in official documents. Also, its members need to be appropriately represented in its decision-making bodies. Finally, the applying cluster initiative also needs to demonstrate a supply of cluster management services answering the cluster members' specific needs, and its importance for the regional innovative system.

To assure that the cluster enhances SME networks, fifty percent of the members must be companies, whereas again fifty percent of the companies are supposed to be SMEs. At least sixty percent of all cluster members must be based within 150 kilometers distance of the cluster management organization. A mostly representative survey of go-cluster member management organizations by (Ekert *et al.*, 2016) finds that between 2012 and 2015 the majority of *GoCluster* members grew at least moderately with regards to their cluster members and more than eighty percent were using the mandatory silver label for public relations. Seminars and consulting, the Silver-Label Process, project funding and the *GoCluster* hallmark were rated as most important elements of the *GoCluster* program. Following these results, cluster members also reported to profit the most from an increased reputation with regard to funding organizations and policy makers, an increased cluster management know-how and better/faster information of cluster related news.

4 Methodology

To investigate the relationship between cluster membership, cluster support activities, and firm outcomes, we developed an online survey. The survey was sent out to the population of dedicated biotechnology firms in Germany, which comprised 677 firms. Dedicated biotechnology firms are defined as firms whose main line of business relies on using biotechnological applications to manu-

[4] ECEI, `www.clusterexcellence.eu`

[5] `https://www.clusterplattform.de/SiteGlobals/CLUSTER/Forms/Suche/DE/Clustersuche_Formular.html?pageNo=0&queryResultId=null`

facture products, provide services, or to perform RD. To define the population, we purchased data from BIOCOM. Founded in 1986, BIOCOM is the main provider of information on the German biotechnology, and also conducts surveys for the German Federal Ministry for Education and Research and the OECD.[6] BIOCOM provides basic information, including addresses, e-mail contact information, foundation year, numbers of employees, and main fields of activity. The most recent reference year available for our survey was 2018.

The survey consisted of three sections. The first section asked about membership in biotechnology clusters. The second section asked about the firm's R&D activities, subsidies, R&D collaboration, and use of supporting services by the cluster. The third section asked about the firm's environment and general economic characteristics. The survey was conducted between September and November 2019, and gathered information about the reference period 2016 to 2018. The survey was available in German and English to reduce potential language barriers. The English version of the survey is presented in the appendix. Firms were initially contacted by post, accompanied with e-mail reminders after 9 and 22 days. A sub-sample of 200 firms was additionally contacted by phone after one month. 121 firms were reached by phone. The gross response to the survey amounted to 92 responses, or an overall response rate of 14 percent.[7] Table 2 describes the main characteristics of our sample vis-a-vis the German biotech population and Tables 3, 4 and 5 in the Appendix show detailed response statistics across biotech sectors and age categories. The sample is somewhat over-represented in terms of small firms.[8]

4.1 Survey data

Table 1 presents the composition of the sample. The majority of respondents, 61% was member of at least one biotechnology cluster at the time of the survey. The average respondent was established in 2006, and firms in biotechnology clusters are approximately 2.5 years older than firms outside of clusters. The vast majority of firms conduct internal or external R&D (83%). The average respondent has 14 employees, with firms outside of clusters having on average 16 employees, and firms in clusters 10 employees. Table 1 also shows that the vast majority of the sample, 95% concerns small firms of less than 50 employees. Contrary to the USA, the UK, and France, the German biotech industry is driven by SMEs. The secondary role played by large chemical and pharmaceutical firms in Germany is the consequence of strict regulations on biotechnological research (Müller, 2002).

Figure 2 presents the location of biotech firms at the zip code level to describe their spatial clustering. The two map show that our respondents reflect the general geographical distribution of the overall population: biotech firms tend to locate in large cities, to benefit from the proximity with universities and research institutes but also to attract high-skilled individuals. We can note a strong polarization of the biotech activities in the Western part of Germany despite a few hot spots in the eastern part (Jena), historically known as a biotech hub (see subsection 3.1 in which geographical concentration is measured by the number of biotech firms at the zip code level).

Approximately half of the sample, 48%, focuses on red (human or veterinary health) biotech, and 37% is categorized as nonspecific. This composition of the sample reflects the main characteristics of the German biotech population, which is populated to a large extent by small and red (human or veterinary health) biotech firms (Young, 1998).

5 Results

The results first describe which of the various support activities provided by biotechnology clusters are used by cluster members, and compare these to firms outside of clusters – which might nevertheless still make use of some of these activities. We also compare the importance of cluster support

[6] BIOCOM data has been used as a data source for other academic studies, for instance by Mitze & Strotebeck (2019).

[7] Five firms could neither be contacted by post, e-mail or phone. These firms are therefore excluded for calculating the surveys response rates.

[8] Also note that the share of firms that are older than 7 years and did not have employee information within the BIOCOM data is smaller in our respondent sample than in our population.

Table 1: Sample characteristics

	Full Sample					In cluster	No cluster
	Obs.	Mean	S.D.	Min	Max	Mean	Mean
Cluster membership (0/1)	92	0.61	0.49	0.00	1.00		
Foundation year	92	2006.36	8.42	1983	2018	2004.83	2007.34
R&D activity (0/1)	84	0.83	0.37	0.00	1.00	0.81	0.85
Employees (#)	73	14.34	19.12	0.00	100.00	10.32	16.44
Size Class							
< 50 employees	73	0.95	0.23	0.00	1.00	1.00	0.92
$50 - 99$ employees	73	0.04	0.20	0.00	1.00	0.00	0.06
100+ employees	73	0.01	0.12	0.00	1.00	0.00	0.02
OECD Class							
Agricultural (0/1)	92	0.02	0.15	0.00	1.00	0.03	0.02
Bioinformatics (0/1)	92	0.08	0.27	0.00	1.00	0.03	0.11
Health (0/1)	92	0.46	0.50	0.00	1.00	0.44	0.46
Industrial (0/1)	92	0.08	0.27	0.00	1.00	0.11	0.05
Non-specific (0/1)	92	0.37	0.49	0.00	1.00	0.39	0.36
Observations	92					36	56

