Collaboration Strategies in Innovation Ecosystems: An Empirical Study of the German Microelectronics and Photonics Industries

Fabian Schroth and Johann Jakob Häußermann

> *"As great ideas can be discovered in diverse and unexpected places, we need to collaborate in new and surprising ways."*
>
> Tom Hulme
> Founder of OpenIDEO

Effective collaboration between companies and research organizations is key to successful innovation systems. Against the background of digitalization, a shift from traditional innovation systems towards innovation ecosystems can be observed. In this article, we investigate how companies operating in innovation ecosystems address the challenge of collaboration in dynamic innovation ecosystems. We focus on microelectronics and photonics in Germany as examples of knowledge- and research-intensive industries and analyze the strategies of companies to collaborate with research organizations. We explore whether and to what extent companies develop different and new strategies for collaborating with research institutions within innovation ecosystems, on the basis of which we identify two ideal types of strategies. Whereas ideal type A is aiming towards obtaining specific knowledge in order to further develop a particular technology or product (i.e., towards incremental innovation), ideal type B seeks to harness the new and full potential of innovation ecosystems (i.e., aiming at rather radical innovation). Finally, our findings contribute to a better understanding of innovation ecosystems and give managerial implications for collaborating in such systems.

Introduction

The development of new technologies is extremely knowledge-intensive and entails new challenges, particularly with respect to the generation and diffusion of knowledge: it is becoming highly dynamic and characterized by intensive collaboration. For companies involved in innovation ecosystems (Adner & Kapoor, 2010; Autio & Thomas, 2014; Jackson, 2011; Valkokari, 2015), this implies that they can no longer develop new technologies – much less new products and services – on their own, but instead need to cooperate with external organizations, including research institutes and other companies (Pellikka & Ali-Vehmas, 2016). This is particularly true for companies in knowledge-intensive industries that have seen an increase in external collaboration for creating and commercializing innovation (Dolata, 2016; Siikonen et al., 2011).

Digitalization is creating new ways of exchanging information and completely new approaches to innovation processes – both within companies and at the interface to research institutions or end customers. The resulting challenges and opportunities for innovation affect all sectors, but in particular all knowledge-intensive industries. Here, collaboration intensifies, and we observe the emergence of innovation ecosystems as dynamic and co-productive spaces for research, development, and innovation (R&D&I) activities characterized by a high interdependence of industry and research actors (Adner & Kapoor, 2010; Autio & Thomas, 2014).

Both photonics and microelectronics are knowledge-intensive industries. These companies spend about 10% of their revenue on research and development, which is far above the average of approximately 4% across the manufacturing industry (VDI, 2016). Both industries

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provide key enabling technologies for digitalization and are increasingly affected by it. Companies in these industries engage in collaborative R&D with other actors in their supply and value chain (Häußermann et al., 2018). With photonics, a research-intensive industry has been selected that makes a significant contribution to the competitiveness of German companies. With an export quota of almost 70%, photonics is one of the most export-oriented sectors of the German economy. The photonics industry employs 130,000 people in Germany with a turnover of €31.5 billion (~$47 billion CAD). Of the approximately 1,000 total companies, about 85% are small and medium-sized enterprises (Spectaris, 2010, 2014). With microelectronics, a sector of the capital goods industry has been selected that serves as an important enabler in the business-to-business (B2B) sector and comprises a large number of large companies. As an approximation for evaluating the significance of microelectronics, data from the German electrical industry can be consulted. According to this, the industry generated sales of €176 billion (~$260 billion CAD) in 2016 and employed 849,000 people (ZVEI, 2017).

