TECHNOLOGY TRANSFER AND ABSORPTIVE CAPACITY – PROCESSUAL INSIGHTS FROM FOUR CASES IN OPTICS IN THE U.S. AND GERMANY

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ABSTRACT

Previous studies informed by the concept of absorptive capacity predominantly laid emphasis upon static aspects and for the most part utilized quantitative methods. In contrast, the present comparative case study takes the processual nature of the phenomenon into account. Based upon findings from four case studies in the optics industry in the U.S. and Germany we contribute to the literature by elucidating how technology transfer between research institutions and private sector companies is organized. We highlight the absorption processes involved, the role of meeting management and information exchange practices that are moderated by boundary spanners and power relationships, the institutional and regional embeddedness of actors involved, as well as social factors that serve as a 'glue' for absorptive capacity.

Keywords: absorptive capacity; technology transfer; process perspective; comparative case study; optics industry

Studies devoted to the concept of *absorptive capacity* have gained *increasing attention* in the last number of years (e.g., Easterby-Smith et al., 2008; Jones, 2006; Jones & Craven, 2001; Kim, 1998; Lichtenthaler, 2009; Todorova & Durisin, 2007; Yeoh, 2009; Zahra & George, 2002), making it almost a taken for granted concept (Lane et al., 2006). This is hardly surprising as it addresses a highly relevant aspect of organizational activities by focusing upon a firms' ability to sense their information environment, to recognize new technological opportunities and to capture and integrate new information and knowledge into the firms' processes and routines with the subsequent aim and result of increased competitive advantage (Lane et al., 2001). Therefore, in environments of rapid technological change companies try to stay ahead in the competitive race by innovating. A company's intellectual capital represents the main sustainable source of competitive advantage and the ability to learn is, therefore, a key success factor (Yoeh 2009, 30).

Given the broad diffusion of the concept, the limited and incoherent development of the concept is rather surprising (Lane et al., 2006). However a number of recent refinements to the seminal work of Cohen and Levinthal have to be noted (e.g., Todorova & Durisin, 2007; van den Bosch et al., 1999; Zahra & George, 2002). Nevertheless, only few studies have addressed the theme of *absorptive capacity from a process perspective* (Easterby-Smith et al., 2008; Jones, 2006; Jones & Craven, 2001; Kim, 1998 for notable exceptions). In empirical work most of the time absorptive capacity is analyzed in quantitative terms and is measured via input, output or perception measures applying multivariate analyses (cf. Lichtenthaler, 2009 for an illustration). One critical shortcoming in this connection is the scarce attention to the processual aspects of absorptive capacity by employing *qualitative research methods* (Easterby-Smith et al., 2008).

Therefore, we call for a context sensitive approach supported by means of qualitative methods to elucidate the way knowledge is recognized, evaluated, integrated and exploited by organizations. We deem this to be a critical research void insofar as it are likely to be these very processes – for instance, organizational practices – that are vital to comprehend in order to start becoming able to actually ‘manage’ absorptive capacity.

Against the background of the absorptive capacity framework, this study is guided by the following research question:

> *Which organizational practices and environmental factors do private and public sector actors need to consider in their technology transfer activities in order to manage their absorptive capacity?*

We address this research gap by means of a *comparative case study* in the optics industry in the U.S. and Germany where *technology transfer* between research institutions and private sector corporations is critical. As no single company possesses all the necessary information and knowledge in complex high technological fields, in such settings one possible avenue to learn is knowledge and technology transfer between companies and research institutions. Therefore, the extent and intensity of industry-science relationships is regarded to be an important factor contributing to high innovation performance at the firm-level as well as the industry-level (OECD, 2002). Bearing this in mind, technology transfer activities appear to be particularly well suited for the analysis of absorptive capacity as previous research also pointed out that private sector corporations are not able to transfer and exploit knowledge in the course of their collaboration with partners from academia (Kodama, 2008). One of the main reasons for this observation is the fear of losing know-how from joint research activities, as scientist from academia are primarily eager to publish their findings, whereas the private sector partners are looking forward to secure their competitive advantage in terms of profiting from first-mover advantages. Hence private firms and research universities have profoundly different missions and often display mutual distrust (Slaughter & Leslie, 1997). The optics industry as our research setting is prone for this research in particular as intensive knowledge and technology transfer activities between companies and between research institutions and companies is extraordinarily high.

The *remainder of this paper* is structured as follows: First we introduce the theme of technology transfer by highlighting the problems when it comes to an exchange between industry and academia, as each arena disposes of different incentives. In addition, we briefly review the literature on absorptive capacity, pointing out the adequacy and lack of qualitative approaches to elucidate process phenomena related to absorptive capacity. Second, we elaborate upon our comparative case study design and the research setting, targeting four examples of technology transfer activities between research institutes and private sector corporations in the U.S. and Germany. We discuss the theoretical implications of our findings by refining existing static notions on absorptive capacity by offering processual attributes and the need for an embeddedness perspective concerning the respective institutional and regional environment. Furthermore, we explicate upon the managerial implications for actors engaged in technology transfer activities, in particular the need to engage in boundary spanning activities, creating and sustaining a common knowledge base and dealing with power relationships. We conclude by means of a summary of our main findings, a critical reflection and outlook for future research endeavors.

