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Cluster ambidexterity towards exploration and exploitation: strategies and cluster management

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Abstract Cluster studies have shown that innovation often results from an inter-organizational process, where a division of labor with regard to exploration and exploitation exists among the actors inside a cluster. A cluster is ambidextrous if it manages to balance innovative activities that exploit existing competencies and is open to novel technological approaches by means of exploration. In this context, we are interested in the supportive role of cluster management, assuming that a cluster organization can only persist sustainably if exploitation and exploration are pursued in an appropriate balance. Our analysis is based on surveys conducted between 2011 and 2012 with ten cluster managements and their respective cluster firms of the first two waves of the German Leading Edge Cluster Competition. Our results indicate that the demand for services offered by the cluster management depends on companies' strategies with respect to exploration, exploitation, and ambidexterity. In turn, the priorities set by the cluster management can be explained by the firms' needs. Accordingly, we argue that cluster management acts as a service provider, helping the cluster companies to become ambidextrous which, in turn, makes the cluster as a whole ambidextrous.

Keywords Cluster · Ambidexterity · Cluster management · Exploration · Exploitation

JEL Classification D22 · O32 · R32

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1 Introduction

Innovative firms develop their knowledge base in two directions in order to stay competitive: First, existing products are constantly refined and the efficiency of production processes is increased; second, in order to be competitive in the long run, firms explore new technological paths to develop new capacities that bring future revenue (O'Reilly & Tushman 2004). This ability to pursue exploration and exploitation at the same time is called ambidexterity, a concept that was originally developed by Duncan (1976) and March (1991). Despite the relevance of both activities, it is not easy for firms to pursue both at the same time (March 1991).

We apply this concept of ambidexterity to the level of clusters that facilitate learning and knowledge flows between local actors and enhance local cooperative activities (Porter 1998). We ask to what extent can and do cluster firms[1] actually use cooperation in cluster structures both for exploitation and exploration. In general, cluster cooperation can be useful in both respects: (1) cooperation in clusters can help firms to improve their knowledge base with, however, the danger that too much focus is given to further developing existing competences; (2) cooperation in clusters can also give new impulses that lead to new competences required for the development of completely new products (e.g. by cooperating with firms from other industries or by learning about new developments from science through cooperation in the cluster region with universities or research institutes).

Many studies investigate clusters from the perspective of the organic development of competences at the firm level (e.g. Keeble & Wilkinson 1999; Fornahl et al. 2015): in local cooperation along the value-added chain, firms develop their existing competences and are able to increase competitiveness by cooperating within the cluster region. Based on these studies, one can ask whether and under what conditions cooperation in clusters can contribute to the competitiveness of a cluster. Thus, by extending the analysis from the level of an individual firm to the level of a local cluster, we shift perspective and ask whether a cluster is ambidextrous, assuming that ambidexterity is necessary for the long term success of a cluster. Kauppila (2007) argues that cluster ambidexterity can unfold in two ways: First the cluster becomes ambidextrous when each and all actors are ambidextrous, and second, the cluster becomes ambidextrous as each actor concentrates on either exploration or exploitation.

Cluster policies influence these cluster dynamics by providing impulses for the development of cluster organizations and by directly influencing cooperation behavior. The design of cluster policies determines some framework conditions for firm activities and might, therefore, also influence strategies that address the challenges of ambidexterity. In such a setting, cluster management organizations are intermediaries that directly address the needs of actors within the cluster (also in respect to ambidexterity in cooperation strategies).

We conduct our study on cluster ambidexterity among participants of a recent, large scale cluster policy in Germany. The "Spitzencluster-Wettbewerb" (Leading-Edge Cluster Competition—LECC) encouraged applicants—cluster initiatives of firms, public research organizations and other organizations—to agree on a common strategy in order to utilize unused development potential. The LECC was set up in 2007 within the framework of the

[1] Of course, clusters are characterized by cooperation of different kinds of actors, including universities, research institutes, and other organizations. However, our focus is on firms, since ambidexterity is a concept that relates to long -term competitiveness of firms.

German High-Tech Strategy and based on the positive insights and results of research on high tech-clusters, but also positive experiences with cluster policies (e.g. for the Bioregio contest; see Dohse 2000). This funding tournament provided an impulse towards the development of efficient cluster organizations. At the same time, cooperative research projects between cluster actors were funded. Since the LECC required the applicants to develop a common strategy and promoted regional development, the question arises whether cluster firms[2] used cooperation within the scope of LECC initiatives in order to better cope with the institutional challenges of creating an environment that allows the individual firm or the cluster to be ambidextrous.

On that background, we analyze how cluster cooperation patterns in the leading-edge clusters relate to firms' cooperation strategies with respect to exploration and exploitation and ask how cluster organizations can contribute to ambidexterity in clusters. In Sect. 2, we discuss the concept of ambidexterity on different levels. Section 3 is devoted to the question how cooperation in clusters can support both exploitation and exploration at the firm and cluster levels. In Sect. 4, we provide background information on the LECC. Section 5 presents the data and in Sect. 6, we analyze how cooperation activities of firms in the LECC networks are used to pursue exploration and exploitation strategies. Subsequently, we analyze the role played by cluster management organizations in pursuing exploitation and exploration strategies. Section 7 concludes.

2 Ambidexterity as an organizational and cluster-level strategy

2.1 Exploration and exploitation

The long term innovation dynamics of exploration and exploitation can be displayed within the stylized model of a life cycle of innovation (March 1991; Nooteboom 2000). The life cycle can be observed not necessarily within one organization but rather across the boundaries of single organizations. At the same time, the process is less a logical sequence of predefined events but rather an iterative one that can take different forms (in respect to timing, phases, and involvement of actors). Within a life cycle, exploration is devoted to the search for knowledge and disruptive innovation, while exploitation focuses on the following commercialization and gradual improvement of results out of explorative activities.

Both types of activities pose different challenges for firms, depending on the sector or technology field. However, there are also similarities that can be discussed from a system perspective. In *exploitation*, a product or production process is optimized within a fixed "domain" (a representation of the relevant world, Arthur 2009, pp. 79–80) that comprises certain technologies that are used as a toolbox, pieces of hardware and software, and also fixed rules and practices. So, the focus is on increasing the effectiveness of a given system (whether it is a plant or a vehicle component) within a fixed domain. The challenge is to improve parts of that system by using the tools available in this domain and—at the same time—keeping in mind the effect of these changes on other parts of the system, the system as a whole and its performance. So expertise is needed in knowing how to improve parts (e.g. material characteristics) and how to assess the feedbacks within the entire system.

[2] Please note that a cluster firm is connected to the cluster organization by a formal membership, which is usually associated with the payment of membership fees.

In contrast, *exploration* requires openness and disengagement from current solutions in order to search for new possibilities to create a totally new system. Therefore, a change in the relevant "domain" is needed that is used for the development of new products and the design of production processes relevant in this domain. Experimenting with innovative alternatives and flexibility is required, and also being prepared for the possibility that some routes of innovation will not be successful.

2.2 Ambidexterity at the firm level

The challenge of aligning long-term development of new competences and market fields via exploration with present revenue from an existing knowledge base through exploitation becomes obvious by looking at the situation from a resource-based view of firm development: a firm's knowledge base, which is unique and difficult to imitate, constitutes a key competitive advantage (Grant & Baden-Fuller 1995). In developing their knowledge bases and thereby implicitly coping with this challenge, firms can rely on internal knowledge and/or draw on external knowledge sources (Zahra & George 2002). The relative importance of these different knowledge sources depends on the innovation strategy with respect to ambidexterity and has consequences for firms' internal and external organization (Stettner & Lavie 2014). Especially, the organizational aspects of this problem have been a matter of academic debate.

Implementing the concept of ambidexterity implies a combination of organizational routines, resources or capabilities that, to some degree, contradict each other: organizational efficiency, on the one hand, and organizational flexibility, on the other (e.g. Adler et al. 1999; Raisch et al. 2009). For innovative firms, this boils down to the basic problem of accomplishing sufficient exploitation of known options to secure current profits and, at the same time, to explore new options in order to safeguard future revenues; different framework conditions are needed for both and organizational structures that allow for combining these tasks need to be developed.

