Formal Knowledge Examination Institutions: Chance or Threat to European Medium Technology SMEs?
A Cognitive and Institutional Perspective

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1. Introduction

Many scientific papers and policy debates deal with gaps between knowledge creation and knowledge commercialisation. With the help of supporting entrepreneurship, encouraging start-ups and spin-offs and exploiting intellectual property, closer linkages between knowledge generation and commercialisation processes are expected (Akbar, 2003; Blum; Müller, 2004; Lockett et al., 2005). The major problems are identified in a lack of financial resources on capital markets, individual incentives and mentalities or management capacities and cooperation cultures (Polt et al., 2001; European Commission, 2003; Sapir et al., 2003). Other papers deal with specific barriers of incumbent SMEs to new science-based or analytical knowledge (European Commission, 2004). These barriers include lack of resources for formal R&D projects or R&D cooperation with specialised public or private organisations as well as restricted access to high-quality workforce with international and interdisciplinary experiences. As a result, incumbent SMEs are threatened to be trapped within traditional technological paradigms (Davenport, 2005).

This dichotomy between knowledge generation and exploitation neglects the bridging effect of knowledge examination (Cooke, 2004). Knowledge examination includes any kind of proof of newly developed knowledge from technological feasibility of new single problem solutions to empirical confirmations of theoretical models or economic profitability of new market strategies. During the last decades, the organisation of innovation processes has been characterised by growing complexity. While in the first half of the century, individual inventors with entrepreneurial skills dominated the perspective on innovation and then big organisations exploiting the scale economies in big R&D labs, innovation processes nowadays involve individuals and groups from different organisations and from different scientific and technological disciplines (Gibbons et al., 1994; Liyanage et al., 2006). This increasing complexity is driven by the increasing relevance of integrative technologies no longer restricted to one single sector or paradigm (Benzler; Wink, 2005) – e.g. adaptronics as combination out of electronics, information technology and material sciences – and by the diffusion and adjustment of new technologies across different industrial and service sectors – e.g. composites as flexible and light alternative to metals. The creation of new knowledge depends on two interrelated processes: (1) the use of creativity, i.e. adding something completely new to the existing knowledge base, and (2) learning from own and foreign experiences to identify and apply existing knowledge, which also serves as a basis for creative ideas. These learning processes within complex inter-organisational structures are in the focus of this paper. Learning from foreign experiences is only possible, if two prerequisites are given:

- a common code of communication to prevent cognitive misinterpretations, and
- trust in the quality of the experiential knowledge.

Hence, any new knowledge communicated has to be examined by the communication partners to decide about the applicability and usefulness. Many of the existing examination procedures

exist already for a long time, for example the peer review processes within the scientific community, industrial norms for technical devices or personal and social relationships within SME cooperation. These incumbent procedures are particularly important for medium-technology sectors, as these sectors are based on technological paradigms already generated in the 19th century and then adjusted separately by science, SMEs and public regulation. Three major changes in industrial organisation, however, challenge these incumbent procedures:

- the reallocation of tasks and responsibilities within industrial value chains shifting more and more tasks to cooperation between suppliers (Sanchez; Mahoney, 1996),
- the integration of more and more science into new technologies vanishing existing boundaries between science, applied research and product development (Nowotny et al., 2001), and
- the internationalisation of production processes causing the need for new organisations and individuals to be integrated into cooperation (Nooteboom, 1999).

Consequently, procedures have to be adjusted with more formalism as an expression of institutional proximity in the examination processes due to a lack of other options to secure interactions without loss of information. These new formal requirements, however, cause specific problems for SMEs, as they do not have as much resources to cope with formal issues as bigger organisations. In this paper, we will analyse the relevance of formal examination institutions to secure learning processes and the consequences for SMEs. We will particularly focus on the aeronautics sector, as this is a typical sector, where traditional medium-technology SMEs are confronted with structural challenges by new sourcing strategies of multinational original equipment manufacturer (OEM) and new technological solutions. The paper consists of three parts. In section 2, we will explain the need for formal examination institutions within learning processes based on theoretical models. In section 3, an overview to different formal institutions initiated from different kinds of organisations is provided showing the challenges for SMEs. This serves as a basis for an empirical investigation in section 4, how SMEs in the sector of aeronautics are affected by these challenges and which initiatives have been launched to overcome adjustment processes. Section 5 will summarise the basic results and discuss possible consequences for future European policies.