This article is structured as follows. First, we review the existing literature on innovation ecosystems, concentrating in particular on the need for companies to collaborate in interdependent and dynamic innovation ecosystems. Next, we provide a short overview of our methodological approach. This is followed by a description of our empirical findings, wherein we identify and analyze factors that motivate companies to seek the collaboration of research institutions, their criteria for choosing potential collaborators, common modes of collaboration, and lastly, factors that promote or prevent collaboration. In the fourth part of the article, we present two ideal types of strategies companies employ to deal with the challenges of collaboration within innovation ecosystems. Finally, we discuss our findings within the theoretical context of innovation ecosystems and give managerial implications.

Collaboration of Knowledge and Business Actors in Innovation Ecosystems

Since the early 1990s, innovation studies have focused on knowledge as the central resource for innovation and learning among diverse actors as the central process (Lundvall, 2010). Contrasting earlier conceptions of linear innovation processes, the perspective has changed toward a system perspective of innovations, which takes into account the interaction of diverse actors and the systems of knowledge production and diffusion. From this perspective, the dynamics of the relationships in such systems are of interest as well as different types of knowledge leading to specific characteristics of these systems (Asheim & Coenen, 2005). Studies focus on the capacity of companies to search and learn in such systems (Lundvall, 2007) as well as on the dynamics among different innovation stakeholders – namely industry, academia, the state, and civil society – in innovation systems (Carayannis & Campbell, 2009). In the interaction of the innovation helices, overlays of communications, networks, and organizations may appear (Etzkowitz & Leydesdorff, 2000).

In recent years, the term "innovation ecosystem" has gained prominence in innovation studies as a way to describe one such overlay: the dynamic and co-productive space in which industrial R&D&I takes place. The term highlights both interdependencies between organizations and the co-evolution of value (Adner & Kapoor, 2010; Autio & Thomas, 2014). Within innovation ecosystems, companies do not innovate individually, but rather depend on the resources and know-how of other organizations (Adner & Kapoor, 2010). In contrast to other concepts, such as clusters and innovation systems, this notion encapsulates a wide range of organizations, institutions, and actors in the value chain, both upstream and downstream. Innovation ecosystems are not confined to a single industry either; instead, they form around a specific application or innovation and thus consist not only of companies but also include other actors that contribute to the innovation process as a whole, from exploration to exploitation. This includes investors, marketing agencies, and even knowledge providers – any and all actors, in fact, "that [specialize] in the development, discovery, delivery, and deployment of evolving applications" (Autio & Thomas, 2014).

Most existing studies focus on single companies so as to describe and analyze what we would consider business ecosystems, in other words, they focus on those concerned with value creation (Valkokari, 2015). However, by focusing on single companies and the value-creation process, these studies leave aside collaboration in innovation systems. Collaboration entails two central elements: interactive learning and the creation of new knowledge (Asheim & Coenen, 2005; Lundvall, 2007). Although interactive learning is a process based on learning by doing and using, and thus, it aims at incremental innovations, knowledge creation refers to activities that aim at radical innovations. As innovation ecosystems overlap highly dynamic spheres of innovation (Etzkowitz & Leydesdorff, 2000), the development of collaborative processes for learning and creating knowledge poses particular challenges to the innovation actors.

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Against this backdrop, we ask how companies collaborate with research organizations in innovation ecosystems to gain access to external knowledge and thus to create and transfer knowledge for innovation. Innovation ecosystems result from reflective activities of interdependent innovation actors (Etzkowitz & Leydesdorff, 2000). We assume that collaboration for innovation also results from such reflective processes. Thus, we analyze the strategies companies deploy in two innovation ecosystems, namely the German microelectronics and photonics ecosystems, to deal with the challenge of collaboration in dynamic innovation ecosystems. To this end, we identify the factors that motivate companies to seek collaboration with research institutions, we look at how said collaboration is usually initiated, we examine common types and means of collaboration, and finally, we identify both success factors and barriers to collaboration – thus contributing empirical insights into the collaboration strategies in innovation ecosystems.