How to successfully pursue these two directions in parallel has been discussed in organization science since Burns & Stalker (1961). A first line of research argues that a firm itself is required to pursue both aims at the same time, thus being purely ambidextrous, in order to gain a sustainable competitive advantage (Gibson & Birkinshaw 2004).

Notwithstanding, according to O'Reilly & Tushman (2004), exploration and exploitation are considered enormous complex and opposing concepts such that firms might gain from specializing in one or the other. For a long-term prosperous development, this would require firms specialized in exploitation to interact with firms that rather pursue exploration, and vice versa – a division of labor. One reason for the difficulty of pursuing exploitation and exploration simultaneously is that they require different organizational structures. Exploration benefits from a decentralized and organic design, whereas successful exploitation environments are rather centralized and mechanistic (Boumgarden et al. 2012; O'Reilly & Tushman 2008). Usually, firms devote most of their activities to exploiting their existing knowledge base that creates short- to medium-term revenue and profit, while only a small fraction of effort goes into the exploration of new ventures. Thus, firms do not pursue both paths with the same intensity and not always simultaneously (Gilsing & Nooteboom 2006).

Firms can also try to "externalize" a part of the process in exploration: Ferrary (2011) comes to the conclusion that this specialization model can also describe firm behavior with respect to the use of new knowledge sources: he shows that Cisco Systems has been able to grow successfully, although it has specialized in exploitation. Thanks to its close ties to

venture capital firms and start-ups in Silicon Valley, Cisco was integrating new knowledge by mergers and acquisitions of highly explorative start-ups. However, based on the discussion above, some important activities stay within the firm: these are the monitoring of new technologies and other relevant factors and the competences needed to select between the different possibilities. As the discussion above has shown, addressing both the demands of exploration and exploitation is crucial for long-term firm survival. However, as Lavie et al. (2010) show in their literature review, balancing both kinds of activities is a complex task. Different organizational solutions are discussed for the separation and/or balancing of both types of activities with no superior organization structure arising (Lavie et al. 2010, pp. 129–135; Nooteboom 2000, pp. 261–263).

From the discussion it becomes clear that external sources of knowledge (from within the cluster or other sources) can be important both in exploration and in exploitation. In exploitation, they enable the individual firm to pursue goals within a domain (1) by utilizing commonly created solutions in user-producer relations or (2) by providing external expertise that is needed to refine a product (e.g. by optimizing material characteristics or design). In exploration, external sources are important especially (1) for the creation of new ideas (2) for the common R&D projects that pursue new ideas by combining different technologies under a new technological (or market, distribution etc.) regime (3) for a creative environment that large firms can use as "breeding ground" for new ideas that are followed by new ventures.

Based on these considerations, the following section focuses on the role that cooperation in clusters can play both in exploitation and in exploration within the mentioned steps of implementing new routes for technological progress.

2.3 Ambidexterity at the cluster level

Until 2011, when Michel Ferrary published his paper on "Specialized organizations and ambidextrous clusters in the open innovation paradigm", the ambidexterity literature had solely discussed the issue of a balance between exploration and exploitation activities on the organizational level. With his paper, Ferrary opened the window to discuss ambidexterity on a collective level by introducing the role of the interaction between different organizations. Even though the core of the knowledge base lies within individual firms, cooperation activities play a key role for the development of internal knowledge and for long-term competitiveness. Thus, innovation often results from an inter-organizational process, with a division of labor regarding exploration and exploitation among firms, research institutes, and universities inside a cluster (Chesbrough & Appleyard 2007; Ferrary & Granovetter 2009; Porter 1998). Therefore, it seems obvious to analyze cooperation in clusters by looking at R&D networking between local actors with a focus on ambidexterity. When we look at *ambidexterity of a cluster*, the focus is on the existence and the form of division of labor activities in respect to exploration and exploitation.

According to Kauppila (2007), a cluster can be ambidextrous in two ways. First of all, firms can be specialized either in exploration or in exploitation such that the network as a composite of its parts (firms) is ambidextrous (model A). This would mean that the nodes are either 'explorer' or 'exploiter' while the network becomes ambidextrous. One could say that, according to this view, firms are making the cluster R&D network ambidextrous by serving different functions of the innovation process (Kauppila 2007). The alternative way clusters could function with respect to ambidexterity is that all or most firms engage in both exploration and exploitation, such that each firm (each node of the network) is ambidextrous by itself. According to Kauppila (2007), this idea follows Gibson &

Birkinshaw's (2004) proposition that employees embody ambidexterity, which manifests itself at the level of the organization. Thus, Kauppila (2007) concludes that if each firm in the cluster is ambidextrous, the network is ambidextrous as well (model B).

There is still no definite answer to the question, which of the two models is superior, on the organizational as well as on the cluster level. It might turn out that both work, conditional on the circumstances, such as the characteristics of the industry (Bocquet & Mothe 2015) or the general firm environment (competition, technological opportunities arising, political circumstances). Both models assume that it is nearly impossible for a single firm to pursue exploration and exploitation with the same intensity since both require activities and strategies that are too contradictory. Kauppila (2007) argues that the notion that firms are, in general, ambidextrous might be more appropriate. By accessing resources of other actors, companies are able to avoid the problems that occur in trying to be ambidextrous. To some degree, they "outsource" explorative or exploitative activities and become ambidextrous in the way that their network activities actively pursue both kinds of goals. Clusters comprised of such firms are ambidextrous as their individual actors' networks (whether within the cluster or beyond) are ambidextrous. For cluster management, it is relevant to know whether firms within the cluster are relatively homogenuous or if there is indeed specialization with respect to exploration and exploitation. In the latter case, services might have to be differentiated according to the specific needs of explorers and exploiters. This brings us to our first research question:

> RQ 1: Are clusters collectively ambidextrous because of ambidextrous member organizations or because of a division of labor among its members with respect to ambidexterity?

3 The role of cluster organizations and management for cluster ambidexterity

In the works of Saxenian (1994) and Porter (1998), clusters develop in a self-organized manner, as a result of advantages such as proximity, homophily, spillovers, etc. However, the knowledge-based-view of clusters suggests that knowledge does not hover around a certain region (Antonelli 2006; Malmberg & Maskell 1997, 2002). Rather, structured interactions are crucial to encourage the actors within a region to engage in knowledge processes and generate the fruitful local buzz (Bathelt et al. 2004; Bocquet & Mothe 2015). In her comparison of the development between Silicon Valley and Route 128 in Massasussets, Saxenian (1996) concludes that local proximity alone does not suffice for a cluster to be able to cope with external challenges (reaching ambidexterity). Rather, she identifies the "complex networks of social relationships within and between firms and between firms and local institutions" (Saxenian 1996, p. 57) as a core factor that enables a cluster to stay competitive. Consequently, some kind of intermediated governance might be of value for developing these network ties (Bocquet & Mothe 2015; Howells 2006).

Intermediaries in clusters focus on technology transfer, commercialization of ideas and collaboration with the aim of supporting innovation creation, dissemination and collaboration (Inkinen & Suorsa 2010). Lynn et al. (1996) define them as superstructure organizations that provide collective goods to their members. These superstructure organizations can be technical assistance centers, university outreach programs, vocational training centers, or local research institutes (Bocquet & Mothe 2015). In addition to these more technical intermediaries, there also exist knowledge exchange intermediaries, service

organizations, often created with government funding in order to encourage knowledge transfer (Hine et al. 2010). Similar to these two interpretations of intermediaries is the interpretation by Waxell (2009) who argues that (at least in Biotechnology clusters) the main role as intermediary is played by complementary actors such as research consultants, clinical research organizations, patenting offices, or recruiting firms. In line with these works, Bocquet & Mothe (2015) focus on formal governance structures in clusters and consider these as specific type of intermediary organization. They are local and regional intermediaries that concentrate on the promotion of networking between the actors but also support project development and knowledge dissemination within the cluster (Inkinen & Suorsa 2010). For the cluster intitiatives in France (poles de competitivité) as well as for the cluster initiatives analyzed in this paper (Leading-Edge Clusters), the existence of a formal cluster management is a prerequisite for their very existence. In cluster initiatives, actors within the cluster regions join forces in order to pursue common goals and to develop a common strategy. In formal cluster initiatives, the organizational framework for cooperation is given by a cluster organization that usually comprises boards that decide on strategical and operational issues and a cluster management that takes over several tasks to foster the common strategy and the development of the initiative (Sölvell et al. 2003). Despite the fact that the 'star'- or 'model'-clusters such as Silicon Valley have developed without formal structures, we cannot neglect the existence of cluster initiatives where actors intentionally and formally, sometimes also supported by policy, pool their forces in order to profit from cluster advantages just as occurred in the 'model'-clusters.To what extent cluster initiatives are more or less successful when they have different grades of formalization is not well reviewed yet but shall also not be the focus of our research.