2. Knowledge Examination and Interactive Learning: Theoretical perspectives

Knowledge examination is necessary for all users of experiential knowledge from others. It needs to be tested, whether this knowledge has been understood correctly, for which context it is relevant, which prerequisites are needed for its use and transfer to new applications, which unintended side effects have to be considered and which is the quality of this experiential knowledge (Wink, 2004). In daily practice, these examinations are made without conscious or intended actions mainly driven by personal contacts and relationships. This kind of social proximity seems to overcome cognitive and institutional needs.

The *cognitive problem* arises from inter-individual differences in framing any kind of knowledge (Anderson, 1995; Ashby; Casale, 2003). Within this theoretical argumentation, any process of creating knowledge – turning data into information – is based on a construction of reality by the human brain (Laughlin, 1996; Rizzello, 2000). This constructivistic process is

driven by genetically given neural capacities and socio-cultural influences and therefore special for every individual. As a consequence, any new data generated by own or foreign ideas and experiences are individually processed and framed (Kunda, 2000). This individual framing causes the risk of misunderstandings within processes of communicating data. The receiver might take different information from a message than the sender originally intended. To overcome these problems, codes of communication are used, which range from general codes like languages to specific technical terms. A basic prerequisite for using a communication code effectively is that the sender actually understands all dimensions of his experiential data and is able to convert them into communication. Different kinds of proximity can contribute to the performance of communication codes: we will look at social, geographical, cognitive, organisational and institutional proximity (Torre; Gilly, 2000; Boschma, 2005, for more detail). *Social and geographic* proximity helps to overcome risks of misperception and misinterpretation, as the communication partners have the chance to use frequent and repeated face-to-face-(F2F)-communication with continuous interaction to test, whether the intended message has reached the sender (Bathelt et al., 2004), and these F2F communication is not only restricted to specific professional events but also existing in private personal contacts (Dahl; Pedersen, 2004). Formal communication codes like written language can be easily used, if there is already given a specific joint cognitive dimension (*cognitive proximity*), for example due to common professional or scientific backgrounds (Harhoff et al., 2003). In these cases, publications and manuals are options for communication, although an additional temporary geographical proximity might be necessary to understand specific context conditions of the data provided.

Organisational and institutional proximity are means to build up specific and exclusive communication codes on the basis of formal and informal rules. With the term *organisational proximity*, we mean shared formal relations reaching from relatively weak ties based on an inter-organisational contract (for example joint venture) to strong hierarchical organisations with only a low level of autonomy of the individual (Boschma, 2005). Many concepts of knowledge management on the firm level look for necessary prerequisites for communication, including technological solutions, incentives for documentation and formalisation of non-formal experiential data and opportunities for interaction and creation of codes by routines (Argyris; Schön, 1996; Nonaka et al., 2000; Orlikowski, 2002; Chen, 2004). *Institutional proximity* refers to a more general set of formal or informal rules for individual behaviour (North, 1990). Cognitive barriers are overcome in this framework by improving the conditions for ongoing communication through stable expectations on the behaviour and participation of communication partners. The stability of these institutions is again closely related to social and cognitive proximity, as they can support the effectiveness of interactions and options to sanctions against non-compliance with institutional rules (Coleman, 1986).

The institutional problem arises from typical challenges by information asymmetries between sender and receiver typically discussed within the principal-agent-framework (Aghion; Tirole, 1994; Hart; Holmström, 1987). Even if communication codes are available to prevent cognitive barriers, senders will always have the advantage of superior information due to personal experiences. Major challenges are caused by quality uncertainties, which means that the receiver actually does not know whether the data received are worth to be processed and whether the time used to understand, interpret and apply the data is wasted and leads to failure, and moral hazard, which includes the risk of a communication partner to be exploited by

the other partners, if she is providing her best information but only receives worthless data (Blum; Müller, 2004). Hence, two institutional problems need to be solved: an institution to reduce quality insecurities by credible signalling or screening, and an institution to overcome incentives for default by credible control and sanctions.

Social proximity can help overcome these problems by creating trust through personal contacts (Nooteboom, 2002). Credibility is built up by personal reputation. Any non-compliance with the expectation of the communication partner will not be only sanctioned by loss of professional contacts but also by loss of personal contacts and social acceptance (Tura; Harmaakorpi, 2005). Geographical proximity might support this option by offering better opportunities of social control via ongoing F2F contacts between different individuals spreading information on misbehaviour. Sanctions not only affect the relationship between sender and receiver but also other possible communication partners within the area (Gertler et al., 2000). Cognitive proximity reduces the risks of quality uncertainties and moral hazard by a lower level of asymmetries. The receivers of data are more able to identify sources of low quality, as they can stick to some formalised hints or can use their own experiential knowledge to test. Sanctions are extended to the loss of professional reputation. Organisational proximity might include specialists on examining new data before spreading them within the organisation (Harada, 2003). Sanctions cover the exclusion from the organisation with all its benefits and requests for compensation by the other members of the organisation (Olk; Young, 1997; Foss, 1999). Institutional proximity contributes to the credibility of signalling and screening by securing these instruments with the help of either informal personal sanctions or external – public regulatory – sanctions. Similarly, institutional proximity helps prevent moral hazard by external incentives, for example the agreement on shared risks of using data or the obligation to compensate for any failure caused by wrong data (Tirole, 1999).