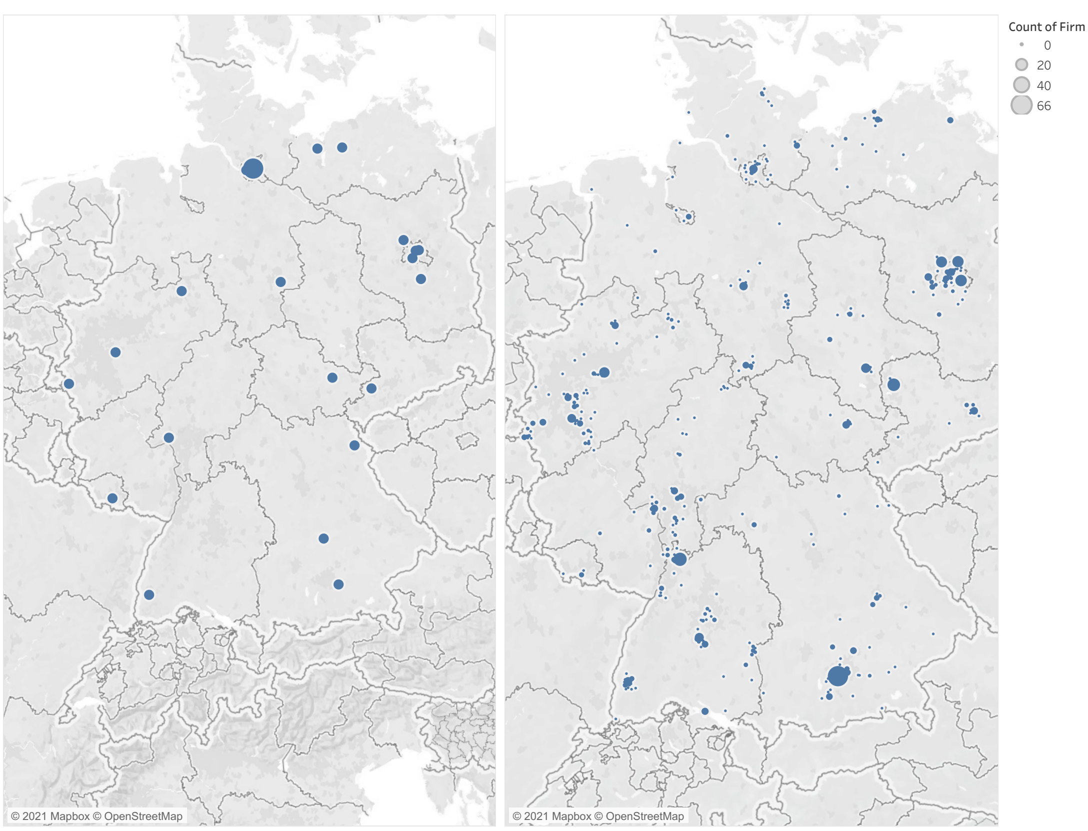

Figure 2: Distribution of biotech firms across region (surveyed vs population)

activities to the same support activities offered by other organisations. After establishing which support activities are prevalent in biotechnology clusters, we show that firms in biotechnology clusters are more likely to achieve the intended outcomes of key support activities: R&D collaboration, attracting funding, and innovation. Overall, our sample reflects the different cluster initiatives introduced in our institutional background. Table 6 presents the distinct clusters and their respective number of firms belonging to them. However, we can see a small over-representation of large and well-established biotech clusters such as BioRN and BioM.

5.1 Engagement with cluster support activities

Figure 3 shows the cluster support activities that firms in biotechnology clusters engaged in between 2016 and 2018. We distinguish several kinds of support: (1) support with operational activities such as management and product markets; (2) providing temporary or permanent infrastructure such as office space and meeting rooms; (3) support in developing networks, including networking events, trade fairs, and job matching events; (4) support with attracting funding, including direct support, investor matching events, and public funding information events; and (5) training programs.

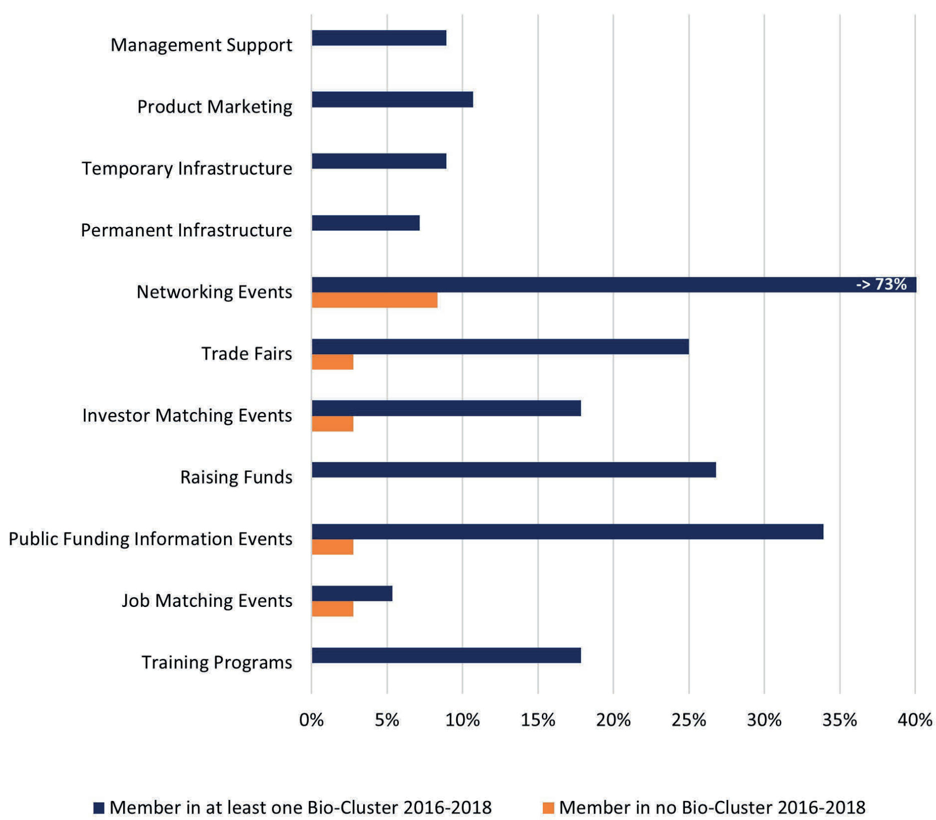

Figure 3: Engagement in cluster support activities by cluster membership, 2016-2018