Bocquet & Mothe (2015) raise the question whether cluster governance (management) is able to support ambidexterity at the cluster level. Cluster governance structures can be defined as intended actions of cluster members aiming at upgrading cluster performance (Gilsing 2000). Sölvell et al. (2003) see the value of a cluster management in taking over several tasks to foster the common strategy and the development of the cluster initiative. To find out to what extent cluster management can be valuable for ambidexterity of the cluster, Bocquet & Mothe (2015) provide a case study of two French 'Poles de competitivité'. They collected information via semi-structured interviews with members of the cluster governance structure and dicsovered that the mere geographical proximity is not sufficient to ensure knowledge exchange for ambidexterity. Especially for clusters with many small firms, the cluster governance structures play an important role for efficient interactions between the cluster actors and for achieving ambidexterity at the cluster level. To foster the development of such governance structures, several policies have been set up in the past to promote cluster initiatives in different ways. Especially, they set incentives and finance cluster initiatives as well as related cluster organizations to support cooperation among individual actors in the cluster regions.

The activities of these cluster organizations can influence both exploitation and exploration in the cluster and thus contribute to the ambidexterity of the individual firms and the cluster in total by stimulating the development of clusters in several ways (Gilsing 2000; Maskell 2001). They can set impulses on different levels of cluster activities:

- At the *project level*, the cluster initiative can foster common projects (R&D and innovation projects) that either can contribute to the further development of existing competencies within the cluster or the development of new competencies and explore future possibilities of cluster development.

- At the *actor level*, firms can use the cluster network and the cluster organization either to develop their existing competencies (by refining products or production processes) or to look for new competencies (e.g. by working together on new topics that may develop into future markets). For individual firms, cooperation in clusters for new topics has the advantages (1) that new views can be incorporated by working together with other actors (2) that it is easier to gain information on new trends in markets or in technology from other actors and (3) that the cluster organization creates a framework that is not so much dominated by strict routines as is often the case within the individual firm.
- At the level of the *cluster organizations*, a common strategy (or common goals) can be pursued that either is related to further developing existing technologies or creating new routes for innovation. This can be done within the cluster initiative or in cooperation within the cluster regions (e.g. by universities and research institutes searching for totally new products and creating new markets), but also in cooperation with other cluster organizations in other regions (or even in the same region, as is the case when, e.g., clusters for aircraft technology and wind park technologies work together in the development of new materials and the creation of new markets with these technologies).

In our analysis, we look at the potentially supportive role of cluster management on ambidexterity of clusters and therefore concentrate only on the actor level and the level of cluster organizations. Results at the project level are used to illustrate the range of activities that were initiated by the LECC. We define the cluster management as a core organizational unit of cluster organizations that supplies services to its members. By pursuing a common strategy and supporting individual actors, cluster management plays an important role in the development of the cluster initiatives and therefore deserve special attention. In most LECC clusters, cluster management has been implemented as an organizational unit with own legal status.[3]

The role of management for ambidexterity in firms has been discussed in some studies: for example, Levinthal & March (1993) argue that knowledge of individuals should be managed in a way that some of them can pursue flexibility and search for new knowledge, while others go for efficiency and the use of already existing knowledge. Translating this to a cluster perspective, the task of a cluster initiative would be to coordinate the interaction among the specialized actors. Bocquet & Mothe (2015) address the cluster level by arguing in favor of a cluster's absorptive capacities; they suggest that a cluster management enhances potential and realized absorptive capacities by managing external knowledge flows into the cluster. In this framework, a cluster management is supposed to provide skills and processing abilities to support acquisition, assimilation, transformation, and exploitation of knowledge. Here, the role assumed by the cluster management is less moderating and supportive, but rather leadership oriented and strategic.

One certainly might question the view of the cluster management as an organizational sub-unit having a hand in all the relations among the cluster actors and beyond, being aware of all their needs and bottlenecks, and being able to guide and position strategically the cluster actors appropriately. Rather, we argue that cluster management assumes the role of a service organization oriented towards the needs of its members, continuously adapting its services in response to cluster dynamics. In other words, we do not argue that cluster

[3] It is important to note that this is one, albeit a rather important, viewpoint of cluster management. In a broader, more functional view not pursued here, cluster management comprises all strategical and organizational activities of the total cluster organization, comprising also the activities and results from the coordination and work within cluster boards where cluster activities are coordinated by the cluster members.

management shapes firms' strategies with respect to ambidexterity. A similar view is presented in the cluster management handbook, suggesting a joint network management by all partners in order to coordinate cluster activities, to handle internal and external networking as well as to develop a common image to the public and the markets as crucial for the success of a cluster (Scheer & von Zallinger 2007). Accordingly, one could conclude that the longevity of the cluster might be promoted if cluster management succeeds in developing and offering services that address the needs and bottlenecks of the businesses—thereby taking a customer oriented perspective.

Applying this to our context of ambidexterity, cluster management can foster cluster ambidexterity by providing services that facilitate the R&D activities of cluster firms. However, the direction (exploration or exploitation) fostered by the cluster management organization has to take into account firms' needs. If the firms should be ambidextrous, the services they demand from cluster management will serve both strategies: exploitation and exploration. By this, cluster management is also sustaining the firms to do what Bocquet & Mothe (2015) propose: kindly handle external knowledge into the cluster, but more in an indirect way. On that background, our paper takes a closer look at core aspects of ambidexterity at the level of the cluster firms and their relation to cluster management by raising the following two research questions:

RQ 2: Dependent on their strategies with respect to exploration, exploitation, and ambidexterity, what kind of support/service do firms demand?

RQ 3: Does a cluster management organization serve the strategy-driven needs of firms?

4 Cluster initiatives in the leading-edge cluster competition

In this section, we provide background information on the LECC and illustrate how it relates to cluster ambidexterity.[4] In selecting the cluster initiatives, the funding instrument LECC followed a bottom-up strategy. Cluster initiatives from all regions of Germany could apply in a competition for selection as a Leading-Edge Cluster and to receive the financial funds for projects (mainly R&D projects). In a two-stage process that involved a jury suggestion, the awarded clusters were chosen based on an outline of the cluster (first stage) and a comprehensive strategy paper (second stage). The program required the members of the cluster initiatives to set mid-term and long term targets (for the following years) and to develop a common strategy.[5] Within the context of the funding instrument, the cluster initiative could address ambidexterity on the strategy level. The program documents required that future market and technical developments are discussed and that targets with respect to common research and innovation are set. Especially, the applicants were also required to address the role of disruptive technologies for cluster development and discuss whether "leap innovations", i.e. the development of completely new products or production processes were necessary in order to stay competitive.

Thus, the LECC required the actors to follow a common strategy, which is partly focused on exploitation but also sets the preconditions to address questions in respect to explorative activities. During the selection process, the jury took into account whether

[4] This section draws on official program documents, cluster strategy documents as well as project level data. Rothgang et al. (2015) give an overview of the data collection process on the different levels.

[5] The program requirements are described in the official guideline for proposals (BMBF 2010).

cluster strategies aimed at new research activities (exploration), or merely focused on what had been done before (exploitation), and if they addressed strategic long-term objectives. In practice, the strategies of the winner clusters represented a mix of strategies that aim at both exploration and exploitation.

