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Strategies for cooperation between companies and research organisations in innovation ecosystems - A case study of the German microelectronics and photonics industries

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Abstract: In this paper, we investigate how companies operating in innovation ecosystems address the challenge of integrating the dimensions of knowledge and business into innovation ecosystems. We focus on microelectronics and photonics in Germany as examples of knowledge- and research-intensive industries in which digitisation plays a significant role. In particular, we analyse the cooperation between companies and research organisations. We explore whether and to what extent companies develop different and new strategies for cooperating with research institutions within innovation ecosystems, on the basis of which we identify two ideal types of strategies. While ideal type A is mostly conventional and traditional, aiming towards obtaining specific knowledge in order to further develop a particular technology or product, ideal type B seeks to harness the new and full potential of innovation ecosystems.

Keywords: innovation ecosystem; cooperation, research organisation; photonics; microelectronics; innovation ecosystem strategies; knowledge ecosystem; business ecosystem; research, development and innovation

1 Introduction

The development of new technologies is extremely knowledge-intensive and entails new challenges, particularly with respect to the generation and diffusion of knowledge: knowledge generation is becoming highly dynamic and characterised by short innovation cycles. So-called Mode-3 knowledge production (Campbell and Carayannis, 2006; Carayannis and Campbell, 2009; Carayannis *et al.*, 2012) poses particular challenges to companies in terms of innovation. Mode-3 knowledge production involves the capacity to combine diverse knowledge and innovation perspectives, and to integrate the different knowledge production dynamics of a variety of actors. Mode-3 knowledge production, diffusion and use happen in innovation ecosystems in which actors co-evolve, co-specialise and simultaneously cooperate and compete. For companies involved in innovation ecosystems, 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 organisations, including research institutes and other companies. This is particularly true for companies in knowledge-intensive industries that have seen an increase in close cooperation between the academic and business sectors (Dolata, 2016).

Digitisation amplifies the challenges posed by this new mode of knowledge production (Brynjolfsson and McAfee, 2012). By facilitating free access to information in innovation systems, digitisation accelerates innovation cycles, changes established research, development and innovation (R&D&I) networks, substitutes traditional value chains with new business models, and changes traditional innovation strategies (European Commission, 2013).

Two examples of knowledge-intensive fields that have seen an increase in cooperation between different actors, are the German photonics and microelectronics industries. Companies in these industries spend about ten percent of their revenue on research and development (R&D) (VDI, 2016). Both industries provide key enabling technologies for digitalisation 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). Focussing on companies and innovation ecosystems within the photonics and microelectronic industries, in this paper we look at how these companies deal with the challenges brought on by new modes of knowledge production and use in innovation ecosystems, and with the rising challenge of digitalisation.

The paper is structured as follows. First, we review the existing literature on innovation ecosystems, concentrating in particular on the tension which arises at the intersection of knowledge and business. Next, we provide a short overview of our methodological approach. This is followed by a description of our empirical findings, wherein we identify and analyse factors that motivate companies to seek the cooperation of research institutions, their criteria for choosing potential collaborators, common modes of cooperation, and lastly, factors that promote or prevent cooperation. In the fourth part of the paper, we present two ideal types of the strategies companies employ to deal with the challenges of cooperation within innovation ecosystems. Finally, we discuss our findings within the theoretical context of innovation ecosystems.

2 Cooperation of knowledge and business actors in innovation ecosystems

R&D&I increasingly happens not only within organisational boundaries, but also in collaboration between different organisations. Thus, the term "innovation ecosystem" is used in Innovation Studies to describe the dynamic and co-productive space in which industrial R&D&I takes place, and to highlight both interdependencies between organisations and the co-evolution of value (Adner and Kapoor, 2010; Autio and Thomas, 2014). Within innovation ecosystems, companies do not innovate individually, but rather depend on the resources and know-how of other organisations (Adner and Kapoor, 2010). In contrast to other concepts, such as clusters and innovation networks, this notion encapsulates a wide range of organisations, 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 (Autio and Thomas, 2014). This includes investors, marketing agencies and even knowledge providers; any and all actors, in fact, "that [specialise] in the development, discovery, delivery, and deployment of evolving applications" (Autio and Thomas, 2014).