Method

In addressing our research questions, we analyzed how companies interact with research organizations – which we take to be the relevant knowledge providers in innovation ecosystems – during collaborative R&D&I. We conducted a total of 42 qualitative interviews comprising 36 interviews with senior management from the research, strategy, and product management departments of both SMEs and large companies, and 6 interviews with representatives of interest groups and cluster organizations. The interviews each lasted between one and two hours. We analyzed the interviews using both in vivo codes and a codebook in order to distinguish ideal types (Weber, 1904) of the collaboration strategies companies deploy in innovation ecosystems. By deriving ideal types from our empirical findings, we were able to identify and highlight certain significant trends in our data.

When analyzing the interviews, we became aware that there were no significant differences relevant to our research interests between photonics and microelectronics. This is due in part to the technological proximity of the two industries, meaning that companies from photonics regularly work with companies from microelectronics, and vice versa. Secondly, both photonics and microelectronics are research-intensive industries in which close collaboration with research organizations plays a central role. Accordingly, we did not differentiate between the two industries in our subsequent analysis, interpretation, and presentation of the data.

Empirical Findings

In order to understand the challenges companies face in dealing with research organizations, we analyzed why, how, and with whom companies collaborate. Together, these observations provide a clearer understanding of how companies collaborate with research organizations, so as to exchange, create, and transfer knowledge for innovation in dynamic ecosystems.

Motivating factors

In this section, we describe the reasons respondents cited for engaging in collaboration with research organizations. This helps reveal the underlying incentive structures for collaboration. Respondents identified the following motivating factors:

1. Environment and market: As both industries are continually evolving through technical innovation, companies are constantly confronted with new challenges. Through collaboration with research institutions, it is possible to integrate external (predominantly technological) expertise, either on a one-off or short-term basis at specific stages of the innovation process, or via long-term collaboration.

2. Outsourcing of research: Although microelectronics and photonics are research-intensive industries, many SMEs in particular outsource their basic research to publicly funded research institutions. In addition, the participation of research institutions is sought when specific external technological expertise is required.

   > *"Why do I collaborate with others? Because I want a specialist and because the specialist can do it faster and more safely than I can do it myself."* (Company representative)

3. Complementary competences and infrastructures: Through collaboration with research organizations, new competencies can be jointly developed for the generation of intellectual property (IP) – which companies can in turn use both to secure their market position and gain access to new markets. Furthermore, collaboration entails access to the infrastructure of partner organizations: thus, companies in the photonics industry, for example, regularly use the facilities and equipment of research organizations.

4. Networking: In addition to the primary benefit of access to new knowledge and technologies, collaboration

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with research organizations also holds significant secondary benefits for companies. Said collaboration can help companies expand their professional networks and gain access to potential customers. Companies can also capitalize on their association with academic establishments for marketing purposes. Secondary benefits furthermore include access to potential future employees.

> *"One could also call it indirect recruiting, because these projects naturally provide access to graduates or PhD students who then get to know our development, our work, our working environment, get to know us personally, and then say: 'Oh, that would be something for me.' So the collaborative projects have multiple benefits."* (Large corporation in the photonics industry)

To summarize, the above analysis reveals different reasons for companies to collaborate with research organizations. While some companies seek access to the knowledge, skills, and infrastructure they themselves lack, others are motivated by opportunities to network and reap the benefits of a functioning innovation ecosystem (Pellikka & Ali-Vehmas, 2016). These differing motivations are indicative of different collaboration strategies, and hence diverging perspectives on innovation ecosystems.

Prerequisites for collaboration

The next step in our research was to examine how companies identify potential collaborators. Our study revealed three relevant sets of criteria for collaboration with a particular research establishment:

1. Sufficient academic and technical expertise: Companies look for research institutions that can provide the technical know-how they need, possess the necessary technological infrastructure, and conduct research work of a high standard – as evidenced by their contributions to academic conferences and publications, for example.