Our study focuses on the ten successful clusters of the first two waves (project activities starting in 2008 and 2010) of the LECC. These ten clusters are specialized in a variety of technologies and/or industries, namely biotechnology, semiconductors, organic electronics, logistics, aviation, medical technology, microelectronics, software, and photovoltaics. Since these technologies are at different stages of development, the clusters put a different emphasis on exploration and exploitation.

Different strategies with respect to exploration and exploitation on the cluster strategy level can be illustrated by the following examples. The LECC awarded 'Software-Cluster' provides a good case for ambidextrous strategies of clusters.[6] The Software-Cluster developed around SAP, one of the two world-leading firms that supply software for the handling of business processes. In the past, a "monolithic" software with different modules for individual applications constituted the core of SAP's product portfolio. Within a given domain, this software was optimized, extended by other modules, and adapted to the needs of different firms. This exploitation oriented strategy was done not only by SAP but also by other firms that closely cooperate with SAP, many of which are located in the same region. A new domain developed as a result of exploration activities in search for a possible future design of business software. Since software in other fields (in consumer products such as smartphones and tablets) was increasingly used as a platform for application software (apps) developed by other software firms, the question arouse, whether such a development would also take place in business software. This would require the development of a new and radically different domain, i.e. exploration. SAP would supply a platform technology and make sure that the interface for software created by other firms would work. As a new platform has been developed, this new software generation would require changes in the market structure. Firms would be needed (especially in the cluster region) to supply the business apps are used by the customers. Thus, the changes in the domain would require different characteristics of the software, a different business model (supplying a platform vs. supplying a fully developed product that would have to be adapted to the needs of the customer), and changes in the structure and relationship between actors in the cluster. As it is not yet clear whether this new model of business software will succeed in the long-run, the future of the cluster depends on the "right" strategy mix in respect to the "old" and "new" domain.

Specialization in exploration can be observed in the cluster Forum Organic Electronics (FOE), which addresses future markets for innovations that use technologies within the field of Organic Electronics. These technologies still have to be developed and markets do not yet exist. Thus, both with respect to the cluster and the individual firms, the cluster activities focus on the exploration of future market innovations with no direct relation to existing exploitative activities.

The strategy of the cluster Microtec Südwest illustrates specialization in exploitation. The strategy of Microtec Südwest focuses mainly on the application of microelectronic devices in the automobile industry, a technology already well established in that industry.

[6] The description of this supposed development towards a new generation of software (called "emergent" software) originates from the cluster strategy document of the software cluster (p. 23, Strategy Document, October 8, 2009). Additional information was collected in several expert interviews with the cluster representatives (both cluster management, cluster board and cluster members).

This primary focus of cluster activities is supplemented by a secondary focus on medical applications, a field in which a far greater potential for new applications is expected.

In general, the strategies of many cluster initiatives address future challenges that require exploration (eco-efficient computers, the future of airplanes, next generation of business software) but also allow for exploitative activities and projects. This is reflected in the mix of R&D projects that were initiated within the cluster strategies. For single R&D projects, the question whether they pursue targets with respect to exploration or exploitation was assessed by asking the project managers whether the project aims at radically new solutions and/or innovations (five categories from "strongly agree" to "strongly disagree"). Twelve percent of the project managers of the first two waves strongly agree that their project aims at something radically new, while another 20 percent agree. As such, the majority of the projects aim at innovation results that are not completely new. This finding is strengthened by anecdotal evidence collected during interviews with selected project managers. While some projects in each cluster address fundamentally new applications, most of them aim at results that exploit and amend the existing knowledge base rather than focusing on exploration.

5 Data collection and variables

For the ten clusters, we collected primary and secondary data. The latter were collected by scanning the strategy papers of the clusters. Primary data were collected in two ways: qualitative data via semi-structured interviews and quantitative data via written surveys. Semi-structured interviews were conducted with cluster managers and with representatives of the cluster firms twice a year. The two surveys used here were conducted between 2011 (first wave) and 2012 (second wave). One survey addressed the ten cluster management organizations, while the other was answered by representatives of the 229 firms that received funding within the first two waves of the LECC. Below, we describe the variables that we used in the two surveys. An overview on the variables and their characteristics is provided in Table 5 in the "Appendix".

The cluster management provided, amongst other things, information on their activities, financial aspects, their number of employees, cluster membership, and the technological focus of the cluster. The cluster firms were asked to provide general information about the firm, on their innovative activities and success, and, most important for our research question, information on the activities of the cluster management and an evaluation thereof.[7] It is important to mention that firms' ambidexterity-related strategies could only be measured in an indirect way. The terms "exploration", "exploitation", or "ambidexterity" were not mentioned in the questionnaire to avoid misunderstandings in case respondents were not aware of these concepts and also to avoid a potential bias if respondents were to meet evaluators' expectations. By using indirect questions, we were able to measure the revealed strategies with respect to ambidexterity. We should also note that we asked about ambidexterity in the future, i.e., whether the firms cooperate in order to *become* more explorative, exploitative, or ambidextrous.

[7] For a more comprehensive overview of the data collection process, see Rothgang et al. (2015).

5.1 Exploration

The variable *Exploration* is based on firms' answers to the question: *How important is the 'development of new technological fields' as a motive for your cooperative R&D activities?* The answer to this question had to be specified according to a 5 point scale, where 5 means 'very important' and 1 means 'unimportant'. Therefore, a high value of this variable indicates that the firm is stressing activities to become more explorative in its R&D strategy.

5.2 Exploitation

The variable *Exploitation* is based on firms' answers to the question: *How important is the 'deepening of existing competencies' as a motive for your cooperative R&D activities?* Again the answer to this question could have ranged between 1 and 5, where 5 means 'very important' and 1 means 'unimportant'.

5.3 Pure ambidexterity

The dummy variable *PureAmbidexTech* combines the two variables *exploration* and *exploitation*. Specifically, *PureAmbidexTech* is equal to 1 if *exploration* and *exploitation* are very important or important (rated with 4 or 5) and 0 otherwise (see highlighted area in the top right of Fig. 1). Therefore, this variable measures whether the firms stress both activities within their R&D strategy in the same way and therefore want to become purely ambidextrous.

5.4 Continuum ambidexterity

As described above, ambidexterity lies on a continuum between specialization in exploration and exploitation, respectively. To display this in form of a variable, we created the variable *ContAmbidex* as the difference between *exploitation* and *exploration*, excluding those observations where both items are rated irrelevant (values of 1 or 2, bottom left area "X" in Fig. 1). For *ContAmbidex*, a value of -4 indicates an aspired specialization in exploration (exploration = 5 and exploitation = 1) and the value of +4 a revealed focus on exploitation (exploration = 1 and exploitation = 5). This indicator is centered at 0, i.e. for cases where both dimension are of equal relevance.

5.5 Cluster management services

One basic aim of this paper is to find out to what extent cluster management is aligning its services with the needs of the cluster firms with regards to ambidexterity.