Firms in biotechnology clusters are by far the most likely to make use of support with networking: 73% of the firms in the sample indicates that they attended at least one networking event, and 25% indicates that they attended at least one trade fair. The dominance of networking support activities is in line with the stated purpose of the German biotechnology support programs (Eickelpasch & Fritsch, 2005). Compared to these, job matching evens are less important: only 5% of firms made use of them. Firms also often make use of support with attracting finance: 34% of firms attended at least one event about public funding opportunities, and 27% of the firms attended at least one fundraising event. 18% of firms attended at least one investor matching events. The other categories are less important: 18% of firms took part in at least one training program. Support with management and product marketing was used by 9% and 11% of firms, and 9% and 7% of firms made use of temporary and permanent infrastructure.

Networking and finance are thus the most commonly used cluster support activities by firms in biotechnology clusters. Figure 3 furthermore shows that firms outside of biotechnology clusters also, to a small extent, benefit from these activities. Some support activities – direct support and infrastructure, in particular – are likely not available to non-members. This is reflected in the results, as no firms outside of biotechnology clusters indicated to have made use of those. Other activities, such as networking, are likely to benefit from including also non-members. In line with that, 8% of respondents outside of biotechnology clusters indicated that they attended at least one networking event organised by a biotechnology cluster. This is one channel through which cluster support activities might generate spillovers to the broader region. However, the contrast with firms in clusters is stark – 73% vs. 8%.

It might still be possible that firms outside of biotechnology clusters are able to compensate for the lesser availability of cluster support by using the assistance of other organisations. Figure 4 shows that this is not the case: across all included support activities, firms in biotechnology clusters make use of support by third organisations to a larger, or comparable, extent than firms outside of biotechnology clusters.

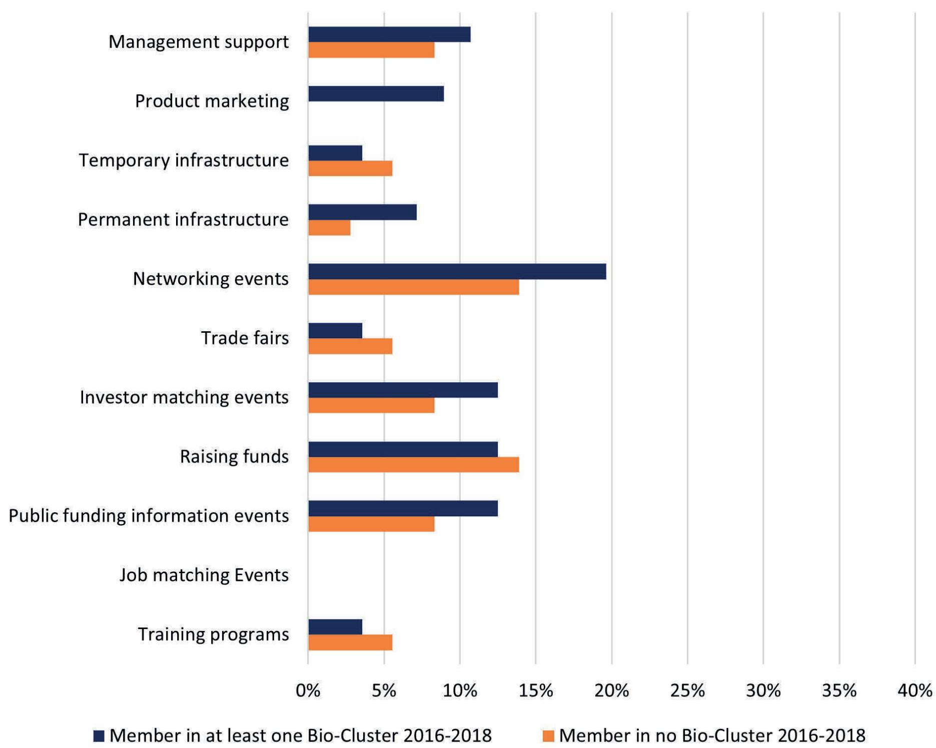

Figure 4: Engagement in support activities from other organisations by cluster membership, 2016-2018

5.2 Outcomes of cluster support activities

The previous section shows that the majority of firms in biotechnology clusters makes use of support concerning networking, and a non-negligible minority of firms makes use of activities related to financing. In this section, we show that firms in biotechnology clusters are also more likely to engage in collaboration, to attract public R&D funding or private investment, and, ultimately, to innovate. Whereas the limited samples of firms in and out of biotechnology clusters do not allow us draw causal conclusions, we take below as a descriptive, indicative, analysis of collaboration, financing, and innovation patterns. As our analysis cannot rule out factors such as firm's endogenous location choices, and their endogenous self-selection into clusters and cluster support activities based on expected gains, our results should be taken as descriptive analyses that take these selections on board.

5.2.1 Cluster support and collaboration

The most important cluster support activities relate to networking. The question thus arises whether members of biotechnology clusters are more likely to collaborate. This is especially relevant given that biotechnology clusters have developing (regional) networks and cooperative R&D programs as their stated objectives (Eickelpasch & Fritsch, 2005). Moreover, the pharmaceutical industry is subject to increasing division of labour along the innovation process (Rafols *et al.*, 2014).

Red biotechnology firms who represent the lion's share of our sample and of the German biotechnology industry, tend to follow the same logic: their collaborations are increasingly specialized in one specific step of the innovation process, calling for increased and specialized collaboration within the biotech innovation ecosystem (West & Nightingale, 2009).