TECHNOLOGY TRANSFER AND ABSORPTIVE CAPACITY

Technology Transfer Concerning Critical Knowledge

In the applied economics and economic policy literature the interaction of the business sector with science institutions through knowledge and technology exchange has been discussed for about three decades and a number of technology transfer concepts have been developed (for an overview and examples see Journal of Technology Transfer 24 (2/3), Research Policy 34 (7), 37 (8), Management Science 48 (1), International Journal of Industrial Organization 21 (9), International Journal of Technology Transfer and Commercialisation 8 (2/3)). Knowledge and technology transfer between academia and industry can be defined as „any activities aimed at transferring knowledge or technology that may help either the company or the academic institute – depending on the direction of transfer – to further pursue its activities“ (Arvanitis et al., 2008: 1866 following Dosi, 1982). Following the „Bayh-Dole Act“ in the U.S. in 1981 universities were assigned the intellectual property rights of their publicly funded research results. As a consequences technology transfer offices were installed to harvest the IP for the universities and the number of university patents increased considerably in numbers (Carlsson & Fridh, 2002: 200; see also Mowery et al., 2002).

Technology transfer most likely encompasses many different types of transactions between research institutes and companies and different types of transactions occur sequentially to reinforce the transfer of knowledge and technology. These may include in the case of involvement of financial resources third party financed research, licensing, spin-off companies and the hiring of students, graduates, and researchers and in the case of absence of financial resources publications, presentations, informal exchange, other spill-overs and serendipity. However, the commercialization of research results and the transfer of knowledge and technology is not a trivial pursuit at all. The main reasons for this difficulty can be found in the different backgrounds and social settings of researchers and company representatives. Each group normally has experienced a different socialization and is confronted with a fundamentally different incentive system (Bercovitz & Feldman, 2006).

Polt et al. (2001) identify a number of incentives and barriers for science and industry relations. The incentives for researchers to engage in such relations can be found in the search for alternative sources of funding, the prospective income for researchers from licensing and in better labor market opportunities for graduates and for companies in the access to new knowledge, in access to R&D resources and infrastructures, opportunities for opening-up new business fields, and in the recruitment of R&D personnel. Both sides equally may profit from cross learning, personnel mobility, exchange of knowledge and experience, knowledge network externalities and synergies. In the literature on science and industry relations a number of barriers have been identified too. On the science sector side these include the lack of qualified personnel necessary for handling the interaction, bureaucratic structures and decision procedures as well as the involved high cost of interaction, contracting, licensing, etc. Both sectors experience information asymmetries and low market transparency, different cultures and incompatible objectives, high transaction cost, uncertainty of the outcome and potentially large and unwanted spillovers. On the industry side the identified barriers in knowledge and technology transfer interactions include risk averse behavior, the lack of qualified personnel, the fear of loosing confidential knowledge and a lack of knowledge absorption capacities (see also Graff et al., 2002).

One of the main barriers in knowledge and technology transfer between organizations is already knowledge itself which is often implicit, complex and difficult to grasp (Simonin, 1999: 598). Explicit knowledge is formal, codifiable and systematically transferable. Implicit knowledge in contrast is difficult or not at all to codify or to communicate and is most often gained through experience (Polanyi, 1966: 24). A possible way to transfer such knowledge is by embedding it in technologies so that it becomes more explicit and possible to communicate (Argote & Ingram, 2000: 158). However, even though most of the knowledge transfer between organizations is based on informal and personal contacts, the receiving organization needs to be capable to integrate and apply this knowledge (Heppner, 1997: 345).

From a conceptual perspective on the one hand internal processes in organizations need to be analysed and on the other hand there is a need to account for the interfaces into the organizational environment. The concept of absorptive capacity primarily focuses on the organizational level. However the concept is open to a relative (Lane & Lubatkin, 1998) and even a relational amelioration as well as a dynamic perspective (Zahra & George, 2002; Tororova & Durisin, 2007). In general the concept of absorptive capacity appears to be applicable to the knowledge and technology transfer arena, its processes and parameters (Kodama, 2008). The role of absorptive capacity in the receiving organizations has been studied before (e.g. García-Morales et al., 2007; Gupta & Govindarajan, 2000; Lane & Lubatkin, 1998; Szulanski, 1996) and has been identified to be one of the most important determinants in knowledge transfer (e.g. Yoeh, 2009: 23).

The Concept of Absorptive Capacity – Origins and Refinements

The term absorptive capacity was introduced by Cohen and Levinthal (1989, 1990, 1994) to describe firm requisite capabilities to innovate. The authors develop the concept starting with an industrial economic explanation and empirically testing their assumptions. Hereby, Cohen and Levinthal define absorptive capacity as the ability „to recognize the value of new, external knowledge, assimilate it, and apply it to commercial ends“ (1990: 128). The authors argue that the "ability to evaluate and utilize outside knowledge is largely a function of the level of prior related knowledge“ (Cohen & Levinthal, 1990: 128) and a byproduct of the companies R&D activities. Hence, the absorptive capacity can be related to the cognitive structures that are the basis for learning processes. In order to integrate external knowledge the company needs to have a certain level of prior knowledge. Here the potential to learn is the highest if new knowledge that needs to be assimilated is closely related to the prior knowledge base (Lane & Lubatkin 1998: 463; for the individual level see already Ellis, 1965).

Absorptive capacity is furthermore moderated by regimes of appropriability. Cohen and Levinthal (1990) as well as Zahra and George (2002) argue that the environment of a firm has a moderating effect on its incentive to invest in absorptive capacity. They argue that weak regimes, competitive spillovers, the efficacy of IP-rights and the ease of replication have a distinctive impact upon the firm's incentive to invest.

In the end absorptive capacity is assumed to influence the innovative performance of the firm due to two features suggested by the basic role of prior knowledge – domain specificity and path-dependency. Those features are expressed by the ease to accumulate absorptive capacity in an area where the company already has developed some knowledge, because its possession helps to identify additional related knowledge (Cohen & Levinthal 1990: 136).