Innovation ecosystems thus overlap with business and knowledge ecosystems (Valkokari, 2015; Clarysse *et al.*, 2014; Jackson, 2011; Etzkowitz and Leydesdorff, 2000). The former consist mainly of research organisations and universities concerned with creating knowledge; the latter of companies concerned with creating value. These two sets of actors have different resources, approaches, goals and incentives (Jackson, 2011; Valkokari, 2015). These must in turn be accommodated and integrated in flourishing and successful innovation ecosystems, in which companies and research organisations innovate interdependently (Jackson, 2011; Etzkowitz and Leydesdorff, 2000) – which entails a new set of challenges and risks.

Against this backdrop, we are particularly interested in the interaction of actors at the intersection of knowledge and business within innovation ecosystems, about which little has thus far been written. Most existing studies instead focus on single companies so as to describe and analyse what we would consider business ecosystems, i.e. those concerned with value creation (Valkokari, 2015).

In our paper, we focus on the development and discovery process in innovation ecosystems. We ask, first of all, how companies deal with the challenge of integrating the dimensions of knowledge and business within an innovation ecosystem. Secondly, we ask how new collaboration strategies in innovation ecosystems differ from traditional cooperation strategies. To this end, we identify the factors that motivate companies to seek the cooperation of research institutions, we look at how said cooperation is usually initiated, we examine common types and means of cooperation, and finally, identify both success factors and barriers to cooperation – thus contributing empirical insights into the evolvement of innovation ecosystems.

3 Methodology

In addressing our research questions, we analysed how companies interact with research organisations – which we take to be the relevant knowledge providers in innovation ecosystems – during collaborative R&D&I. To this end, we focussed on the research-intensive German microelectronics and photonics industries, looking in particular at what companies perceive as challenges, motivating factors, advantages, and barriers to cooperation. 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 organisations. The interviews took 60 – 120 minutes each. We analysed the interviews using both in vivo codes and a codebook, in order to distinguish ideal types (Weber, 1904) of the strategies companies deploy in dealing with the challenges of innovation ecosystems. By deriving ideal types from our empirical findings, we were able to identify and highlight certain significant trends in our data.

When analysing 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 cooperation with research organisations plays a central role. Accordingly, we did not differentiate between the two industries in our subsequent analysis, interpretation and presentation of the data.

4 Empirical findings

In order to understand the challenges companies face in dealing with research organisations, we analysed why, how and with whom companies collaborate. To this end, we first investigated the factors that motivate companies to engage in cooperation with research institutions. We then examined the prerequisites for such cooperation, after which we looked at how companies identify potential partners. Next, we distinguished the most common modes of cooperation. Finally, we identified the most significant factors that promote or impede cooperation. Together, these observations provide a clearer understanding of how companies interact with research organisations, so as to facilitate the integration of the dimensions of business and knowledge, and so as to establish innovation ecosystems.

Innovation ecosystems in Germany's microelectronics and photonics industries

As research-intensive industries, German microelectronics and photonics are both characterised by close and sustained cooperation between research organisations and companies. Below we describe the factors that motivate companies to enter into cooperation with research institutions, the processes for initiating said cooperation, particular modes of cooperation and, finally, success factors and barriers to cooperation.

Most respondents described R&D as a cooperative process involving multiple partners or advancing joint projects. It is only in very rare cases that most of the work is being done internally.
Depending on the phase of the innovation process – be it needs assessment, analysis, development or testing – different external sources of knowledge are used. During the initial stage of R&D, companies usually collaborate with publicly funded research institutions, whereas in later development phases they primarily tend to cooperate with other companies or contract research organisations. Furthermore, according to our respondents, customers and users are seen as driving forces for new developments and are thus involved at an early stage of the innovation process. By virtue of these significant and diverse forms of cooperation, the German microelectronics and photonics industries both display highly developed innovation ecosystems. Large companies, SMEs and startups cooperate with universities and non-university research institutions in a variety of ways both formal and informal in these usually local systems.

> "All I can say is that it is common in the industry for there to be close cooperation between companies and research institutions." (Industry expert)

In addition to these local ecosystems, there are organisations and associations in both microelectronics and photonics that represent the interests of the industry in question and establish cross-cutting or national networks. These networks in turn coordinate and carry out activities such as joint applications for research funding and the promotion of pre-competitive research.

> "So, essentially, we collaborate with research institutions and universities on quite a few projects, and we also work together quite a lot in publicly funded consortia." (Large corporation, photonics)

Motivating factors

In this section, we describe the reasons respondents cited for engaging in cooperation with research organisations. This helps reveal the underlying incentive structures for cooperation – and thus for the establishment of innovation ecosystems. Respondents identified the following motivating factors.