With respect to these activities and services, the cluster management as well as the cluster firms were asked several questions. First, in order to find out about the supply of services in a cluster, the cluster management was asked about the importance of offering specific services. Possible answers ranged between 1 (unimportant) and 5 (very important) for each of the services listed in Table 1, which gives in the first column the number of clusters that provide a specific service and, in the second column, the mean relevance among those clusters offering the service. Second, we asked the cluster firms whether they require a certain service of the cluster management. The answers are reflected in a binary

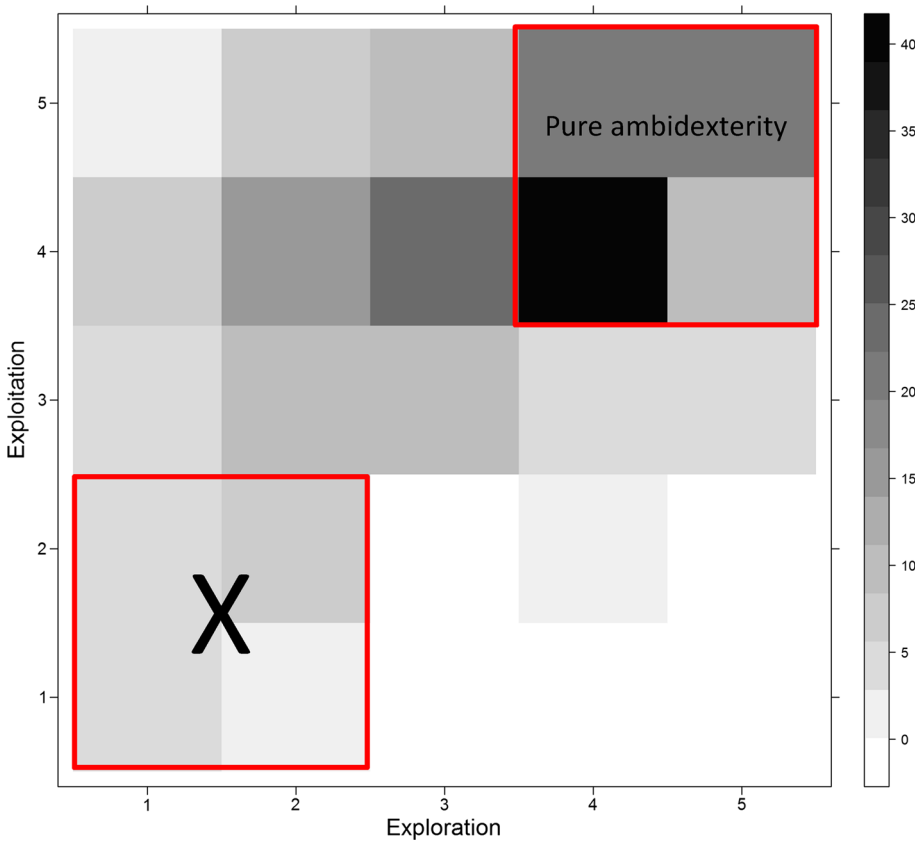

Fig. 1 The two ends of the ambidexterity continuum. Levelplot based on the cross-tabulation of exploration and exploitation. Top right area defines the variable PureAmbidexTech. Lower left area "X" is excluded in the calculation of ContAmbidex

variable for each service (*Need_…Service* with yes = 1 and no = 0). Column three in Table 1 delivers the mean share of firms that demand a specific service.

5.6 Controls

We use cluster dummies to control for technological fields and account for firm size with the variable *SME*, which is equal to 1 if the firm is small or medium sized and 0 if it is a large company. As an additional control, we used the variable *Benefits/Costs LECC* that accounts for a firm's evaluation of the overall benefits of the LECC, which in turn might indicate the degree of identification with the cluster strategy and influence the demand for cluster management services. This variable is based on answers to the question: *How do you evaluate the present relation between benefits and costs for your company of attending the Leading Edge Cluster Competition?* The answers could range between 1 (costs exceed the benefits) and 5 (benefits exceed the costs). The variable *Member of other cluster* is of a binary nature and indicates whether the firm is also member of another cluster organization. Finally, we control for experience in joint R&D (*experience in cooperation),* since

Table 1 Descriptive overview on the services as provided by the cluster management

	Number of cluster managements providing this service	Mean strategic importance of this service as evaluated by the cluster managements that offer this service	Mean percentage of cluster actors stating a demand for the respective service (%)
Common R&D infrastructure for the actors (*R&DInfrastructure*)	5	2.20	59.53
Qualification/Education for the employees of the actors (*Qualification/Education*)	9	1.56	67.68
Events/common activities of the cluster actors (*Events for cluster actors*)	10	1.50	92.93
Public relations (*Public relations*)	10	1.60	87.20
Consulting with regards to R&D funding (*Consulting R&D funding*)	9	1.56	74.91
Networking within the cluster/connecting cluster actors (*Networking within the cluster*)	10	1.40	90.26
Providing an IT-Platform for the exchange of information and knowledge within the cluster (*IT Platform*)	9	2.11	81.36
Contact to the funding agency of the Leading Edge Cluster Competition (*Contact to funding agency of LECC*)	9	1.78	81.23
Networking outside the cluster/connecting cluster actors to external actors (*Contact to external actors*)	10	1.90	81.05
Networking with other clusters with similar technological focus (*Networking with other clusters*)	10	2.10	88.76
Establishment of international contacts (*International contacts*)	9	1.56	77.58

experienced firms might require other services than firms that have not cooperated in R&D before.

In the following section, we analyze the aspects of cluster cooperation, cluster organizations, and their influence on ambidexterity empirically. This is accomplished from three perspectives: First of all, we ask, from the perspective of the individual firm, how cluster cooperation contributes to ambidexterity at the firm level. Second, we analyze, whether and under what conditions, a cluster as such can be assessed to be ambidextrous,

Table 2 Distribution of ambidexterity in clusters

	Observations								Shares						
ContAmbidex	−2	−1	0	1	2	3	4	Total	−2	−1	0	1	2	3	4
BioRN	0	0	6	5	0	1	0	12	–	–	0.50	0.42	–	0.08	–
CoolS	0	2	1	5	1	2	0	11	–	0.18	0.09	0.45	0.09	0.18	–
FOE	0	3	3	2	0	0	0	8	–	0.38	0.38	0.25	–	–	–
LogistikRuhr	1	1	21	13	14	4	0	54	0.02	0.02	0.39	0.24	0.26	0.07	–
Luftfahrt	0	0	5	3	3	0	0	11	–	–	0.45	0.27	0.27	–	–
MedicalValley	1	1	9	5	4	3	0	23	0.04	0.04	0.39	0.22	0.17	0.13	–
MicroTEC	1	4	18	11	5	2	2	43	0.02	0.09	0.42	0.26	0.12	0.05	0.05
Software	1	1	3	4	2	1	0	12	0.08	0.08	0.25	0.33	0.17	0.08	–
Solar	1	0	4	4	0	2	0	11	0.09	–	0.36	0.36	–	0.18	–
m4	0	3	5	5	2	1	0	16	–	0.19	0.31	0.31	0.13	0.06	–
Total	5	15	75	57	31	16	2	201	0.02	0.07	0.37	0.28	0.15	0.08	0.01

ContAmbidex is defined by the difference between exploitation and exploration. A negative (positive) value indicates specialization in exploration (exploitation)

being able to cope with external threats to long-term development. Third, we look at the cluster management and at how it contributes to cluster ambidexterity.

6 Analysis

Similar to ambidexterity at the firm level, cluster ambidexterity relates to the mix of exploration and exploitation in cluster activities. Our empirical analysis of cluster ambidexterity proceeds along the distinction of two models (types A and B) of cluster ambidexterity, suggested by Kauppila (2007) and introduced above. We have to note that previous studies usually analyze the general R&D strategy of firms with respect to ambidexterity. We take a slightly different avenue and concentrate our analyses on the question as to the extent firms use R&D cooperation in order to pursue exploitation and exploration strategies, which is, of course, part of the whole R&D strategy of the firm.

6.1 Classifying clusters

In a first step, we address research question RQ1 and classify clusters as type A or type B in our dataset. In order to do this, we use the variable *ContAmbidex,* which indicates the degree of ambidexterity of the cluster firms' R&D strategy. Table 2 and Fig. 2 both present the distribution of this ambidexterity variable for all firms within the ten LECC clusters.

Table 2 shows that, within each cluster, as well as for all clusters together, most of the firms are ambidextrous in the sense that they devote rather similar relevance to exploration and exploitation.[8] In each cluster, the majority of firms falls in the range between (−1) and

[8] One could argue that high-tech firms are ambidextrous per se because they perform R&D and invest in long-term competititveness. However, investing in R&D and exploration are not the same, as R&D investments can also aim at improving products and production processes in technologies that are already in use, which would mean a medium- and long-term investment in exploitation.