For the purposes of this study we consider organizational practices of valuing, assimilating and applying external knowledge but also newer concepts like boundary spanning, power relationships, social integration mechanisms, and regulating. *Boundary spanning* (Bengtsson & Söderholm, 2002; Tushman & Scanlan, 1981) is important for the absorptive capacity of an organization as it allows to access knowledge outside the company, bridging information among organization internal and external members (Jones, 2006: 359; Easterby-Smith et al., 2008: 498; Todorova & Durisin, 2007: 780; Zahra & George, 2002: 194). Although Siegel et alii (2003) do not revert to the concept of absorptive capacity, they highlight the role of such boundary spanning in the case of technology transfer offices at universities. The findings suggest that the offices' activities are deemed to establish contacts and strengthening existing ties among actors, culminating in an improved knowledge flow between the various actors involved.

Furthermore, Todorova and Durisin (2007) refine the absorptive capacity concept by introducing *power relationships*, defined as activities shaped by internal and/or external actors who pursue their own objectives and at the same time dispose of a necessary influence regarding the (non-)absorption of knowledge. Easterby-Smith and colleagues underscore this aspect likewise when they relate to political issues that pervade the daily activities in the three companies they analyzed (Easterby-Smith et al., 2008: 495).

Social integration mechanisms consist of social structures that foster the acquisition and dissemination of knowledge within an organization (Zahra & George, 2002: 194). Hereby we share the claim of Todorova and Durisin (2007: 780) who refine this aspect when they argue that these very mechanisms might not only be positive, that is, they might have counterproductive effects. For instance, existing ties of powerful individuals might lower the absorptive capacity as knowledge flows are restricted by being dependent upon the benevolence of these individuals. The work of Granovetter is relevant with regard to his concept of embeddedness (Granovetter, 1985), referring to the assumption that actors are not rational and independent in their behavior, but always anchored in existing social relationships and institutional as well as regional contexts. Herein a parallel can also be drawn to previous absorptive capacity research that stresses the relative nature of the concept, i.e., the interrelatedness between organizations in their pursuit of identifying, acquiring and utilizing novel knowledge (Dyer & Singh, 1998; Lane & Lubatkin, 1998). This aspect is also inherent in the refinement of Van den Bosch and colleagues (1999) when they revert to Cohen and Levinthal by calling for a path dependent comprehension of absorptive capacity, that is, acknowledging expectation formation as a crucial element for a refined understanding of the way absorptive capacity evolves.

Moreover, *regulative practices* are essential to consider, as they moderate the nature of how technology transfer activities actually take place. We comprehend practices per se in line with Giddens (1976; 1984) as being represented by ordered, recurring social activities that are stable in time-space. The term regulative is supposed to highlight the nature of the legal and institutional context the respective organizations are operating in. Todorova and Durisin (2007) revert in their conception of absorptive capacity to Cohen and Levinthal (1990) when they refer to *regimes of appropriability* as the extent to which organizations can protect their innovativeness by means of patents, trademarks etc. They presume that this is a crucial factor for the decision to which extent an organization engages with external actors, such as participating in joint ventures, alliances, mergers and acquisitions and the like. For instance, a strict regime of appropriability might entice organizations to engage in mutual exchanges as their critical know-how is safeguarded against opportunistic behaviour of the respective counterpart(s).

In a comprehensive literature review Lane et al. (2006) analyzed about 900 peer-reviewed publications in which the absorptive capacity construct had been used. Despite the large number of studies, there are only few studies that attempt to modify or broaden the concept. The analysis of 289 peer reviewed articles revealed that only 22% of these articles made more than fleeting references to the absorptive capacity concept. The attempt to refine or broaden the concept was only pursued by four articles (1.4%). As a result, Lane et alii argue that the absorptive capacity concept has become a ‘taken for granted’ concept, which is not subject to closer scrutiny anymore (cf. also Easterby-Smith et al., 2008: 484). Moreover, their analysis elucidates that only few publications are actually cited in the discourse, which might be indicative of a weak cumulative progress in the field. Easterby-Smith and colleagues (2008: 485) argue that the reason for slow progress can be traced back to the dominance of quantitative approaches, which are rather geared towards theory testing than refining or broadening the notion of absorptive capacity theory development. Moreover, Lane et al. (2006: 856) argue that “focussing on processes[s] is critical in order to move away from the structure/content assumption of prior research, as well as to extend it beyond the R&D context”, which might help to rejuvenate the concept.

To date only very few studies have taken a process perspective on absorptive capacity, have focused on managerial agency and have described how an organization’s absorptive capacity actually works (see table 1 for notable exceptions).

Table 1 about here

In a process perspective we propose to focus on “key social actors” (Geppert & Clark, 2003: 433) within and outside the organization and how they are involved in valuing, assimilating and applying external knowledge. We further propose to center the analytical attention on “boundary spanners” and “gate keepers” and to analyze the power laden “practices which constitute the day-to-day activities of organizational life” (Johnson et al., 2003: 3) since domination practices of internal and external actors may influence allocation processes fostering or hindering the recognition and exploitation of new knowledge. A process perspective also needs to consider the social integration mechanisms that foster connectivity between actors and that build shared meanings among actors because these mechanisms influence the processes and social interactions of technology transfer and knowledge absorption (Todorova & Durisin, 2007). Regulative practices are of equal importance and offer an opportunity to study not only the influence regulation has on the absorption of knowledge but also the recursive influence of power, social integration mechanisms and regulation.

RESEARCH SETTING

We focus in our analysis upon optical technologies, which is used here as a synonym for optics, opto-electronics and photonics. It has been observed that actors in this technology cluster spatially around academic centers of excellence (Hassink & Wood, 1998; Holton, 2000; Sydow et al. 2007). Due to its often multi-disciplinary technologies and innovative products, its high R&D rates and rapid growth, it appears to be an adequate setting for studying technology transfer activities against the background of the absorptive capacity framework.