- Environment and market:

As both industries are continually evolving through technical innovation, companies are constantly confronted with new challenges. Through cooperation 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.

- 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)

- Complementary competences and infrastructures:

Through cooperation with research organisations, 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, cooperation entails access to the infrastructure of partner organisations: thus companies in the photonics industry, for example, regularly use the facilities and equipment of research organisations.

- Networking:

In addition to the primary benefit of access to new knowledge and technologies, cooperation with research organisations also holds significant secondary benefits for companies. Said cooperation can help companies expand their professional networks and gain access to potential customers. Companies can also capitalise 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, photonics)

To summarise, the above analysis reveals different reasons for companies to cooperate with research organisations. 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 and Ali-Vehmas, 2016). These differing motivations are indicative of different cooperation strategies, and hence diverging perspectives on innovation ecosystems.

Prerequisites for cooperation

The next step in our research was to examine the background conditions that affect how companies approach cooperation – in particular how they identify potential collaborators. An awareness of these factors enables us to analyse how partnerships between companies and research organisations in innovation ecosystems are initiated. Our study revealed three relevant sets of criteria for collaboration with a particular research establishment.

- 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.

- 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 which allow for the bilateral exchange of complementary knowledge and skills without the risk of direct competition with the partner organisation.

- Social criteria

Though less tangible and harder to measure than the above two sets of criteria, companies strongly emphasise 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, microelectronics)

Companies accordingly prefer to enter into cooperation with organisations 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. Firstly, these networks constitute companies' primary source of contacts and recommendations. Secondly, 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 organisations and companies interact. Fairs, congresses, business meetings, conferences and networking events all provide spaces for regular exchange – on both a professional and formal, and a personal and informal basis.

> "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, microelectronics)

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

Modes of cooperation

We now come to an examination of the ways in which companies and research organisations collaborate. These include both established practices and newly emerging forms of cooperation that are still partly undefined. The exact modes of cooperation companies choose are indicative of their respective perspectives on innovation and general cooperation strategies, and can to a greater or lesser extent result in the formation of innovation ecosystems.

In general, companies look for modes of cooperation 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 cooperation 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, microelectronics)

Companies also often recruit new employees from the staff of their partnered research organisations (or vice versa, in exceptional cases). In addition to formalised and regulated practices, companies also engage in many types of less formalised, short-term cooperation 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 organisations, 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".

The establishment of successful partnerships is often said to depend on personal networks, which can be fostered through spatial proximity (e.g. shared canteens or neighbouring addresses) and industry-specific events that are attended by representatives of both research institutions and companies.

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

Success factors and barriers to cooperation

Finally, in our study we identified factors that foster or impede cooperation between companies and research organisations – and by extension, either foster or impede (or even prevent) the establishment of productive innovation ecosystems.

Firstly, companies are drawn to cooperation with research organisations, 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. Secondly, companies stand to benefit by gaining access to expertise and research infrastructure. Finally, cooperation with research institutions affords companies access to potential new employees.

On the other hand, respondents in our study noted particular disadvantages to cooperation 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 for 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 organisation 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 and the establishment of innovation ecosystems. On the other hand, problems associated with IP and intricate negotiations can hamper cooperation and the development of productive innovation ecosystems. In light of this, companies adopt different strategies – so as to address the challenges of cooperation, and in order to capitalise on the advantages of innovation ecosystems. In the next section, we reduce these strategies to two ideal types.

5 Discussion: towards ideal-typical cooperation strategies

The empirical findings presented above paint a rather diverse picture of why, how and with whom companies in German microelectronics and photonics collaborate, as well as what they perceive to be the main advantages of and barriers to successful collaboration. Nevertheless, within this diversity two distinct ideal-typical innovation and cooperation strategies can be identified.

Type A is characterised by an understanding of the innovation process as specialised and fragmented. Here, the company predefines the problems to be addressed through cooperation, and the solutions that are expected. This limits research organisations to being suppliers of knowledge and expertise in the early stages of the innovation process. The underlying model of innovation is based on a linear understanding of innovation processes in terms of technology readiness levels. The motivation for cooperation stems from lacking expertise and resources. Accordingly, potential partners are identified on the basis of relevant expertise. Cooperation is restricted to the short to medium term; the preferred modes of cooperation being contract research and joint target-oriented research projects. The outcome is a market-ready product. Finally, changes tend to be met with a (pre)defined response.