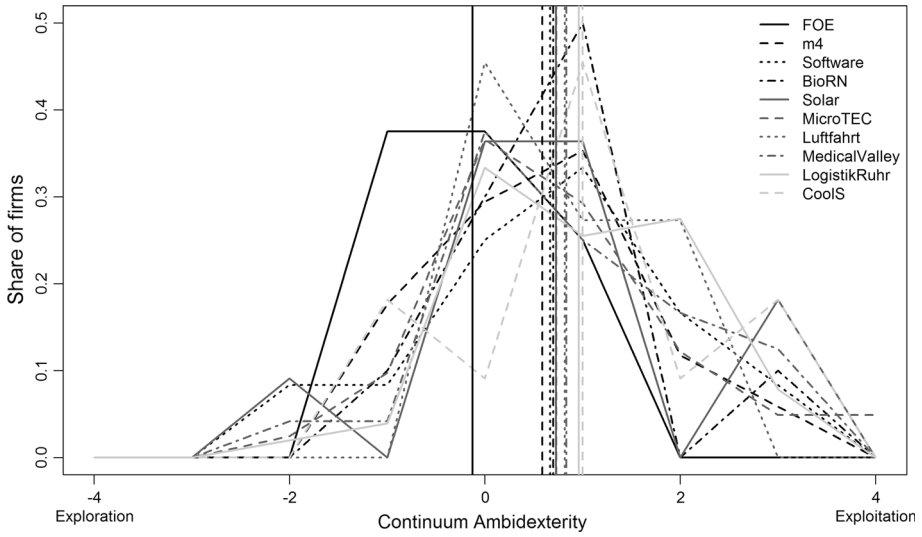

Fig. 2 Clusters in the ambidexterity continuum. The vertical lines are positioned at the mean of Continuum Ambidexterity for each cluster

(1) (on the cluster level between 65 and 100%; and overall 73%). Examining the observations outside this range, we see that almost all of these specialized firms (overall 24% and between 0 and 33% on the cluster level) tend towards exploitation (*ContAmbidex* >1). We find only two cases where firms have a priority in exploitation and do not explore at all (*ContAmbidex* = 4). With one exception, the cluster means are between 0.5 and 1; only the firms in the FOE tend to follow an explorative strategy. Bringing these first descriptive results together with Kauppila's (2007) models of network ambidexterity, we find that the ten LECC clusters are rather of a model B type. This means that the majority of firms follows an ambidextrous strategy in their research activities.

6.2 Demand for cluster management services

In order to answer our further research questions RQ2 and RQ3, we use a two step procedure. In a first step, we analyze firms' demand for cluster services, depending on their strategies towards ambidexterity. In a second step, this strategy-dependent demand is regressed on the relative importance of the respective services for the cluster managements. In this way, we evaluate whether cluster management organizations base their services on the needs of cluster firms.

We have argued above that cluster management can be seen as an agency offering different services for cluster agents. On that background, we take a look at the services provided by the cluster managements and their relation to the cooperation strategies of individual firms. As there is in general no market for these services and no market prices are paid for by the cluster firms, it is not clear whether these services relate to the demand of individual firms. However, there are other mechanisms that can provide safeguards for these services to be closely related towards what individual firms expect: first of all, all clusters have established cluster boards with firm representatives as members that accompany the activities and services of the cluster managements, and second, clusters

depend on the membership and active participation of the firms that itself depends on their assessment of the benefits associated with cluster membership. Thus, the services supplied by the cluster management are expected to reflect the demand of its participants. This is what we want to test in our analysis. This analysis can also be taken as a kind of test of Bocquet & Mothe's (2015) model on the intermediary role of a cluster management for firms' ambidexterity strategies.

In order to explore this dimension, we need to find out those service firms that require offering by their cluster management, depending on their strategy with respect to exploration, exploitation, and ambidexterity. Table 3 shows the results of logistic regressions for each of the 11 types of services offered by cluster managements. We are particularly interested in how the firm strategies of exploration and exploitation as well as the ambidextrous strategy are related to them, controlling for additional firm characteristics such as firm size, cluster affiliation, cooperation experience, membership in other clusters and the perceived benefit from the LECC.

To align our analysis to the relation between firm strategies, on the one hand, and a more cluster-internal or cluster-external orientation, on the other, we group the 11 services into (1) general services, such as qualification measures or a common R&D infrastructure (2) services that aim at improving cluster-internal cooperation and networking (contacts to a funding agency for common projects, internal networking) and (3) services that aim at external relations for new impulses (such as international contacts or contacts to other clusters). In general, the 11 different services often can be used both in activities that relate to exploitation, exploration, or both, i.e. ambidexterity. On the basis of the three broader groups, we test whether firms that aim at exploitation in their research cooperation seek assistance more in cluster-internal activities, while firms that aim at exploration in their cooperation activities demand services in respect to cross-cluster activities.

Focusing on the research strategies, we find that purely ambidextrous firms show a need for R&D infrastructure, but compared to firms that are more specialized in their research strategy, they do not need a cluster management to provide networking with other clusters and international contacts. Firms that view exploration as an important motive to cooperate need cluster management services with respect to activities that provide them with new R&D financing sources (consulting with respect to R&D funding and contacts to the funding agency), with respect to help in networking with other clusters and international contacts and with respect to services related to public relations. Thus, cluster management seems to have a special role for initiating contacts with actors in other clusters who might add new impulses for research. For firms that concentrate on exploitation (recall that this is the majority of the not purely ambidextrous firms), no special demands of cluster management services can be identified. In addition, they explicitely do not need the cluster management to provide an IT-platform for knowledge exchange—which might be a special feature of our dataset. As we know from our interviews, the use and benefit of these IT-platforms often suffers from data quality issues.

With respect to research question RQ2, we find that, depending on the individual strategy, firms have different needs with respect to the services offered by the cluster management organizations.

6.3 Cluster management response to firm demand for services

The preceding estimations were aimed at explaining to what extent exploration, exploitation, and ambidextrous strategies drive demand for services provided by cluster management. In the second step devoted to RQ3, we now bring together the strategy-

Table 3 Logistic regression on the influence of firms' R&D strategy on its demand for cluster management services

	(1) General services				
	Need_R&D infrastructure	*Need_Qualification/Education*	*Need_Public relations*	*Need_IT Platform*	*Need_Events for cluster actors*
Exploration	−0.234 (0.31)	0.059 (0.79)	0.970(0.02)	0.337 (0.23)	0.201 (0.59)
Exploitation	0.051 (0.81)	−0.073 (0.72)	0.346 (0.31)	−0.448 (0.06)	−0.007 (0.98)
PureAmbidexTech	1.234 (0.04)	0.520 (0.38)	−0.951 (0.45)	0.249 (0.73)	0.010 (0.99)
SME	−0.004 (0.99)	−0.042 (0.91)	1.052 (0.18)	0.355 (0.44)	1.065 (0.11)
Clusterdummies	yes	yes	yes	yes	yes
Benefits/Costs LECC	−0.104 (0.16)	−0.009 (0.90)	−0.154(0.19)	0.001 (0.99)	−0.148 (0.18)
Member of other cluster	0.012 (0.98)	0.768 (0.05)	2.371 (0.01)	1.163 (0.02)	–
Experience in cooperation	0.945 (0.04)	0.976 (0.03)	−0.092 (0.91)	1.078 (0.03)	0.959 (0.15)
Obs	166	181	157	161	83
Wald chi2(15)	26.44	31.06	39.38	42.76	24.33
Prob > chi2	0.0336	0.0196	0.0003	0.0002	0.0114