There is no standard definition for the field of optical technologies and current industrial categories and patent classes are of only limited use (Feldman & Lendel, 2010). A currently widely used definition of optical technologies has been provided by the U.S. National Research Council (1998, 5) as the ‘field of science and engineering encompassing the physical phenomena and technologies associated with the generation, transmission, manipulation, detection, and utilization of light.’ Moreover this scientific and industrial field can be described by its wide range of high-technology applications, products and intermediate markets like telecommunication equipment, material processing and analysis, scientific instruments and medical devices, imaging, reproduction and lighting, defense and security (see for example Hassink & Wood, 1998) – to name just a few. Insofar optics shows characteristics of a general purpose technology (Kodama, 1992).

Optical technologies are also termed ‘enabling-technology’ to stress the importance as a basis for further technological developments and applications in different industries (U.S. National Research Council, 1998: 6; Frietsch & Grupp, 2002: 1). Therefore this high technology not only constitutes as an innovation driver for those future markets but rather safeguard a high amount of jobs (Heybrock & Brinkmann, 2000: 1).

The economical impact of the industry also results from the worldwide market volume which amounted to $ 120 bn in 2005. Industry experts expect duplication until 2015 (Spectaris 2006). Germany and the U.S. are two of the four main regions in the world optics industry, the others being Japan and UK (Hendry et al., 1999; Hendry et al., 2000).

According to a current industry study (Optech Consulting, 2007a) the production volume in optical technologies in Germany was € 16.3 bn in 2005. In the U.S. the production volume in optical technologies was estimated to amount to € 34.2 bn (Optech Consulting, 2007b). The high innovation potential of the optics companies is represented by the above average investment in R&D. The R&D ratio for German optics companies amounted to 10.1 % of sales in 2007 – in terms of employees the ratio was even higher (13.6 %; Optech Consulting, 2007a). For the purpose of a general comparison, this ratio was 4.9 % in the general manufacturing trade (ZEW 2008, 1). The innovativeness of German optics companies is also displayed in the share of sales of innovative products (younger than 3 years) which was 34.7 % in 2007 (Spectaris, 2008, 13). In order to secure this high level of innovativeness optics companies – apart from in-house R&D – heavily invest in interrelationships with the science community.

Based upon a large scale investigation into the way optical technologies are developed in the clusters first of Berlin, later in Tucson/AZ, the ‘Silicon Glen’ (Scotland) and the “midlands” (England) that started in 2001, we concentrate in this study upon a subsample of organizations that are involved in technology transfer activities. In this sense, we reverted to established contacts in the Berlin cluster and identified two cases. Starting from these two cases in the Berlin optics cluster, we subsequently contacted – based upon referrals from our

Berlin key contacts (senior scientists and CEOs) – two organizations involved in similar fields of technology development in two different US clusters. Table 2 gives an overview of the cases.

Table 2 about here

Insofar we have selected two cases from the U.S. and from Germany to allow for a cross country analysis and we have selected two different types of organizations – two firms and two research organizations – to focus our analysis and to include both industry and science perceptions (US – company / research – DE – company / research). In order to gain a more complete picture of the processes involved in the absorption of knowledge in technology transfer, we also value to include research organizations – so far the process literature on absorptive capacity has only focused on firms, their representatives' perspectives and practices involved.

X-Radia is a spin-off company from Stony Brook University in New York established in 2000 and located in Concord, California in the San Francisco Bay Area. The company has specialised in the manufacturing of state of the art x-ray microscopes and generated revenues of $ 16 mio with its 55 employees in 2008. The company that is supplying x-ray analytics to semiconductor companies like Intel, other computer hardware companies and scientific institutions is experiencing rapid growth (50 % p.a.). The company has still very strong ties to the x-ray analytics and x-ray microscopy group at Stony Brook University but also to Argonne National Laboratory, a brilliant x-ray light source in Chicago, Illinois and less but increasing contacts to Berkeley Lab in Berkeley, California.

The Carolinas Photonics Consortium (CPC) is a collaboration of six universities active in the field of photonics and located in North Carolina. Those universities all have strength in different competences and therefore profit from synergy effects. In the previous 5 years the state of North Carolina invested over $ 300 Million into the cluster, making it to the largest concentration of photonics resources in the country (CPC 2009). CPC defines its mission as 'to provide resources and to proactively interface between key stakeholders in the region (universities, companies, economic development, government agencies, and investment groups) to commercialize CPC university photonic technologies' (CPC 2009). Within the CPC we focused on the North Carolina State University, the largest university in the CPC, which is engaged in technology transfer with several local companies.

The Berlin based company Institute for Scientific Instruments (IfG) is an engineering company in selected fields of x-ray optics and x-ray analytics as well as a manufacturer of x-ray components. The company was founded in 1996 by a former leading scientist in x-ray analytics and director of the scientific instruments department of the former Academy of Sciences of East Germany. Today the company still maintains a number of strong ties to local research organizations and companies that were spun-off of the Academy of Sciences when it was terminated in 1991 after German reunification. IfG consists of 16 employees (most of them engineers and scientists) generates revenues of about € 1.6 mio. p.a. The founder and CEO of the company has organized an extended network in the local but world leading x-ray community to transfer latest technologies from Berlin based x-ray research organizations into his and the other companies in his network.

The Berlin based Ferdinand-Braun-Institut für Höchstfrequenztechnik (FBH) is located in the technology park Adlershof and can be seen as a successor institute of the Central Institute of Electron Physics of the former East German Academy of Sciences. The FBH, founded under the new name in 1992, is expanding fast. Cutting-edge technologies in the fields of microwaves and optoelectronics for applications in communications and sensor technology are developed by the now 235 researchers, engineers and administrative staff (FBH, 2008). The FBH produces high-power diode lasers with excellent beam quality for applications in materials processing, medical technology and high precision metrology. For future applications, in e.g. life sciences and space technology, light sources in the blue and ultraviolet spectral range as well as transistors for very high voltages are explored. These developments rely on basic investigations on new III-V semiconductor materials systems like nitrides (FBH, 2006). The FBH is very successfully spinning off companies. The latest optoelectronics spin-offs include eagleyard Photonics (founded in 2001) and JENOPTIK Diode Lab (founded in 2002).