The availability of these forms of proximity to support knowledge examination has changed in many medium-technology sectors during the last decades due to internationalisation of production, needs to link incumbent technologies with new more science-driven paradigms and new ways to organise production. In the context of aeronautics, accuracy of knowledge is of specific importance, as any failure of the final product endangers the life of the passengers and causes loss of trust into a whole mode of transportation. Consequently, innovation with its changes of existing knowledge creates a challenge for this need for safety and requires intensive forms of knowledge examination. In the next section, we look at different forms of knowledge examination and their relevance in the civil European aeronautics market.

3. Knowledge Examination: Experiences in the Civil Aeronautics Sector

All forms of proximity described in the last section are used for knowledge examination in the civil aeronautics sector. Cognitive proximity seems to be the traditional basis for interactive learning processes. At the beginning of civil aircraft production, engineers with common technological backgrounds look for basic solutions (Wengenroth, 2000: Viscenti, 1990, on the emergence of engineering epistemic cultures and institutions). With improved qualities of aircrafts – for example speed, number of passengers, use of fuel, specific weight, convenience for passengers and pilots, safety etc. – the complexity of used technologies was increased causing the need to include scientific and technological knowledge from different disciplines like electronics, material sciences, physics or information science (Zuliani et al., 2002). As a

consequence, the range of the cognitive dimension of aircraft production has been extended causing challenges to find cognitive proximities between the different strands of R&D.

This process of extended cognitive dimensions corresponds to changes within the organisation of aircraft production. Traditionally, original equipment manufacturers (OEM) within civil aeronautics are big companies with a high level of integration due to high capital-intensity of production. Research and development were dominated by processes within the organisations, often connected to aerospace or military segments. Specific components were delivered by a high number of suppliers, which are located close to the production sites. Any generation of new knowledge was driven by the big demanders and by the objective to solve specific problems and needs, which meant that analytical knowledge skills with a high level of specificity was needed. Hence, organisational and geographical proximity played a major role for interaction and knowledge examination (Beckouche, 1996; Beaudry, 2001). In Europe, specified agglomeration areas emerged according to the demand of multinational OEM or their system suppliers.

These patterns, however, have been challenged recently by two processes: an increased level of internationalisation of production, partly driven by political influences (for example explicit local content requirements and relations between orders and share of domestic production) and partly driven by the search for lower production costs, and the reduced level of production integration within the OEM. Internationalisation always includes new cognitive challenges, as incumbent communication codes have to be adjusted, not only for language reasons but also due to cultural and social differences (Grotz; Braun, 1997; Wink, 2003). As a consequence, geographical and social proximity cannot be used as before to strengthen communication codes and support credibility in inter-organisational issues within the value chain. For the OEM, two communication codes act as substitutions: communication via ICT based systems, for example within the concurrent engineering program of Airbus connecting engineers from different locations simultaneously, and communication based on formal industry norms to guarantee compatibility of single components within the value chain. The reduction of the level of production integration means for the OEM the concentration of sourcing to fewer suppliers, which are responsible for whole systems. This modular sourcing process creates another challenge to the knowledge examination process, as the OEM are no longer developing their knowledge within their own specific implicit production processes but in close cooperation with system suppliers, which increases the difficulties to understand the complex interrelationships of knowledge elements within the whole process. Like in the automotive sector within the last two decades, the OEM use specialised engineering business service providers to manage the challenges to define the knowledge needed along the interfaces between the single system modules (Gann; Salter, 2000). As a result, the access to knowledge interaction within the value chain requires an increasing level of ICT technology and formalised knowledge to cope with the requirement by OEM, system suppliers or engineering business service providers.