Figure 5 displays the share of firms in and out of clusters that engaged in collaborative R&D, by type of partner, between 2016 and 2018. The results show that firms in biotechnology clusters are almost four times more likely to have collaborated with clients (30% vs. 8%), suppliers (23% vs. 6%), and other firms (34% vs. 8%), and almost three times as prone to collaboration with clinical and non-clinical research partners (39% vs. 14% and 54% vs. 19%, respectively).[9] Only collaboration with competitors is comparable across firms in and out of biotechnology clusters (6% vs. 7%). As such, German biotechnology cluster initiative seem, at least descriptively, to achieve their purpose of building collaboration networks.

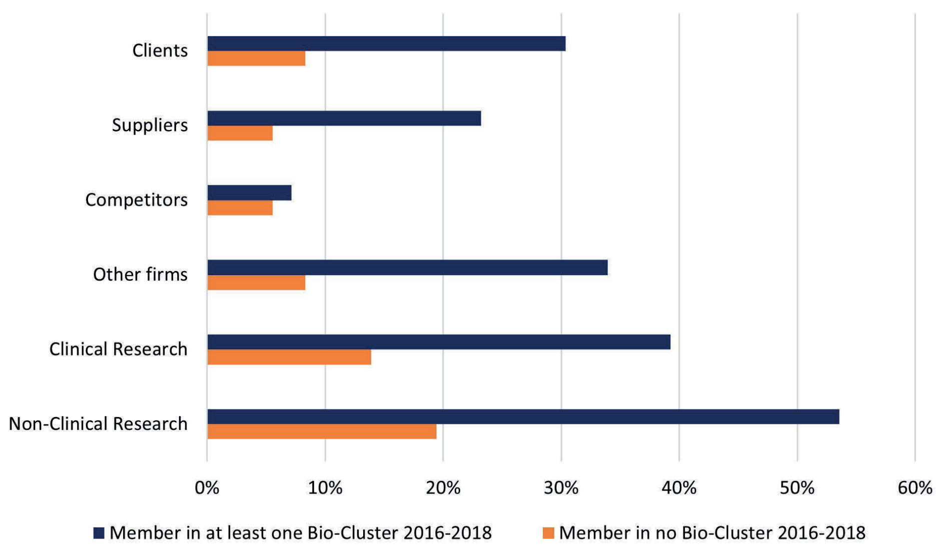

Figure 5: Firms' R&D collaboration portfolio by cluster membership, 2016-2018

The survey also asked whether new R&D collaborations arose between 2016 and 2018. The results are shown in Figure 6. Compared the full portfolio of collaborations shown in Figure 5, Figure 6 draws a closer link to cluster policies, as it rules out pre-existing collaboration networks. The results show that, across the full spectrum of possible collaborations, members of biotechnology clusters are vastly more likely to have established new R&D collaborations. Whereas only up to 6% of firms outside of biotechnology clusters indicates starting a new R&D collaboration (for collaborations with clinical and non-clinical research partners), the share of firms in biotechnology clusters reaches 34% (for collaborations with non-clinical research partners).

5.2.2 Cluster support and funding

The second main cluster support activity related to research funding and investment. In this section, we compare firms in and out of biotechnology clusters in terms of attracting these key inputs. Figure 7 compares the share of firms that obtained public R&D subsidies in and out of biotechnology clusters. Note, first, that the share of firms that obtained R&D subsidies is fairly high: 61% of respondents obtained subsidies from at least one source. The share of firms that obtained subsidies is higher among firms in biotechnology clusters, 68%, than among firms outside of clusters, 48%. Figure 7 further differentiates the sources of the R&D subsidies. Firms in biotechnology clusters are especially more prone to attract subsidies from German Federal and State governments (46% vs. 28% of firms, and 27% and 14%, respectively). Firms in biotechnology clusters are also more prone to attract subsidies from the EU Framework programmes (23% vs. 11%) or other EU programmes (13% vs. 8%). Firms outside of biotechnology clusters are more likely to obtain subsidies from city governments or other sources, which are however both only of

[9]We define clinical research partners as university hospitals, medical schools, and other clinical research institutes. Non-clinical research partners are universities and other research institutes without a clear clinical orientation.

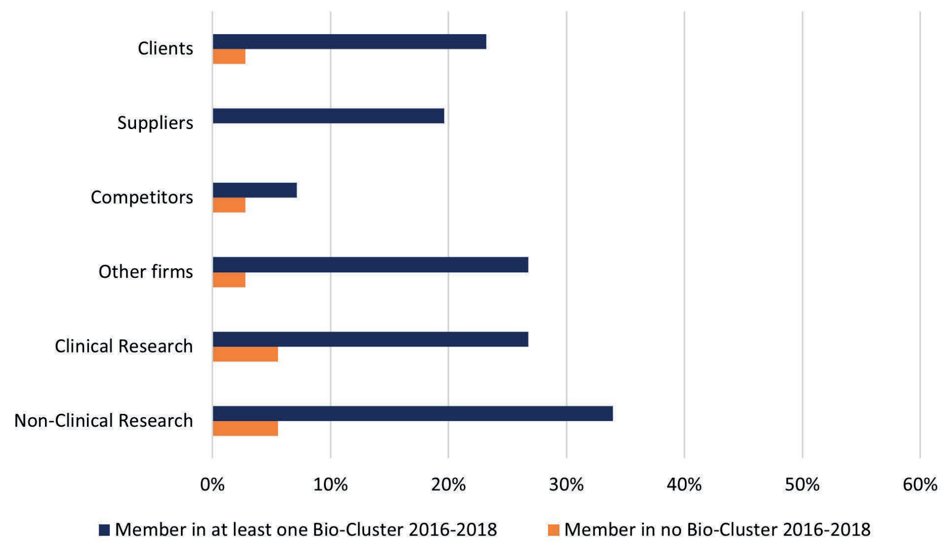

Figure 6: Firms' newly established R&D collaboration(s) by cluster membership, 2016-2018

marginal importance (0% vs. 6%, and 4% vs. 6%). Our results are indicative that biotechnology clusters are effective at disseminating funding opportunities from German and European funding sources. The difference might also be due to biotechnology clusters assisting with grant applications, which can be resource intense and administratively complex, especially for SMEs. However, our data does not allow us to dig deeper into the sources of these differences.