2. Favourable terms and conditions: This includes both the basic legal terms and conditions, in particular with respect to IP rights and non-disclosure agreements – which can contribute to the failure of newly established or emerging partnerships – and factors such as time frames, the possibility of recruiting employees, and conditions that allow for the bilateral exchange of complementary knowledge and skills without the risk of direct competition with the partner organization.

3. Social criteria: Though less tangible and harder to measure than the above two sets of criteria, companies strongly emphasize the importance of social factors. In particular, trust is described as the most important criterion for identifying potential partners.

> *"Personal contacts play an important role here. Especially when the involved parties have been around longer, they usually have a shared history, know each other well, and so on. There is no denying that this also plays a very big role."* (Large corporation in the microelectronics industry)

Companies accordingly prefer to enter into collaboration with organizations and individuals with whom they already have a shared working history, and hence consider reliable. Local proximity is of key importance here, as regional networks play two vital roles. First, these networks constitute companies' primary source of contacts and recommendations. Second, they are used as a means of indirect control, as word of satisfaction or dissatisfaction tends to spread throughout the network. The photonics and microelectronics industries both have a highly developed infrastructure of formal and informal platforms on which research organizations and companies interact. Fairs, congresses, business meetings, conferences, and networking events all provide spaces for regular exchange – on both professional and formal, and personal and informal bases.

> *"The most important thing* [in identifying potential partners] *is of course always the network you bring along or the network you create through events, conferences, and congresses."* (Large corporation in the microelectronics industry)

In addition, it is common practice for companies to actively seek out and contact previously unknown potential collaborators. Job exchanges and employment agencies, on the other hand, were rarely described by our respondents as a means of identifying potential partners.

In the end, although companies tend to emphasize expertise as the major criterion for identifying the "right" partner organization, soft factors such as trust often have a deciding influence. In this respect, innovation ecosystems provide a fertile environment for the initiation of collaboration, as they comprise multiple and dynamic forms of interaction between the relevant actors.

Modes of collaboration

We now come to an examination of the ways in which companies and research organizations collaborate.

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These include both established practices and newly emerging forms of collaboration that are still partly undefined. The exact modes of collaboration companies choose are indicative of their respective perspectives on innovation and general collaboration strategies.

In general, companies look for modes of collaboration and business models that allow for an exchange of complementary competencies without direct competition. In both microelectronics and photonics, joint applications for funding (usually by consortia consisting of different companies and research institutions) and contract research are among the most common types of cooperative relationships. There are various lines of funding for the promotion of collaboration with research institutes in both industries – and despite the administrative effort involved in the application processes and the coordination of consortia, as well as the often difficult negotiations about IP resulting from these projects, almost all of the companies surveyed reported implementing publicly funded collaborative projects. Contract research, in turn, is favoured by some companies because of the clear delineation of rights and obligations between client and contractor.

> *"We only award contracts that specify that it must be 100% ours afterwards. When we pay for something, then it is ours and then the contract says: everything you have done belongs to us and you are not allowed to talk about it for so long. But we'll pay for that."* (Large corporation in the microelectronics industry)

Companies also often recruit new employees from the staff of their partnered research organizations (or vice versa, in exceptional cases). In addition to formalized and regulated practices, companies also engage in many types of less formalized, short-term collaboration with research establishments, such as taking part in committees and associations or assigning student research projects.

Companies furthermore place great value on long-term strategic partnerships with research organizations, in which they can jointly uncover new markets and research fields while building up a solid basis of trust that also makes it possible to collaborate in legal "grey areas".

In summary, companies and research institutions cooperate and collaborate in a variety of ways, ranging from highly formalized practices such as contract research, through long-term partnerships, to more flexible and open forms of collaboration. Preferences for different modes of collaboration reveal general tendencies towards varying strategies within innovation ecosystems. While some companies make use of formalized frameworks to obtain specific knowledge, others prefer to engage with different partners in more open settings, so as to harness the innovative potential of ecosystems.