From the beginning of civil air transport, information asymmetries play a major role between aircraft producers, airlines, passengers and other affected individuals due to safety issues. As private individuals are not able to overcome information asymmetries on their own and private regulatory schemes might face limits to credibility, public safety regulation via norms on quality and maintenance had been introduced in all developed countries. Any change in air-

crafts has to be approved by public authorities. Regulation does not only cover safety risks, but also environmental risks, including noise, and qualifications of professional staff. Therefore, a high level of formalism characterises this area of knowledge examination. Within the context of internationalisation, these formal regulatory standards as a signal for quality even serve as a factor of competitiveness for domestic firms, because foreign firms have to look for adjustment to these standards to overcome market entry barriers. As long as domestic markets are still attractive sales markets, as in the case of the European Union due to its size and purchase power, these standards influence patterns of internationalisation.

Summing up, on all three segments of knowledge interaction in the aeronautics sector changes in the processes of knowledge examination can be observed towards a higher relevance of formal codes and institutional or organisational proximity (Cowan et al., 2000). For SMEs, these changes cause specific challenges. According to the scientific literature, incumbent SMEs are more dependent on geographical and social proximity, because they do not have the resources for specialised staff to develop international experiences and skills to cope with formal standards (Asheim; Isaksen, 2002; Capello; Faggian, 2005). Many cooperation patterns are driven by organisational dependence on the main demanders and personal contacts. If they, however, intend to stay or even rise within the value chain, they have to be able to cooperate with foreign partners or even integrate organisations with different technological expertise and socio-cultural background. The restricted availability of capital further hinders the investment in ICT to be integrated within "virtual value chain and knowledge examination systems" (Gerst, 2005). In the following section, we will take a look, whether SMEs in the aeronautical sector actually recognise these challenges and how they try to react on these challenges.

4. Knowledge examination and the changing environment for SMEs: Empirical evidence

The following results are based on qualitative and quantitative empirical research in different European regions.

At this stage, this paper refers to empirical results from the German research.

The basic questions of the empirical investigation are, (1) if and how the knowledge examination processes of SMEs are affected by the changes in value chains, technological development and production systems, (2) how they are related to interregional knowledge flows, and (3) which instruments are used to overcome recognised barriers for SMEs to knowledge examination. The empirical investigation consists of a series of interviews with fourteen aeronautic medium-technology SMEs, four engineering services firms, three personal services firms and six public and private research services organisations. All of these organisations are located in Northern Germany and within the value chain of the Airbus production sites in Hamburg, Bremen, Varel, Nordenham, Stade. The production of Airbus in Germany include responsibilities for forward and aft fuselage, vertical tail planes, structural components, cabin interior and cargo customisation. Due to the diversity of technological challenges at the different sites, the relationships between Airbus and its suppliers differ. Using the terminology of the cluster typology by Bottazzi et al. (2002), we found two different cluster organisations:

- a hierarchical cluster dominated by an "oligopolistical core" connected to sub-contracting systems

This is typical for the cabin interior segment, where only two main demanders – Airbus as aircraft producer and Lufthansa Technik as specialist for maintenance, repair and overhaul but also for VIP customisation – dominate the cluster and define its organisational structure. Linkages between the single suppliers are poor with only weak advantages of geographical proximity (Bönte; 2003). Most of the firms are conventional SMEs with a low level of formal knowledge, as the share of academic employees is below 10%, and formal R&D cooperation or patents almost not existing. These conventional firms are concentrated to regional markets with only few international contacts. Only few of these firms belong to knowledge-intensified firms with shares of academic employment between 10 and 20%. These firms are aware of the need for internationalisation, but they face problems due to lack of financial resources. Hence, organisational proximity is the most important feature of interaction between the firms in this cluster. There is only weak cooperation between the SMEs, while all of them are linked to Airbus as the dominant demander.

- a cluster based on knowledge complementarities, which is science or technology driven

This is typical for the development of composites mainly around the Airbus location in Stade. This cluster consists of public and private research institutions, a formal service organisation, several engineering companies, spin-off companies from OEM and research organisations, specialised suppliers and OEM from different sectors, including aeronautics as well as automotive sector. The main interest of this cluster is the development and commercialisation of composites as an alternative to metals with less weight and a higher level of flexibility. Most of the organisations involved belong to knowledge intensive organisations with even more than 50% academic employment and several formal R&D cooperation contracts as well as several international contracts. Here, cognitive and geographical proximity become more important to find specific solutions for new products and services based on composites and related technologies. Geographical proximity with its opportunities of frequent F2F communication is used to improve the compatibility of existing communication codes from different sectors and disciplines involved. Organisational proximity is relevant in this context to secure exclusiveness of the benefits from cooperation within the cluster.