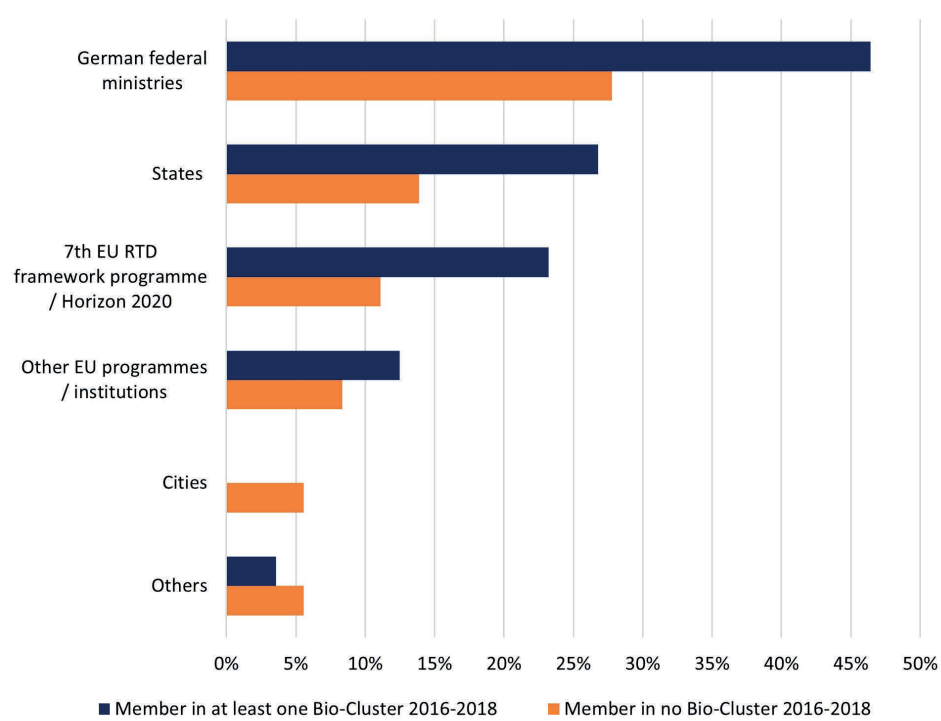

Figure 7: R&D Subsidies by cluster membership, 2016-2018

Firms in biotechnology clusters also engaged intensively in investor matching events. Figure 8 shows the share of firms in and out of biotechnology clusters that report attracting investment in 2016-2018. We differentiate investment by Venture Capital firms, investment by other private actors, including private equity, business angels, and initial public offerings, and funding from other sources such as credits and loans. As Figure 8 shows, firms in biotechnology clusters are more likely to attract each of these sources. The difference is most stark for venture capital, where 11% of firms in biotechnology clusters attracted investment, and none of the firms outside of clusters. Firms in biotechnology clusters are also more likely to attract investment from a broader group of private sources (30% vs. 11%). The difference is smallest, yet still positive, for other sources of funding (25% versus 17%).

The differences in funding propensities across the different sources of finance is indicative that biotechnology clusters are successful in their fundraising support activities. However, these effects are sure to be partially determined by differences in venture's economic potential. This is most likely for venture capitalists, the most selective group of private funders, that expect a high economic return in a short period and rely on networks in their funding decisions (Hsu *et al.*, 2014). The high concentration of venture capital investment in biotechnology clusters might thus stem from both a higher economic potential of firms in biotechnology clusters, and better networking of these firms. As both factors influence each other, disentangling both effects is not straightforward.

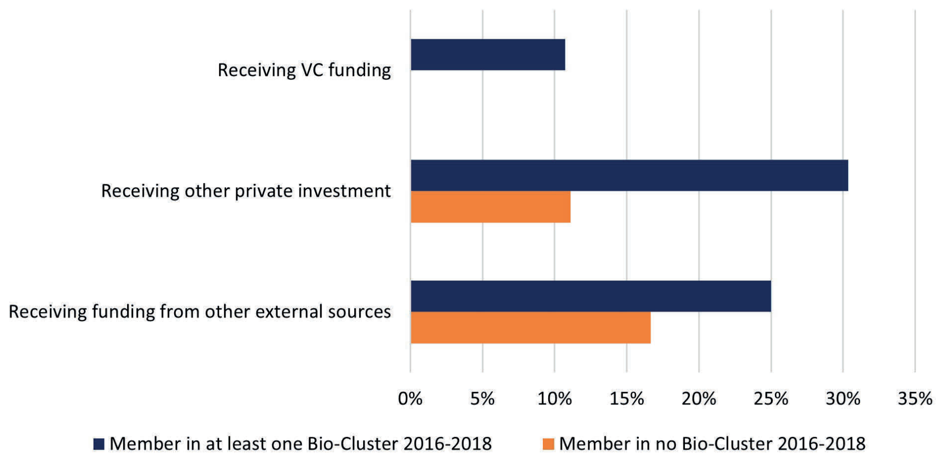

Figure 8: Private investment by cluster membership, 2016-2018

5.3 Cluster support and innovation

Lastly, we ask whether firms in clusters are, on average, more innovative, than firms outside of clusters. Whereas both groups are comparable in terms of their propensities to engage in R&D, size class, and focus, firms in clusters might be more likely to successfully introduce innovations because their better access to vertical and horizontal networks and financing opportunities. Figure 9 confirms this idea: Firms in biotechnology clusters are more likely to have introduced product and process innovations than firms outside of biotechnology clusters. Half of the firms in biotechnology clusters introduced product or process innovations (48% and 50% of firms, respectively), whereas only 36% of firms outside of biotechnology clusters introduced product innovations, and 28% introduced process innovations.