Success factors and barriers to collaboration

Finally, we identify factors that foster or impede collaboration between companies and research organizations – and by extension, either foster or impede (or even prevent) the establishment of productive innovation ecosystems.

First, companies are drawn to collaborate with research organizations, as they have a different set of goals to their own (this applies especially to universities). This allows for the joint discovery of new markets and research fields without competitive pressure. Second, companies stand to benefit by gaining access to expertise and research infrastructure. Finally, collaboration with research institutions affords companies access to potential new employees.

On the other hand, respondents in our study noted particular disadvantages to collaboration with research institutions. These include difficulties in IP negotiations and agreeing on codes of conduct, high resource expenditure (particularly in joint projects), protracted processes, a lack of understanding of the business sector's application-oriented approach, a lack of pragmatic approaches to the development of solutions, and conflicting goals as the result of differing interests. In addition, some of the respondents mentioned that in cases where the research organization retains the rights to the generated IP, there is the risk that it will be sold to other companies.

To conclude, differences in objectives are key to collaboration in innovation ecosystems. On the other hand, problems associated with IP and intricate negotiations can hamper collaboration and the development of productive innovation ecosystems. In light of this, companies adopt different strategies – so as to address the challenges of collaboration, and in order to capitalize on the advantages of innovation ecosystems. In the next section, we reduce these strategies to two ideal types.

Discussion

The empirical findings presented above paint a rather diverse picture of why, how, and with whom companies

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in German microelectronics and photonics collaborate, as well as what they perceive to be the main advantages of and barriers to successful collaboration. They reveal that companies often lack an overall, coherent, and explicit collaboration strategy. However, this does not mean that companies do not have implicit strategies. We define collaboration strategies as instruments to facilitate the creation, exchange, and transfer of knowledge in dynamic ecosystems with the aim to develop unique competencies and resources in order to foster competitiveness (Asheim & Coenen, 2005; Etzkowitz & Leydesdorff, 2000). Based on our findings, we derived five dimensions of such a strategy along which company collaboration differs. These are the general perspective on innovation; the motivation behind collaborations; the time-frame and mode of collaborations; and the expected outcome. For each of the dimensions, we identified characteristics relating to learning as well as characteristics related to knowledge creation so that we are able to come up with two ideal-typical collaboration strategies (Table 1). The first type describes a strategy that aims at learning; the second aims at creating new knowledge (Asheim & Coenen, 2005).

Type A represents a strategy to learn from an existing stock of knowledge aiming at incremental innovation, whereas type B represents a collaboration strategy to create new knowledge aiming a radical innovation (Asheim & Coenen, 2005). The basis of both strategies is a different perspective to innovation processes. Type A is characterized by an understanding of the innovation process as specialized and fragmented. Companies collaborate with research organizations to increase their stock of knowledge in very specialized technological areas. The company predefines the problems to be addressed through cooperation and the solutions that are expected. It tends to favour established practices, such as contract research or joint research projects, with a rather narrow time frame and the aim of developing products or services. More often than not, collaboration is seen as a means to reduce or outsource risk, and to get answers to pre-defined questions and problems aiming at incremental innovations.

Type B is characterized by an understanding of innovation processes in terms of ecosystems. It seeks to harness the potential of diverse and new actors in dynamic relationships, embraces more open and flexible structures, and seeks to develop novel applications, more holistic solutions, and new business models in co-creative collaboration and innovation processes. In short, this strategy aims at radical innovations. This entails an

Table 1. Two ideal types of collaboration strategies

Dimension	Type A Strategy A collaboration strategy to learn from existing stock of knowledge	Type B Strategy A collaboration strategy to create new knowledge
Perspective on innovation	Linear and in terms of technology readiness	Non-linear and complex
Motivation for cooperative R&D&I	Lacking expertise and resources	Develop networks, identify new trends, and create strategic value
Timeframe for cooperative R&D&I	Short-term and medium-term	Long-term
Forms of collaboration	Contract research	Various more open modes of collaboration (e.g., joint projects and strategic partnerships)
Outcome of cooperative R&D&I	Incremental innovation	Radical innovation

acceptance of uncertainty and the pursuit of entirely new knowledge, partners, and ideas. Last but not least, type B entails seeking new and more flexible modes of collaboration beyond (lengthy) contract research or joint research projects. This may take the form of collaborative endeavours without pre-defined results, or strategic and long-term yet flexible and dynamic partnerships that accommodate uncertainty.