In contrast to the above, type B is characterised by an understanding of innovation processes in terms of ecosystems, in which innovation results from open, interactive and transdisciplinary activities. Relationships between companies and research organisations are complex and open, and problems and expected solutions are not necessarily defined beforehand. Here, the underlying model of innovation and value creation processes is non-linear and complex. Motivation for cooperation results from the high significance ascribed to networks, and the wish not to miss but rather benefit from new trends. Accordingly, potential partners are identified on the basis of their innovative potential and their strategic value. Cooperation tends to be long-term, open and flexible; preferred modes of cooperation include joint research and strategic partnerships. Outcomes of cooperation are likewise flexible and not strictly defined. Finally, changes are met with openness, so as to harness new developments.

Two ideal types of innovation and cooperation strategies

	Type A	**Type B**
Innovation and value creation model	Linear and in terms of technology readiness level	Non-linear and complex
Motivation for cooperative R&D&I	Lacking expertise and resources	Networks and new trends
Identification of potential collaborators	Provider of expertise	High innovative potential; strategic value
Time frame for cooperative R&D&I	Short- and medium-term	Long-term
Forms of cooperation	Contract research	Various more open modes of collaboration, e.g. joint projects and strategic partnerships
Outcome of cooperative R&D&I	Market-ready product	Open and varied

Type A represents a more traditional and conventional perspective on cooperation, whereas type B represents cooperation strategies based on an innovation ecosystem-approach. As type A is based on the assumption of linear innovation processes, 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, cooperation is seen as a means to reduce or outsource risk, and to get answers to pre-defined questions and problems following a traditional value chain model. In contrast to this, type B recognises the complexity of current innovation ecosystems and seeks to harness the potential of diverse and new actors in dynamic relationships. It embraces

more open and flexible structures and seeks to develop novel applications, more holistic solutions and new business models in co-creative cooperation and innovation processes. This entails an acceptance of uncertainty and the pursuit of entirely new knowledge, partners and ideas. An ideal-typical innovation ecosystem-based view thus takes into account that value creation is being re-engineered, and that this carries significant implications for cooperation. Last but not least, type B entails seeking new and more flexible modes of cooperation beyond (lengthy) contract research or joint research projects. This may take the form of cooperation within a very limited time frame, collaborative endeavours without pre-defined results, or strategic and long-term yet flexible and dynamic partnerships that accommodate uncertainty.

In the photonics and microelectronics industries in Germany, companies can be seen to employ strategies corresponding to both of the above ideal types. It is important to investigate how companies following such disparate strategies can co-exist, and perhaps even co-operate, within the same industry – yet this must form the subject of future research.

6 Conclusion

In this paper, we investigated how companies operating in innovation ecosystems address the challenge of integrating new and diverse actors within a dynamic and evolving environment. To this end, we focussed on microelectronics and photonics in Germany as examples of knowledge- and research-intensive industries in which digitisation plays a significant role. Integrating the dimensions of knowledge and business into innovation ecosystems is of crucial importance and presents its own set of challenges. Accordingly, our examination of the interaction of different actors in innovation ecosystems focussed in particular on cooperation between companies and research organisations. We explored whether and to what extent companies develop different and new strategies for cooperating with research institutions within innovation ecosystems, on the basis of which we identified two ideal types of strategies. While ideal type A is mostly conventional and traditional, aiming towards obtaining specific knowledge in order to further develop a particular technology or product, ideal type B seeks 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 cooperation. It is interesting to note that some companies follow a cooperation strategy based on a conventional linear model of innovation processes, despite operating within a complex, dynamic and evolving co-creative innovation ecosystem. Future research might track the long-term development of such strategies within specific industries, and look at how these strategies relate to the advantages and challenges of innovation ecosystems.

Our study contributes to the conceptual debate on innovation ecosystems by providing empirical insights on how companies and research organisations cooperate in new non-linear and interdependent innovation ecosystems, as identified by e.g. Carayannis and Campbell (2009). It also reveals that companies adopt different cooperative strategies within innovation ecosystems. This in turn is helpful in further empirically refining the theoretical concept of innovation ecosystems. On a more practical level, our study carries a number of implications – and not only for companies. If they are to continue to meet the

needs of companies following different and sometimes new strategies, research organisations, for example, must likewise adapt their strategies. Furthermore, research-funding bodies need to provide support for a greater variety of open and flexible forms of cooperation.

Our research suggests that companies develop a variety of cooperation and innovation strategies in response to emerging 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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