	(2) Internal networking			(3) External networking		
	Need_Consulting R&D funding	*Need_Networking within the cluster*	*Need_Contact to funding agency of LECC*	*Need_Contact to external actors*	*Need_Networking with other clusters*	*Need_Inter-national contacts*
Exploration	0.503 (0.05)	0.318 (0.36)	0.798 (0.01)	0.239 (0.35)	0.986 (0.01)	1.197 (0.00)
Exploitation	−0.119 (0.58)	0.165 (0.57)	−0.143 (0.53)	0.333 (0.15)	−0.226 (0.44)	−0.202 (0.39)
PureAmbidexTech	−0.859 (0.18)	−0.121 (0.90)	−1.103 (0.12)	−0.891 (0.18)	−2.011 (0.06)	−1.357 (0.08)
SME	0.869 (0.03)	0.400 (0.54)	0.112 (0.80)	0.743 (0.09)	0.645 (0.27)	1.278 (0.01)
Clusterdummies	yes	yes	yes	yes	yes	yes
Benefits/Costs LECC	0.004 (0.96)	−0.081 (0.44)	−0.155 (0.05)	−0.020 (0.80)	−0.034 (0.74)	−0.105 (0.23)
Member of other cluster	0.299 (0.45)	2.140 (0.01)	0.355 (0.41)	0.342 (0.44)	0.767 (0.20)	0.734 (0.13)
Experience in cooperation	0.157 (0.74)	1.717 (0.01)	0.010 (0.98)	0.665 (0.17)	0.365 (0.57)	0.278 (0.60)
Obs	181	166	172	170	142	175

Table 3 continued

	(2) Internal networking			(3) External networking		
	Need_Consulting R&D funding	*Need_Networking within the cluster*	*Need_Contact to funding agency of LECC*	*Need_Contact to external actors*	*Need_Networking with other clusters*	*Need_Inter-national contacts*
Wald chi2(15)	38.84	46.83	41.90	44.56	44.21	49.46
Prob > chi2	0.0019	0.0000	0.0004	0.0002	0.0000	0.0000

P values in parentheses

Table 4 OLS regressions of firms' demand on cluster management's perceived relevance of services

	CM offer of the respective service	No Obs	Pseudo R2	Prob > chi2	LR chi2	
Fit_Need_R&D infrastructure	3.016	(0.05)	77	0.046	0.040	4.230
Reported/Fit_Need_R&D infrastructure	−0.249	(0.66)	125	0.001	0.662	0.190
Need_R&D infrastucture	−0.102	(0.78)	125	0.000	0.779	0.080
Fit_Need_Qualification/ Education	−0.169	(0.84)	170	0.000	0.840	0.040
Reported// Fit_Need_Qualification/ Education	−0.383	(0.44)	215	0.001	0.441	0.590
Need_Qualification/Education	−0.112	(0.42)	215	0.000	0.676	0.170
Fit_Need_Events for cluster actors	3.306	(0.08)	83	0.039	0.051	3.800
Reported//Fit_Need_Events for cluster actors	2.453	(0.01)	229	0.031	0.002	9.610
Need_Events for cluster actors	0.913	(0.06)	229	0.012	0.050	3.830
Fit_Need_Public relations	−1.686	(0.13)	157	0.011	0.126	2.350
Reported//Fit_Need_Public relations	−0.445	(0.49)	229	0.002	0.490	0.480
Need_Public relations	−0.219	(0.63)	229	0.001	0.628	0.230
Fit_Need_Consulting R&D funding	4.887	(0.00)	170	0.074	0.000	20.370
Reported//Fit_Need_Consulting R&D funding	1.894	(0.00)	215	0.030	0.001	10.440
Need_Consulting R&D funding	0.499	(0.09)	215	0.008	0.094	2.800
Fit_Need_Networking within the cluster	−3.334	(0.00)	166	0.041	0.002	9.410
Reported//Fit_Need_Networking within the cluster	−0.504	(0.45)	229	0.002	0.443	0.590
Need_Networking within the cluster	−0.203	(0.63)	229	0.001	0.626	0.240
Fit_Need_IT Platform	0.330	(0.72)	161	0.000	0.715	0.130
Reported//Fit_Need_IT Platform	0.692	(0.23)	215	0.003	0.226	1.470
Need_IT Platform	0.191	(0.52)	215	0.001	0.523	0.410
Fit_Need_Contact to funding agency of LECC	2.414	(0.06)	161	0.020	0.052	3.770
Reported//Fit_Need_Contact to funding agency of LECC	1.899	(0.02)	215	0.022	0.014	6.070
Need_Contact to funding agency of LECC	0.529	(0.20)	215	0.006	0.190	1.720
Fit_Need_Contact to external actors	3.854	(0.00)	170	0.036	0.000	12.400
Reported//Fit_Need_Contact to external actors	1.413	(0.02)	229	0.013	0.016	5.780
Need_Contact to external actors	0.401	(0.20)	229	0.004	0.200	1.640
Fit_Need_Networking with other clusters	3.518	(0.29)	142	0.021	0.231	1.440

Table 4 continued

	CM offer of the respective service	No Obs	Pseudo R2	Prob > chi2	LR chi2	
Reported//Fit_Need_Networking with other clusters	0.294	(0.75)	229	0.000	0.755	0.100
Need_Networking with other clusters	0.102	(0.86)	229	0.000	0.855	0.030
Fit_Need_International contacts	1.298	(0.05)	164	0.012	0.051	3.810
Reported// Fit_Need_International contacts	0.514	(0.27)	215	0.003	0.272	1.210
Need_International contacts	0.221	(0.47)	215	0.001	0.471	0.520

P values in parentheses

driven demand of firms with the actual management supply and ask: *Does a cluster management organization serve the strategy-driven needs of firms?* In an OLS regression, we use as a dependent variable the cluster management's evaluation of the priority of a certain service; here the answers ranged from 1 for a very low to 5 for a very high priority. Since the demand of a specific service depends on several characteristics of the firm, we explain this priority with the needs of the firms, for which we use the fitted values of the estimations in Table 3, which gives us the probability of having a demand for this service given the individual R&D strategy and given some other characteristics such as size, cluster membership, and so on (see Table 3). Table 4 shows the results.

For each service, we estimate three different models. In model 1, we use the fitted value of the demand for each service in order to explain the supply of this service (*Fit_Need_…Service*). Since we lose some observations when generating the fitted values due to missing values, we also used models 2 and 3 as a robustness check. In model 2, we take either the fitted value or the reported value of the demand as explanation for the supply (Reported/*Fit_Need_…Service*). In model 3, we explain the supply of a certain service with the reported value of the demand (*Need_…Service*).[9]

Referring to the results of models 1, we find that, overall (in 7 out of 11 cases), cluster management organizations indeed align their services with the needs of the firms (as indicated by a positive and significant coefficient). The argument by Bocquet & Mothe (2015) that a cluster management is an intermediary for the fulfillment of ambidexterity strategies of cluster firms seems to find support here. In detail, we find that a need on the side of the firms is positively related with a high priority for the cluster management for the following services: 'R&D infrastructure', 'Events for cluster actors', 'Consulting R&D funding', 'Contact to funding agency of LECC', 'Contact to external actors' and 'International contacts'. For the service 'Networking within the cluster' we find a negative effect (a higher need correlates with less priorization). This surprising result can be explained by the fact that all cluster managements give a priority of 5 and 4 to this service, which are actually the two highest possible values. But in the regression, 5 is the 'good' while 4 is the

[9] Our robustness checks either reinforce the results from model 1 estimations or show up as not significant.

'bad' value and the variance of this variable is very low. Since, in our data, a high need for this service on the side of the firms is usually combined with a priority of 4 on the side of the cluster management, a negative relationship is not surprising at all.

These analytical results on RQ3 are also confirmed by expert interviews both with firm and cluster management representatives. Cluster managements closely align their services to the needs of the cluster firms and, therefore, also support the strategies of the individual firms towards ambidexterity. The relation results from the fact that cluster management activities are oriented towards the cluster strategies developed in close coordination with the individual actors of the cluster organizations. In some cases, activities were as well started with a special focus on exploration, as in the case of Hamburg Aviation where a knowledge management tool was developed that particularly aims at fostering completely new ideas.

7 Discussion and conclusion

A rich literature on the topic ambidexterity shows that addressing the conflicting demands of exploiting the existing knowledge base and developing new routes (exploration) is one core task for long-term firm survival (e.g. Adler et al. 1999; Raisch et al. 2009). A closer look into the preconditions for both kinds of activities shows that it is rather difficult to pursue both of them within one firm. This has especially to do with the change in domain (rules and instruments used for solving R&D problems) required by switching from exploitation to exploration (Arthur 2009).