METHODS

Since we attempt to approach the concept of absorptive capacity from a processual stance, we adopt an interpretative research methodology (Lincoln & Guba, 1985) that allows us to capture the technology transfer activities. Therefore, a comparative case study approach was chosen (Yin, 2008), as this allows us to compare across cases and strengthen the validity of our claims when it comes to offering a first step towards a refinement concerning a processual account of absorptive capacity.

Data sources

The empirical research process for this concrete study started in March 2009. In one of the Berlin cases as well as the optics industry in general, however, one of the authors has been involved as a researcher and consultant for more than nine years now (conducting more than 200 interviews and attending numerous meetings, workshops and trade fairs). Apart from an initial data collection for this study in 2009, we made use of *three main sources for triangulation*, which helped us to heighten construct validity and avoid respondent bias:

First, we analyzed a broad range of *secondary sources*, that is, relevant online magazines (for instance, LaserFocusWorld, www.photonik.de, www.photonics.com, www.nature.com/nphoton, www.laser-photonik.de, www.photonicsonline.com), optics industry reports from federal ministries in the U.S. and Germany, and trade fair reports (e.g., www.world-of-photonics.net).

Second, we conducted 20 *semi-structured interviews* (on average: 45 minutes) on- and off-site with respondents from the optics industry private sector corporations (seven), members of research institutes (four), technology transfer organizations (seven) and cluster organization representatives (two). Table 3 offers an overview of the respondents that informed our study.

Table 3 about here

Each interview was geared towards an interview guideline that consisted of a series of open-ended questions, augmented by follow-up and clarifying questions. The interviews were divided into three central themes that aimed to solicit exploratory information about the way technology transfer actually takes place and knowledge is from external sources is absorbed and supplied to other organizations. In particular, the three central themes addressed were: (1) general involvement and barriers in technology transfer activities, (2) role of absorptive capacity in technology transfer, (3) processes relevant to the absorption of knowledge.

Third, one of the authors attended several formal and informal meetings for the two German cases that are situated in the larger cluster context of OpTecBB in the German capital region in order to gain first-hand knowledge about the actual practices of technology transfer activities. OpTecBB itself fosters the exchange of knowledge in several technological focus groups. Meetings of such groups were attended on a regular basis (at least four per year since 2001). Additionally the second case (IfG) has been observed since 2001. The company organized a number of so called Roadmap meetings with local research organizations and companies in the field. These roadmap meetings (bi-annual) were attended by one of the authors since 2001.

Finally, due to an ongoing exchange with actors from the optics industry in all cases, the authors were able to verify the information gained and interpretation derived by consulting respondents in those cases where issues remained unclear. Such a form of member validation allows us to strengthen our line of reasoning as we integrated their valuable remarks.

Data analysis

A qualitative content analysis of the empirical data was performed in order to reconstruct the subjective perspectives of the interviewees toward the technology transfer activities in the optics industry against the background of our central theoretical underpinning, absorptive capacity. Due to the qualitative and at the same time explorative nature of this study, inductive categories 'emerged' from the data and were the result of multiple observations that reinforced the same essential message or meaning regarding the refinement of absorptive capacity from a processual stance. It is worth noting that only those perspectives were integrated which were shared by respondents in order to strengthen the validity of our claims

FINDINGS FROM THE FOUR CASE STUDIES

Relating to our research question, our findings suggest that there are distinctive patterns discernible how companies and research organizations involved in technology transfer manage to recognize and embed novel information on latest technological developments from the research and economic field into their ongoing activities. This helps us to refine existing absorptive capacity notions. However, despite diverse similarities across cases, differences are also evident between each of the cases, which is why we present the findings for each case separately before we offer first attempts to generalize our findings.

In the case of *X-Radia*, the state of the art x-ray microscope manufacturer, essential knowledge resources lay outside the firm, predominantly in a selected number of research institutes. Whereas a number of (research) organizations in the world can build x-ray microscopes, it is presently only X-Radia that can build smaller, table top and laboratory size x-ray microscopes that can be integrated in production processes of other companies. On one hand the company develops its own technologies and product related knowledge, predominantly how to integrate all the components into small instruments (size of a desk). Insofar it builds on prior related knowledge X-Radia has developed after the company was spun-off from Stony Broke University and builds on the specific knowledge of the founder/CEO and CTO of the company that was developed when they worked as researchers for the x-ray microscopy group at Stony Brook. On the other hand X-Radia is involved in strategic collaborations with Argonne National Lab, a one of a kind national large scale (x-ray source) research facility, to develop strategic components. Here strategic links are maintained to researchers and technologies are licensed. The other strategic research partner is the x-ray microscopy research group at Stony Brook University.

In order to identify and acquire novel, valuable and useful new knowledge X-Radia has contacts to researchers in these strategic partner universities and research facilities. The company is also using its contacts to other technological experts in the scientific community: "We have actually people in academia that are kind of our intelligence in the scientific field." In order to monitor the technological developments X-Radia is studying and monitoring industry magazines and representatives as well as researchers of the company attend scientific conferences and trade shows where new developments are picked up. The transfer of knowledge into the company is organized to a large extent by mean of hiring highly qualified experts from the few American research organizations working in x-ray microscopy. "About half of the graduates from my research group at Stony Brook now work here."