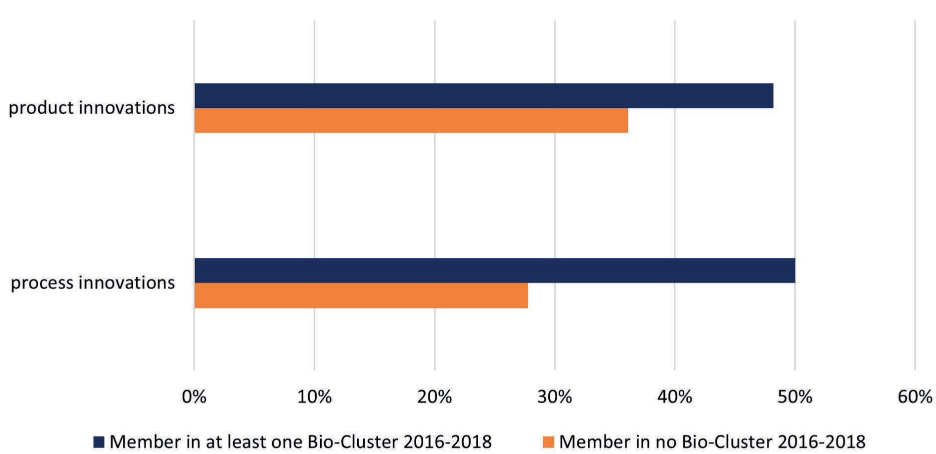

Figure 9: Firms' innovation activities by cluster membership, 2016-2018

Likewise, if firms in biotechnology clusters benefit from stronger collaboration networks, and can draw on more resources than firms outside of biotechnology networks, they might be able to engage in more fundamental forms of innovation. Figure 10 supports this idea: the share of firms that introduced new research lines in their portfolios is much higher among firms in biotechnology clusters (36% vs. 17%). The generally high share of firms engaging in this more radical form of innovation is related to the nature of our sample of R&D active SMEs.

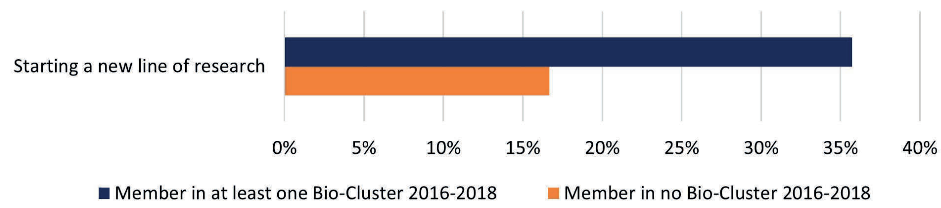

Figure 10: Firms' research portfolio dynamics by cluster membership, 2016-2018

5.4 Discussion

Our results contrast former findings for different countries. Ugo (2009) argues that being located in a cluster can be seen as a quality signal: from an outside perspective, the number of firms active in a cluster signals the profitability of the location. Belonging to a cluster might either reflect better conditions to establish a business (e.g. spillovers and complementarity of activities), or better abilities to compete for local resources. Our results expand on that, and raise the possibility that part of these effects might derive from cluster support activities. Moreover, our trends support the idea that firms with cluster membership tend to receive more public and private sources of funding to innovate. Removing the financial constraint combined with more possibilities to collaborate along the R&D spectrum are the two key inputs to re-direct and enhance the R&D portfolio. The higher innovation performance described in the literature focused on biotech is then partially explained by more knowledge flows and funding opportunities. Surprisingly, we do not find any link with operational support from clusters. We hence specify the indirect impact of clusters described in Nishimura & Okamuro (2011) who stress the role of clusters in coordinating R&D partnerships and relaxing constraints. The risk and costs involved in the biotech sectors in contrast to material sciences could explain why relaxing funding constraints is more important, and why concentrating resources is on average more efficient.

6 Conclusion

This study investigates how cluster innovation policies are related to the biotech sector in Germany. Our analysis aims to assess how and to what extent cluster support influences biotech firms' innovation performance. To do so, we conduct a survey within the German biotech industry that studies the distinct means of cluster support. In line with previous studies, we document that firms within clusters are more innovative and more collaborative. Our assessment differs from previous studies by relying on the membership reported by firms themselves to avoid ad-hoc assumptions supposed to delineate between geographical clustering and cluster support. We specify this assessment by analyzing the different channels though which cluster support influence biotech firms' innovation. Our results are twofold: first, we show that the biotech firms' R&D portfolio is more diversified and more agile with than without cluster membership, second, we evidence that firms with cluster membership tend to use more funding and networking possibilities. Our analysis puts to the front the importance of cluster support via non-financial means in easing the access to collaboration and to funding sourcing. We confirm the importance of indirect cluster support described in Nishimura & Okamuro (2011) in sustaining innovation efforts for material sciences. Our results differ slightly from Nishimura & Okamuro (2011) by exhibiting a stronger use of indirect financial support among cluster members than incubation related support (here, measured by the use of infrastructure). As suggested in Nishimura & Okamuro (2011), the nature of the R&D process and the industry characteristics are two key dimensions to consider in evaluating the impact and the type(s) of cluster support on firms' strategies. In our case, the potentially high costs and risks of failing in innovation are might give a stronger emphasis to networking to increase collaboration and funding possibilities than in the case of material sciences.

Our findings imply that policy makers should keep considering the "professionalisation" of cluster management to fully grasp the benefits of these indirect effects. The importance of raising funds previously defined requires to also act on the availability of private funds on capital markets. The German market for capital from a Venture Capital or Business Angels is still under-developed vis-a-vis other European countries (Cornell University & WIPO, 2020; Bersch *et al.*, 2020). In a recent interview, the BioNTech CEO (Uğur Şahin) refers to this issue specifically in explaining why German biotech firms hardly grow (Cornell University & WIPO, 2020). The lack of investors reduce the number of research opportunities to develop and reinforces risk-aversion in the selection of funded projects. Relying on tax incentives represents an avenue to create a culture of capital risk and raise the amount of private investment in high tech sectors.

Our study is not without limitations. We cannot deny the existence of a selection bias in the decision to become a cluster member, especially regarding the nature of innovative activities. Even though we cover all key cluster initiatives in our survey, many firms reported a membership related to two large and well-established red biotech clusters (BioM and BioRN). Moreover, the conditions or intensity of support are likely to differ across clusters. Also, it is likely that the composition and the size of clusters moderate the positive effects from clustering: on the one hand, spillovers from collaborations decrease with distance, and increase with the cluster size. Similarly, very specialized clusters have probably more chances to generate local spillovers than more diversified clusters. On the other hand, specialized clusters may face issues such as technological lock-in. Unfortunately, sample size limitations did not allow us to investigate these issues further. Future studies may consider these avenues in order to compare the short vs long run impacts of cluster support and how cluster management moderate those.