Recently, some studies have looked at the role of clusters for achieving ambidexterity (Bocquet & Mothe 2015; Kauppila 2007). Cluster ambidexterity can have different meanings, which we analyze in this paper: Cluster cooperation can contribute to competitiveness of individual firms either by promoting exploitation or exploration. As firms closely cooperate in a cluster, their patterns of ambidexterity also influence the degree of ambidexterity of the cluster. Cluster initiatives and, more specifically, cluster management promoted by cluster policies can contribute to cluster ambidexterity without actively shaping the ambidextrous strategies of firms. Rather, we argue that cluster managements as a service provider for the firms react to the specific demands of its "customers" and simply help firms to realize their ambidexterity strategies.

Our empirical analysis of 229 firms in ten successful LECC clusters contributes to this literature and explores the influence of cluster management on the ambidexterity of a cluster and among cluster firms. Since we can build our analysis on a rich dataset on both, firm and cluster level, the LECC clusters are well suited for the analysis of cluster ambidexterity and the role of cluster initiatives.

In respect to cluster ambidexterity, different concepts have been discussed. Especially, it was not clear as to which individual strategies were followed by the individual firms. Therefore, in our first research question, we explicitly asked whether clusters are collectively ambidextrous because of ambidextrous member organizations or because of a division of labor among its members with respect to ambidexterity. Our analysis shows that cluster firms use R&D cooperation for pursuing both exploitation and exploration. Different patterns emerge which indicate that cluster firms partly search for new ideas within the cluster, partly use cluster cooperation in looking for new technological and market trends, and partly for probing new solutions. All leading-edge clusters we analyzed are

ambidextrous in the sense that most individual firms pursue both strategies and thereby also contribute to cluster ambidexterity.

The second research question asked for the kind of service firms require dependent on their strategies with respect to exploration, exploitation, and ambidexterity. We find that firms that tend to follow an exploitation strategy seem to have a comparably low need for such services. Therefore, it does not seem that any particular cluster service is necessary for activities directed at incremental improvements of existing products and production processes. The benefits of cluster services are rather perceived by firms with activities that relate to exploration. These firms require cluster management services, such as public relations, consulting with regards to R&D funding, contacts to the funding agency, and networking with national and international organizations, to help them scan their environment for new technological possibilities (either by gaining information from cluster organizations, by holding contact with universities and research institutes or by looking for the success of high-tech ventures in the cluster regions). Firms that follow a purely ambidextrous strategy demonstrate the need of a common R&D infrastructure. This might well be a sign that conducting exploration and exploitation requires high investments such that, for these firms, sharing the burden is especially valuable. At the same time, these firms have a significantly lower demand for services related to external networking.

While cluster managements do not have the core task to address the relationship of cluster activities that relate to exploration and exploration, they influence both kinds of activities in their role as service providers who orient their activities at the needs of their customers, namely, the cluster firms. In this respect, they can develop into supporters for both exploitation and exploration. We find that different R&D strategies influence the demand for different services of the cluster management. Especially, firms focusing at exploration use cluster management services that aim at cross-cluster contacts, which can give impulses for cluster development.

Our third research question aimed at analyzing the coherence between the strategy-dependent demand for services by the respective cluster firms and the services offered by the cluster management. We find that cluster management organizations are largely successful in identifying demand of their 'customers', the cluster firms, and offering the respective services. In contrast to Bocquet & Mothe (2015), our interpretation of these findings is that the relation between the cluster management and ambidextrous strategies of the firms is an indirect one. It is not the cluster management orchestrating the activities of cluster firms towards a predefined level of ambidexterity, but rather a decentralized mode of organization. Even though the mechanisms for the alignment between cluster service demand and supply were not explicitly analyzed, our impression from selected interviews is that this alignment at least partly took place already during the formulation of the cluster strategy.

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Appendix

See Table 5.

Table 5 Variable description

Variable	Description	Obs	Mean	SD	Min	Max
R&D strategy						
Exploration	Importance of 'search for new technological fields' in firms' research cooperation. From 1 (low) to 5 (high)	217	3.27	1.26	1	5
Exploitation	Importance of 'deepening of existing competences' in firms' research cooperation. From 1 (low) to 5 (high)	217	3.96	0.97	1	5
ContAmbidex	Continuous variable: *exploitation–exploration*	217	0.70	1.16	−2	4
PureAmbidexTech	Dummy variable: 1 if *exploration* AND *exploitation* ≥ 4	217	0.45	0.50	0	1
Reported demand for cluster management services						
	Dummy variable, indicating, whether the firm has a need for the respective service offered by the cluster management					
Need_R&D infrastructure	… need of R&D infrastructure …	229	0.59	0.49	0	1
Need_Qualification/ Education	… need of Qualification/Education …	229	0.67	0.47	0	1
Need_Events for cluster actors	… need of events for cluster actors …	229	0.90	0.31	0	1
Need_Public relations	… need of public relations …	229	0.90	0.30	0	1
Need_Consulting R&D funding	… need of consulting in R&D funding…	229	0.72	0.45	0	1
Need_Networking within the cluster	… need of networking within the cluster …	229	0.89	0.32	0	1
Need_IT Platform	… need of an IT-platform…	229	0.79	0.40	0	1
Need_Contact to funding agency of LECC	… need of contact to funding agency of LECC…	229	0.78	0.41	0	1
Need_Contact to external actors	… need of organized contacts to external actors …	229	0.79	0.41	0	1
Need_Networking with other clusters	… need of networking with other clusters …	229	0.87	0.33	0	1
Need_International contacts	… need of international contacts …	229	0.76	0.43	0	1
Controls						
SME	1 if the firm is a small and medium sized company	225	0.61	0.49	0	1
	1 if the firm belongs to the cluster …					
Solarvalley	… SolarValley Mitteldeutschland	229	0.05	0.21	0	1

Table 5 continued

Variable	Description	Obs	Mean	SD	Min	Max
m4	… m4	229	0.08	0.27	0	1
BioRN	… BioRN	229	0.06	0.23	0	1
CoolS	… CoolSilicon	229	0.06	0.24	0	1
FOE	… Forum Organic Electronics	229	0.03	0.18	0	1
LogistikRuhr	… LogistikRheinRuhr	229	0.27	0.45	0	1
Luftfahrt	… Hamburg Aviation	229	0.06	0.24	0	1
MedicalValley	… Medical Valley	229	0.12	0.32	0	1
MicroTEC	… MicroTEC Südwest	229	0.21	0.41	0	1
Software	… Software-Cluster	229	0.06	0.24	0	1
Benefits/Costs LECC	Answer to the question: How do you evalueate the benefits as compared to the costs of the participation of your firm in the LECC? From 1 ('costs are considerably higher than the benefits' to 5 ('benefits are considerably higher than the costs'.	159	3.64	1.09	1	5
Member of other cluster	1 if a firm is member of a cluster outside the the LECC	217	0.36	0.48	0	1
Experience in cooperation	1 if the firm experienced cooperation before the LECC	220	0.75	0.43	0	1
Relevance of CM's offers						
	CM's priority of offering … (1: the clustermanagement agency rates the meaning of this service quite low; 5: the clustermanagement agency rates the meaning of this service very high					
IT Platform	…IT Platform	215	3.479	1.10152	2	5
R&D infrastructure	…R&D infrastructure	125	3.736	0.57000	3	5
Qualification/ Education	…Qualification/Education	215	3.595	1.70458	1	5
Events for cluster actors	…Events for cluster actors	229	4.432	0.49648	4	5
Public relations	…Public relations	229	4.406	0.49218	4	5
Consulting R&D funding	…Consulting R&D funding	215	4.512	0.57079	3	5
Contact to funding agency of LECC	…Contact to funding agency of LECC	215	4.126	0.57847	2	5
Networking within the cluster	…Networking within the cluster	229	4.493	0.50105	4	5
Contact to external actors	…Contact to external actors	229	4.175	0.67217	3	5
Networking with other clusters	…Networking with other clusters	229	3.978	0.37981	3	5
International contacts	…International contacts	215	4.381	0.63660	3	5

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