A preference is shown towards the home university of the founder and CEO as well as the CTO indicating the importance of common understandings and a common knowledge base in evaluating and assimilating as well as transforming new external knowledge. If the cognitive maps of employees but also of external partners are similar it appears easier to the X-Radia management to integrate new knowledge into the company and to apply it to new component and/or product developments. Insofar shared meanings appear to positively influence the absorption of new knowledge because of the similar socialization of X-Radia employees.

The assimilation and transformation of new and valued external knowledge and information is also fostered by X-Radias organizational practices. New technological developments are not only monitored by single researchers or employees, but it is also gathered and discussed in a special x-ray optics team. The x-ray optics team is meeting weekly and here if something new is learned it is discussed in these meetings – connectivity of the group's members and exchange of ideas is enhanced. However there is a filter function exhibited by the CTO who is deciding what issues to put on a company internal roadmap. Such internal power relations in the selection of new issues obviously influences the assimilation and application of new knowledge within the firm.

The CEO, CTO as well as the researchers and engineers of the company can be seen as boundary spanners in that they operate at the boundaries of the firm or rather organizational interfaces with other organizations when they engage in more occasional and incidental exchange of information at conferences and industry meetings or frequent and intensive interaction with researchers from external facilities or customers in technology or product development projects. Gatekeepers within the company, these include the CEO and CTO in the case of the rather small X-Radia, interpret the information gained and make sense of it an then apply it to internal processes, technologies and products "if there is a project identified where the new knowledge makes sense, then we decide what to do with it and then it is handed off to a member of the group who will then interact with the other party and execute that project". Such interaction however always involves powerful action of the involved actors.

As already indicated above the Berlin based x-ray analytics company *IfG* has engaged in extensive networking activities. Thereby it is identifying and securing valuable external knowledge resources. IfG and especially its CEO, the former director and professor at the Center for Scientific Instruments at the former East German Academy of Science, is also actively organizing and powerfully shaping this network of regional x-ray analytics companies and research organizations. This regulation is possible because of his charismatic appearance, the power resulting from his expert status as well as the market and technological expertise residing in his company. Within the network IfG has been in charge of collaboratively drawing and coordinating a network technology roadmap. In this roadmap IfG researchers and engineers but also members of the network elaborate and describe latest technological and market developments that appear relevant for the development of components, methods and instruments in x-ray analytics. The roadmap and the included information are then exclusively circulated within the network. However the main beneficiary is IfG. Within IfG the roadmap is being used as a strategic tool to align company research and development activities as well as collaborative projects, which are organized along the developmental lines of the document.

In addition the company is organizing a bi-annual convention and exhibition on process integration of x-ray analytics (PRORA) in Berlin with speakers and exhibitors from the strong regional x-ray community as well as representatives from national and international research institutes and companies. Insofar the conference provides a pristine opportunity to pick up new technological and market trends and to take new information into the company. Internally the information, just like in the case of X-Radia, is being evaluated in meetings of the R&D staff. Since these meetings are generally convened and overseen by the patriarch of the company, he is mostly deciding or at least powerfully influencing the direction of new developments, even though he likes to call it “making an offer”. However the processing of the knowledge, that is the connection of new knowledge to products of the company, mostly appears in the form of inter-organizational projects. In such projects the company (temporarily) integrates the knowledge of external research partners into new product or method developments. Insofar the boundaries of the firm are blurring in the case of IfG. This is also because a number of IfG employees are also temporarily working for an association (Verein) that is applying for public project funding and that is executing a number of the collaboration projects.

North Carolina State University (NCSU) is rather experienced in working with different partners from industry. The university is also quite famous within the Research Triangle for spin-offs and therefore creating jobs in the region. The researchers and technology transfer officers have seen different ways how companies try to identify and then assimilate new knowledge. Most high-tech companies are employing technology scouts that oftentimes use some of the same tools the university is using to identify technology space. With those tools (data bases) they are able to look for overlaps in the technology companies are using and technologies that are developed in research facilities and identify gaps or disruptive technologies. Those scouts act as gatekeepers for the companies they are working for and try to filter the knowledge on the "market" to match the companies' needs.

In addition the open innovation models applied by many of the involved industry partners is helping to facilitate more interaction with NCSU. Such an open approach is providing the university with the industries needs by means of clearer and more open articulation but also by more openly contacting university researchers and other representatives. The assimilation of the knowledge that companies identified on campus or scientific meetings is oftentimes done by student internships and the company providing jobs for postgraduates or PhDs to foster the relationship and granting access for future research. Thereby the relationship during the application process remains still strong. In the case of NCSU most of the contacts were established on scientific or regional meetings where companies are always looking for new knowledge. The identification of knowledge on campus was many times done by companies that already cooperated with the university and that way already had access to at least one faculty.

To facilitate social integration with its transfer partners the technology transfer office (TTO) of NCSU is predominantly hiring employees that have been working in industry and therefore know the specific needs and language of companies. In order to help companies searching for certain technologies and specific knowledge and advice and that try to cooperate with the NCSU, the TTO provides template agreements. Those templates can also be seen as a regulative practice by which the NCSU is providing rules of interaction and cooperation. Companies interested in a cooperation contract with the university are always referred to those documents. That way it becomes more transparent to the involved actors what basic rules are mandatory and which agreements can be negotiated.

At the transfer office of NCSU the spanning of organizational boundaries is to some extent institutionalized. Since it appears to be essential to the technology transfer people at NCSU "to find a champion at the university to maintain that relationship [with a specific company]" the university saves information on who talks to whom in technology transfer activities and pre-engagement conversations in a database in order to know the right point of entry for future requests. If a company approaches the technology transfer office not only available contacts and apparently transfer ready technologies are presented, also the companies are usually required to provide at least internships for NCSU students. That way both sides appear to profit. The student learns about the company/industry needs and the company in the best case has access to new academic knowledge and may establish a closer link to a specific research group, institute or department. In that sense power relationships however become visible too. Since these companies often come from the Research Triangle as well, this unofficial part of the agreement is oftentimes accepted by the companies as part of the regional industry rules and common sense and rules of engagement in co-operation and technology transfer.