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Table 2: Distribution of firms among our German biotech survey vs population

OECD class	size class	age class	pop.	answer	pop. share share	sample share	difference in shares	response rate
health	< 49	< 7 years	54	10	0,08	0,11	0,03	0,19
health	< 49	> 7 years	65	14	0,10	0,15	0,06	0,22
health	> 50	< 7 years	3	0	0,00	0,00	0,00	0,00
health	> 50	> 7 years	45	4	0,07	0,04	-0,02	0,09
health	missing	< 7 years	60	6	0,09	0,07	-0,02	0,10
health	missing	> 7 years	136	10	0,20	0,11	-0,09	0,07
non-health	< 49	< 7 years	36	11	0,05	0,12	0,07	0,31
non-health	< 49	> 7 years	76	20	0,11	0,22	0,10	0,26
non-health	> 50	< 7 years	0	0	.	.	.	.
non-health	> 50	> 7 years	23	1	0,03	0,01	-0,02	0,04
non-health	missing	< 7 years	57	6	0,08	0,07	-0,02	0,11
non-health	missing	> 7 years	117	10	0,17	0,11	-0,07	0,09
Overall			672	92	1,00	1,00	0,00	0,14
RMSE							0,01	0,04

Table 3: Response rate across firm size

size class	**population**	**response**	**population share**	**sample share**	**difference in shares**	**response rate**
smaller than 49	231	55	0,34	0,60	0,25	0,24
50 to 100	42	3	0,06	0,03	-0,03	0,07
more than 100	29	2	0,04	0,02	-0,02	0,07
missing	370	32	0,55	0,35	-0,20	0,09
Total	672	92	0,14	1,00		

Table 4: Response rate across firm age

age class	**population**	**response**	**population share**	**sample share**	**difference in share**	**response rate**
younger than 7 years	210	33	0,31	0,36	0,05	0,16
between 7 and 14 years	181	22	0,27	0,24	-0,03	0,12
between 15 and 21 years	187	24	0,28	0,26	-0,02	0,13
older than 21 years	93	13	0,14	0,14	0,00	0,14
missing	3	0	0,00	0,00	0,00	0,00
Total	672	92	0,14	1,00		

Table 5: Response rate across biotech areas

OECD class	population	response	population share	sample share	difference in share	response rate
health	342	42	0,51	0,46	-0,05	0,12
agricultural biotechnology	21	2	0,03	0,02	-0,01	0,10
industrial biotechnology	66	34	0,10	0,37	0,27	0,52
non-specific applications	204	7	0,30	0,08	-0,23	0,03
bioinformatics	39	7	0,06	0,08	0,02	0,18
missing	0	0	.	.	.	.
	672	92				

Table 6: Distribution of biotech membership in our survey

Biotech awarded clusters	Memberships	BioRegio/Profile	Spitzenclusters	GoCluster
BioM	14	x	x	x
BioRegio Stern	4	x		x
BioRegionN	1	x		
BioRiver	2	x		
BioRN	5	x	x	x
Bioeconomy Cluster	2		x	
Ci3	1		x	
BioTOP/HealthCapital	3	x		x
IGZ Würzburg	2			x
IBB	1			x
InfectoGnostics	2			x
Life Science Nord	5			x
Life Science Verband Bremen	1			x
medways	1			x
Technologiepark Heidelberg	1			x
Biotech non-awarded BioRegio/Profile				
BioCity Leipzig	2	x		
BioCon Valley	2	x		x
BioLago	1	x		x
BioNRW	5	x		
BioRegio-OWL	1	x		
BioPark Regensburg	5	x		x
BioPro	2	x		
BioRegio Freiburg	3	x		
biosaxony	1	x		x

We found 9 additional memberships to clusters which were not associated to any of these initiatives: Diagnostiknet, BioValley, BiomarkersNet, NetPhaSol, Tübingen, BioMittelDeutschland GmbH.

Block A: Cluster membership

1. a) Has your firm been a **member** of at least one **biotechnology cluster** during **2016-2018**? Yes / no

   b) If Q1a yes: Please select the respective cluster(s) your firm has been a member of during 2016-2018 from the following list:
   \+ **one "open" box** where firms can write in another cluster

   b) If Q1a no: Does one of the following apply to your firm? (Please choose only one)

   - My firm was **never a member** of a German biotechnology cluster.
   - My firm **was a member** of at least one biotechnology cluster **before 2016**, but is not anymore. (Please provide the last cluster(s) your firm was a member of)
   - **+ one open box**

Block B: R&D and Support

2. During the years **2016-2018**, did your firm engage in **internal research and development activities (**internal R&D activities**)** or **issued R&D contracts to third parties (**external R&D activities**)**?

   R&D is defined as the systematic creative work to increase the stock of knowledge and its use to devise new products or services and new processes (incl. software development). **Internal R&D** activities are R&D activities undertaken by your own firm. **External R&D** activities are R&D activities carried out by third parties (firms, higher education institutions, or research institutes) through R&D contracts issued by your firm to those third parties (incl. other firms of your company group).

Internal R&D	Yes:	No:
External R&D	Yes:	No:

3. a): Did your firm receive **monetary support (subsidies) for R&D projects** during the years **2016-2018**? Yes/No:

   b): (Show if yes in Q3a) Please select from which of the following **sources** your firm received R&D subsidies during **2016 and 2018**.

German federal ministries	
States (German state government departments)	
7th EU RTD Framework Programme / Horizon 2020	
Other EU programmes / institutions	
Cities (e.g. "Wirtschaftsförderung" = economic promotions)	
Others: open box here	

4. **Did your firm use** any of the following **benefits from biotechnology cluster organizations or from others** (consultants, economic promoters, regional initiatives, city governments, etc.) during **2016-2018**? (Tick what applies)

1

	Cluster	Others	No
Organisation & Infrastructure			
Support in management questions			
Support in product marketing			
Temporary usage of office or lab space/meeting rooms/technical infrastructure			
Permanent usage of office or lab space/meeting rooms/technical infrastructure			
Networking & Collaboration			
Networking events			
Support in the attendance of trade fairs			
Finance			
Investor matching events			
Support in raising funds (incl. grant attraction & management)			
Information events regarding public funding			
Human Resources			
Job matching events			
Training programs			

5. Did your enterprise **collaborate in any of your R&D activities during 2016-2018**? (if yes): Please indicate **the types of R&D collaboration partners** (tick all that apply), and whether the collaborations in question concerned at least one **newly added collaboration partner in 2016-2018**, i.e. at least one partner with whom the firm had not had any R&D collaborations before.