Our main hypothesis is that knowledge examination and changes of knowledge examination processes differ between the two types of clusters causing different challenges for more formalised and international knowledge examination processes (Giuliani, 2005).

Within the hierarchical cluster, SMEs are dependent on communication codes set by the dominant demanders. The increased use of formal company-specific norms by Airbus has to be accompanied by adjustment strategies of the SMEs. Even if knowledge intensified companies try to develop their own new experiential knowledge, they are confronted with the challenges of formal public regulation and do not have necessary financial means to cover the costs of processes for approval. As a result, they have to negotiate with the demanders to convince them to integrate their ideas into joint applications for approval. The low formal level of the knowledge base in conventional SMEs makes it necessary for them to demand for additional business services to receive formal certifications, which serve as prerequisites to stay within the value chain. As a result, they are not able to develop dynamic capabilities on their

own (Teece et al., 1997). Barriers to private capital markets cause further hindrances for the SMEs, as they might not be able to cover investments costs for ICT standards, the risks of relocating production processes to low-cost countries or to finance investments in attractive foreign sales markets.

Hence, SMEs within this type of cluster are primarily restricted to knowledge flows based on codified knowledge by OEM-specific norms and the OEM or specialised business service providers acting as gate keepers for knowledge from other regions or countries (Muller, Zenker, 2001). In the medium to long term, this dependence cause the risk to loose the access to the value chain of the OEM, as no specific advantage against foreign competitors can be obtained. Two main strategies to overcome these problems can be observed. The first strategy tries to enhance the social proximity between the SMEs within the regional cluster. By improving the prerequisites for closer cooperation, first attempts to extend the cognitive dimension within the SMEs and to improve the access to private capital markets shall lead to internal growth of system competences as well as sales. The second strategy refers to temporary geographical proximity via international fairs. Again, contacts and cooperation of SMEs shall be improved to overcome existing barriers to formalised knowledge examination. The interviews, however, show that the actual impact on SMEs organisation and strategies is limited.

Within the cluster based on knowledge complementarities, many basic international and formalised knowledge examination processes are already given (Markman et al., 2006; Mol, 2005). The basic research in the field of adaptronics, which is closely linked to the use of composites, as well as in other aeronautic research fields is characterised by frequent international interactions with conferences, publications and joint research stays. Knowledge examination at this stage is typically based on peer review processes. Similarly, many basic applications are communicated in codified form. The specific integration of these new technologies within new products, however, is dependent on frequent and close interaction between researchers and engineers of the OEM (Vinding, 2002). Consequently, Airbus supported the service organisation for the composites cluster in Stade (CFK Valley) from the beginning, as this offered the chance to use geographical proximity to the Airbus site to integrate knowledge from different research fields. In this context, knowledge can only be partly formalised, as most of the knowledge produced is highly specific and leading-edge. For the SMEs in this field, this means that they have to be closely linked to international research, which is given due to their high share of academic employees and formal R&D cooperation contracts, and sufficiently flexible in their cognitive dimension to cooperate with OEM and other demanders from different sectors. The exclusiveness of benefits within this kind of cluster and the threat of exclusion in case of default helps against fears of free-rider behaviour by single members. Accordingly, cognitive and organisational proximity are strengthened between the suppliers of R&D intensive services and Airbus as the dominant OEM. The danger of inertia due to close linkages within the regional cluster (Hassink, 2005) is reduced by the intensive international interactions of R&D intensive firms and the OEM.

5. Conclusions

The transition towards “knowledge and learning economies” (European Commission, 2003) has often been connected to a better commercialisation or generation of new knowledge. The objective of this paper was to stress the importance of the examination of new experiences.

Only if there is trust in the experiential data communicated via formal and informal channels and the cognitive capabilities to understand, interpret and apply correctly, learning can actually happen. International modular sourcing strategies, vanishing boundaries between the technologies and between scientific disciplines and technologies and increasing relevance of emerging countries for production as well as R&D cause new challenges to incumbent examination processes. We showed that in the aeronautical sector these changes lead to an increasing relevance of formalised communication. These changes, however, affect regional production clusters differently. We showed that the existing formal knowledge base and the existing embeddedness into regional and international knowledge flows seem to be important aspects, how examination processes are adjusted and which role SMEs can play within these processes. For the European Commission, three important messages seem to be worth for further discussion: (1) the relevance of formal public regulation to obtain international competitiveness of domestic firms; (2) the importance of access of SMEs to formal and informal knowledge bases to rise within international value chains, and (3) the need for strategic support for conventional and knowledge-intensified firms to overcome barriers to grow within knowledge value chains.

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