The *Ferdinand-Braun-Institute* (FBH) is an established research organization within the Berlin optics cluster and beyond and has strong ties to other research institutes but also to numerous companies in the area. Those relations can be traced back to the common origin of the institute and the companies that is the former Academy of Science as well as newly spun off companies, now employing former FBH personnel. These companies are attempting to expand the cooperation with the FBH to get in touch with researchers and to profit from novel technologies invented at the institute.

The FBH is open to the selected transfer of its technologies and is applying some practices to help those companies with the evaluation of new technologies. First there is a monthly newsletter for existing co-operation partners, informing the community about new inventions or innovations. Second there are seminars being held where interested companies are invited to get in touch with the FBH and its researchers. Those seminars are also open for companies that like to introduce themselves and to give the opportunity to express what they are working on and looking for. The third way were the valuation of companies might be affected is participation of companies in conferences and conventions hosted by FBH. At such scientific conferences FBH always tries to look for future co-operation partners by presenting current research projects and presenting possible avenues for transfer.

After a contact is granted and the co-operation contract is signed, FBH also uses several processes to actively facilitate the assimilation and application of novel knowledge and technology within co-operating companies. FBH provides employee training and on site consulting. Furthermore the institute allows trusted partners to detach an employee acting as a boundary spanner for the company. This is used especially by the spin-offs, where the employee is working with the FBH and reports the CTO of his company once a week about the research progress and possible points of intersection. In that sense the detached employee also acts as a company internal gatekeeper since he interprets the externally gained knowledge and channels the information into the internal decision processes to relevant company representatives. For the top management of the close co-operation partners there are monthly meetings held by FBH or rather by the co-operating team in order to maintain the spanned boundaries and active exchange of information and latest developments.

All interview partners stated that the close relations between the transfer partners are the key to success. In order to convey those (selected close) relations to all employees of the selected co-operation partner companies, FBH and its partners are fostering the social integration by hosting summer or Christmas parties and an annual get togethers for collaboration partners. The FBH director stated “there is a difference between what’s on the paper and what’s done. You have to live the cooperation”.

However, partners are also powerfully influencing the co-operation, the access to information and the allocation of resources within the collaboration. Power relationships become visible when the intensity of a co-operation of the FBH with its partners is analyzed. Those who are maintaining a trusted relationship with the director are receiving sort of more opportunities when it comes to the transfer. For the transfer itself the FBH also tries to profit from new insights and therefore prefers the physically close team-ups. This can be illustrated by the following example: the choice of location of one of the recent spin-off companies that is affiliated to a globally acting company has been indirectly influenced by the FBH director. He made it clear that in order to archive the best out of the co-operation, that basically includes the transfer of FBH technologies to the company that the spin-off was to locate in the direct neighborhood on a then vacant lot across the street from FBH. This closest possible proximity now fosters short distances and frequent face-to-face interaction and offers FBH also the opportunity to learn about the needs of the company.

IMPLICATIONS OF THIS RESEARCH

In line with recent studies that call for a processual analysis of ACAP (e.g. Easterby-Smith et al., 2008), our analysis of four cases in technology transfer in the optics industry illustrate that practices are of utmost importance for comprehending how ACAP actually unfolds with regard to the involved actors.

The practices of the respective actors engaging in technology transfer and absorbing knowledge into their organizations that we identified as being most relevant for the absorption process are in line with prior ACAP and especially process-oriented research. These include processes describing the valuation, assimilation and application of novel knowledge and technologies within the company. These processes are however influences by four additional external elements: boundary spanning, power relationships, social integration mechanisms and regulative practices.

Our cases are prone for actors to span organizational boundaries. Due to the optics industry's high innovation degree and interdisciplinary character, interactions of different actors are likely. Boundary spanners (Tushman, 1977) in all our cases identify idle market chances, collect information about technological possibilities, shortcomings and potential problems and channel it into the organization (Reid & de Brentani, 2004), acting in effect as conduits for ACAP.

Within the organization management is disposing over organizational resources (Pfeffer & Salancik, 2003) in that it decides where to allocate R&D activities, to develop new product related knowledge in conjunction with new external knowledge and so to channel scarce attention to newly arising technological opportunities in technology transfer. Insofar we adopt a processual perspective when we perceive regulation as representing the development of a regulation framework for social interactions and in a practical sense as a spectrum of activities for the enactment of this regulation framework (Giddens, 1984).

The wide spread practice of participation of company employees and researchers in exhibitions, convention and/or scientific conferences offers opportunities to engage in new relationships with representatives of other research organizations, firms, suppliers and customers or to at least foster weak ties (Granovetter, 1973) and bridge possible structural holes (Burt, 1992) to relevant knowledgeable actors. Such weak ties are said to especially foster the exchange of novel, however rather simple information. As Hansen (1999) has indicated strong ties and social integration mechanisms are beneficial in the transfer of complex knowledge. Such knowledge and technology transfer usually takes place in the form of projects with repeated project partners that also share a common understanding of the technology, as well as the way to collaboratively interact. In the case of firms, but also research institutes that are embedded in regional clusters this common understanding is part of the industrial atmosphere (Marshall,

1890) in the region. However, the thread of hindering the inflow of new information and ideas associated with cohesive groups (Coleman, 1988) in our cases is surpassed by the constant influx of new ideas and technologies not only due to the opportunities to exchange at the conventions, projects and roadmapping activities but also by the steady arrival of new researchers into the numerous research institutes and research groups in the region.