   An **R&D collaboration is an active participation** with other firms or institutions on R&D activities. The collaboration does not need to be commercially successful. An R&D collaboration **excludes pure contracting out of work with no active collaboration**.

R&D Collaboration with…	Yes	No	(if yes:) At least one newly added collaboration partner during 2016-2018
Private partners			
Clients			
Suppliers			
Competitors			
Other firms			
Public partners			
Clinical research: University-hospitals, medical schools, and other clinical research institutes			
Non-clinical research: Universities (incl. universities of applied sciences), and other non-clinical research institutes			

6. a) If yes in Q5 and Q1a: Regarding your **R&D collaboration partners** of the years **2016-2018**, have they also been a **member** of at least one **biotechnology cluster you belong to**?

	Newly added collaboration partner(s)		**Already existing collaboration partner(s)**		**I do not know**
	Yes	No	Yes	No	
Private partners (firms)					
Partners from clinical research: University-hospitals, medical schools, and other clinical research institutes					
Partners from non-clinical research: Universities (incl. universities of applied sciences) and other non-clinical research institutes					

b) If yes in Q5 and no in Q1a: Regarding your **R&D collaboration partners** of the years **2016-2018**, have any of them been a **member** of at least one **biotechnology cluster**?

Yes / No / I don't know

Block C: General information on your enterprise

7. Please state **the extent** to which the following characteristics **changed in 2018**, **compared to 2016**.

	Does not apply at all	Does not apply	Neither applicable nor inapplicable	Does apply	Does fully apply
It became **easier** for the firm to **find and recruit qualified personnel**					
Laws/regulations/conditions made it **easier** for the firm to **focus on its business operations**					
It became **easier** for the firm to **conduct translational research**					
It became **easier** for the firm to **conduct interdisciplinary research**					
Possibilities for the firm to receive subsidies for R&D projects **increased**					

8. **During 2016 and 2018**, did any of the following **events** occur in your enterprise?

	Yes	No
Products/services were exported to other countries (i.e. your enterprise generated turnover with clients located outside of Germany)		

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Products/services were exported to countries that have not been products/services sold to by your enterprise before		
Received private investment by a venture capitalist (VC)		
Received other types of private investment (private equity, business angels, initial public offering (IPO))		
Received funding from other external sources (e.g. credits, promotional loans)		
Taken on lines of research new to your firm		

9. During the years **2016-2018**, did your firm **introduce product innovations**, i.e. **any new or improved products/services** that **differ significantly** from the **firm's previously offered** products/services?

Yes:	No:

Product/service innovations are new or improved products/services whose components or basic characteristics (technical features, integrated software, applications, user friendliness, availability, design) **differ significantly** from the **firm's previously offered** products/services.
The innovation must be **new to your firm**, it does **not** have to be **necessarily new to the market**. It is irrelevant who developed the innovation. The **simple sale of innovations**, which have been produced by other firms, is **not** regarded as a product innovation, neither are pure aesthetic modifications.

10. During the years **2016-2018**, did your firm **introduce process innovations**, i.e. **new or improved processes or methods** that **differ significantly** from **your previously implemented** processes/methods?

Yes:	No:

Process innovations are new or improved processes and methods that have a noticeable positive impact on costs or quality. Process innovations can refer/relate to **methods for producing products or providing services**, **logistics/delivery/distribution methods**, **methods for information processing**, **support activities (e.g. accounting)**, and **organisational, management and marketing methods**.
The process innovation **must be new to your firm**. It **does not have to be necessarily implemented by your firm at the very first**. It is irrelevant who developed the innovation.

11. Please situate your enterprise's **main line of business** (pick one):

a. **Health and medicine** (Development of therapeutics and/or diagnostics for the field of human medicine, drug delivery, human tissue replacement)
b. **Animal health** (Development of therapeutics and/or diagnostics for the field of veterinary medicine)
c. **Agricultural biotechnology** (Genetically modified plants, animals or micro-organisms, as well as non-genetically modified plants grown using biotechnological procedures, for use in agriculture or forestry)
d. **Industrial biotechnology** (Biotechnological products and processes for the handling of waste or sewage, for chemical synthesis, for the extraction of raw materials and energy etc.)
e. **Non-specific biotechnology** (Equipment or reagents based on biotechnological principles, for research or provision of services in this field ('ancillary industry'))
f. **Other: (please complete)**

12. Is your enterprise **part of an enterprise group** (corporate group or a consortium of several enterprises?)

    a. Yes, a national enterprise group
    b. Yes, a multinational enterprise group
    c. No

13. What was your enterprise's **average number of employees in 2016 and 2018**

	2016	2018
Employees (annual averages, incl. apprentices and interns, excl. contract workers)		

14. What was your enterprise's **total turnover in 2016 and 2018**?

	2016	2018
Turnover (excl. VAT)	,000 EUR	,000 EUR

15. Please estimate the **amount of internal research and development expenditures** (internal R&D expenditures) and the **amount of R&D expenditures your firm contracted out to third parties** (external R&D expenditures) during **2016 and 2018** (Show only if Q2 at least one yes)

R&D is defined as the systematic creative work to increase the stock of knowledge and its use to devise new products or services and new processes (incl. software development). **Internal R&D** activities are R&D activities undertaken by your own firm. **External R&D** activities are R&D activities carried out by third parties (firms, higher education institutions, or research institutes) through R&D contracts issued by your firm to those third parties (incl. other firms of your company group).

	2016	2018
Internal R&D expenditures	,000 EUR	,000 EUR
External R&D expenditures	,000 EUR	,000 EUR