Conclusion

In this article, we investigated how companies collaborate with research organizations within a dynamic innovation ecosystem. To this end, we focused on microelectronics and photonics in Germany as examples of knowledge- and research-intensive industries in which digitalization plays a significant role. We explored whether and to what extent companies develop different and new strategies for collaborating with research institutions within innovation ecosystems, on the basis of which we identified two ideal types of strategies. Ideal type A is based on interactive learning from external stocks of knowledge, aiming towards obtaining specific knowledge in order to further develop a particular technology or product, thus at incremental innovation. Ideal type B seeks to create new knowledge and thus to harness the new and full potential of innovation ecosystems. Accordingly, type B embraces complexity and uncertainty, entails looking for new and innovative collaborators, and favours open, flexible, and long-term modes of collaboration

Our study contributes to the conceptual debate on innovation ecosystems by providing empirical insights on how companies and research organizations collaborate in new non-linear and interdependent innovation ecosystems, as identified by Adner and Kapoor (2010) as well as to debates about strategies in innovation ecosystems (Pellikka & Ali-Vehmas, 2016). Focusing on collaboration strategies, we took analytical concepts developed for national and regional innovation systems (Asheim & Coenen, 2005; Lundvall, 2007) to analyze reflexive learning activities of companies in innovation ecosystems. Collaboration comprises both learning from existing knowledge and the creation of new knowledge to achieve competitiveness (Asheim & Coenen, 2005). Based on this understanding, we developed a definition of collaboration strategies in innovation ecosystems as instruments to facilitate the creation, exchange, and transfer of knowledge in dynamic ecosystems with the aim to develop unique competencies and resources in order to foster competitiveness. Our study reveals that companies adopt different collaborative strategies within innovation ecosystems, aiming at radical as well as incremental innovations. Thus, in contrast to Asheim and Coenen (2005), we were able to show that, in high-tech industries, collaboration strategies are based on either learning from existing stock of knowledge or on creating new knowledge. Taking this diversity into account is helpful in further empirically refining the theoretical concept of innovation ecosystems.

On a more practical level, our study carries a number of implications. Our study highlights the importance for companies of developing appropriate strategies for collaboration with research organizations as the importance of collaboration is strongly increasing. This includes the clear definition of a goal for the collaboration, the systematic search and selection of the partner, and the development and design of a suitable collaboration format. One interesting tool here is, for example, the "University Partnership Canvas", which helps business executives to develop a strategic perspective on such collaborations (Frølund et al., 2018). In particular, our study reveals that the development of long-term, strategic partnerships can be of particularly high added value for companies, although the initiation phase to establish such partnerships can be more complex. Finally, three overarching trends have important implications for the development of corporate collaboration strategies:

1. The growing diversity of players requires not only a careful selection of partners, but also one's own strategic positioning in the innovation ecosystem.

2. Non-linear, dynamic value chains also enable new research partnerships. Here, the development of new collaboration formats is key.

3. Innovation ecosystems provide space for interdisciplinary and cross-sectoral collaboration. This requires not only understanding and appropriate communication channels, but also the creation of internal adoption capacities.

Our research suggests that companies develop a variety of collaboration strategies in response to innovation ecosystems. However, while some companies within innovation ecosystems embrace the new potential of co-creative and dynamic interaction, others continue to employ more linear strategies. At least in the case of the German microelectronics and photonics industries, the two types of strategy currently seem to be equally successful.

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