Political issues can be identified in all our cases. Power and politics appear to be a normal side effect of or a medium in transferring knowledge and technologies between individuals and between organizations. Political practices of more or less powerful actors in the course of transferring technologies and absorbing knowledge may include recurring on specific resources in order to dominate a decision process, to mobilize support for a specific idea, or to simply decide on a specific option. Such power relations can be found within the organization and can include relations with external partners, suppliers, customers and research organizations in the technology transfer arena.

Research on absorptive capacity therefore should not only focus on the R&D activities of the firm, but also at the involved research partners in the technology transfer arena. These research organizations support technology transfer in specific ways and employ specific matching practices in order to supply the knowledge companies are looking for. Only the inclusion of the perspective of the research organizations enables a more complete understanding of the processes of technology transfer and how firms incorporate such technologies and knowledge from the scientific field.

CONCLUDING REMARKS

The *guiding research question of this paper* was to elucidate, which organizational practices and environmental factors do private and public sector actors need to consider in their technology transfer activities in order to manage their absorptive capacity. We answered that question by reverting to insights from four case studies where private and non-profit organizations are interacting in the area of technology transfer in Germany and the U.S.

Against this background, our *contributions to the literature* on ACAP are as follows: First, in line with recent theorizing on ACAP (Easterby-Smith et al. 2008) we offer a more fine-grained conception of ACAP by venturing beyond mere quantitative and deductive approaches. Hereby this study is also one of the few attempts that try to generalize across cases, making our findings robust and – at least against the backdrop of technology transfer activities – partially generalizable. Instead, we observed how ACAP unfolds in praxis, adopting a processual perspective. As a result we offer meeting management practices as a fruitful venue to explain the way ACAP unfolds. Herein a parallel can be drawn to other research streams. For instance, studies devoted to a strategy-as-practice perspective have recently (e.g. Jarzabkowski & Seidl, 2008) pointed out at the importance of practices like meetings as everyday micro-activities that help to explain strategic outcomes, which makes it suitable for ACAP perceived as a facet of strategic managerial activities.

Second and in a similar vein, boundary spanning and power relationships are moderating influences that need to be considered, wherein we confirm previous ACAP research (e.g. Todorova & Durisin, 2007). In the light of our findings we suggest that ACAP is by no means free of powerful interventions, which is important insofar as it shows how ACAP is fostered or impeded in praxis. Herein we can draw a parallel to another stream of research that also addressed the problem of knowledge transfer, that is, research on the transfer of ‘sticky knowledge’ (Szulanski, 2003). Although ACAP is not the focal concern of Szulanski’s inquiry, he adheres to the same problems as ACAP oriented studies do when it comes to integrating prior knowledge or – in more general terms – he acknowledges the problems arising from the path dependent nature of ACAP, e.g. being primed and therefore locked-in concerning certain technological developments, whereby neglecting others.

Options for *future research endeavors* ensue from the limitations of our paper and are both theoretical, as well as empirical in nature. From a theoretical stance it might be worth to elaborate further upon the different levels of analysis and their respective influence. For example, in our four cases we analyzed different organizations, but did not qualify, or rather, quantify any of the practices as being more relevant than the other. This does not necessarily entail that we call for multivariate analyses, but our analysis would benefit from putting these practices into such a perspective as this would also allow generating insights into possible cause-and-effect chains.

Moreover from an empirical stance future research might consider alternative organizational constellations or research settings. For instance, ACAP research might benefit from taking into account the different geographical settings, e.g. not highly industrialized countries, but ‘emerging economies’ in South East Asia or Eastern Europe. Furthermore, we reverted to well-established clusters. Maybe in more nascent agglomerations different patterns of how technology transfer activities unfold might be observable as we concentrated upon well know technology-intensive clusters.

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Table 1: Contributions focusing on processes

Article	Setting	Analyzed processes
Kim, 1998	Proactive constructed crisis in the catching up process of the Hyundai Motor Company in four phases	▪ Preparation (literature review) ▪ Acquisition (hiring of expats) ▪ Assimilation (Learning by doing)
Jones & Craven, 2001	Increasing the coordination capabilities of an office furniture company	▪ New (learning) routines: literature scan, idea capture form, committees, meetings
Jones, 2006	Individual agency of change agents in a manufacturing firm	▪ Introduction of regular meetings for the exchange of knowledge
Easterby-Smith et al., 2008	Comparative case study (internet, health care, chemical industry) that illustrates the role of power and political processes; discussion of the importance of boundaries	▪ M&A and exchange of personnel ▪ Recruitment and project groups ▪ „Friday time“

Table 2: Empirical cases

	U.S.	**Germany**
Firm	X-Radia	IfG
Research organization	North Carolina State University	Ferdinand-Braun-Institut für Höchstfrequenztechnik

Table 3: Overview over the respondents of the study

Region	Case	Interviewed organization	Type
Berlin-Brandenburg (BB)	FBH	Ferdinand-Braun-Institut für Höchstfrequenztechnik	RO
		Ferdinand-Braun-Institut für Höchstfrequenztechnik	TTO
		eagleyard Photonics	SME
		Jenoptik Diode Lab	SME
	IfG	IfG	SME
		Bruker	SME
		Technical University Berlin	RO
		Berlin Laboratory for innovative X-ray Technologies	TTO
		Max-Born-Institut	RO
		OpTecBB e.V.	CO
		IAP e.V.	TTO
North Carolina (NC)	NC State	CPC (Carolinas Photonics Consortium)	CO
		North Carolina State University	TTO
		East Carolina University	TTO
		Bioptigen	SME
		Semprius	SME
		University of North Carolina at Chapel Hill	TTO
California (CA)	X-Radia	X-Radia	SME
		Berkeley Lab	RO
		University of California	TTO

Type: CO: Cluster organization;
TTO: Technology Transfer Organization;
RO: Research Organization;
SME: Small and Medium Enterprise