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Knowledge-intensive entrepreneurship in a low-tech sectoral innovation system

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Abstract

The intention of this doctoral thesis is to shed more light on the emergence of new industrial lifecycles in mature low-tech sectors by looking at cases of knowledge intensive entrepreneurship (KIE). The phenomenon is rather related to so-called knowledge-intensive industries or firms that permanently innovate and create new knowledge. Entrepreneurial innovation activities in low-tech sectors have been neglected by entrepreneurship as well as innovation research so far.

In the context of industrial dynamics the process of KIE in low-tech sectors is understood as implementing an innovation new to the sectoral knowledge base by deviating from routines ? rather than a permanent condition. This depicts a rare phenomenon especially in mature industries from which the lifecycle theory supposes that innovation activities are incremental and organized in routines by established firms following technological paths (Malerba 2005). Since KIE is ascribed to extend the sectoral knowledge base it can contribute to the establishment of new innovation paths. Therefore this unusual phenomenon is of economic significance even though it is not assessable by econometrics. Likewise it describes a gap in the economic sociology that prefers dealing with recurring action patterns. For these reasons the analysis of KIE can contribute to a better understanding of sectoral dynamics and persistence in mature low-tech sectors like the textile industry.

Starting point is that different sectoral systems of innovation have various effects on entrepreneurial performance and the organisation of innovation activities due to different opportunities (Malerba 2005). Moreover, current research about KIE (AEGIS project) presumes that KIE is sector-specific but the empirical exploration for sectoral characteristics is still at the very beginning. Besides, it is assumed - referring to the lifecycle theory - that mature low-tech industries have a less entrepreneurial orientation or offer less opportunities in this respect. On these suppositions the doctoral thesis will

explore how KIE nevertheless succeed in generating an innovation in the institutional environment of a low-tech sector. For answering this question the "sectoral system of innovation" concept is applied to characterise the structure and innovation practices of the textile sector by using data from expert interviews, the Mannheim Innovation Panel and industrial reports. In a further step three qualitative case studies of KIE will be embedded in this environment. They are analysed for technical, market and institutional opportunities related to Radosevic (2010). But distinct from his systemic entrepreneurship approach the opportunities are additionally ascribed to sectoral innovation systems instead of the national innovation system. More precisely it is further asked for the certain background of the opportunities (other sectoral or national innovation system). In addition bridging or creating activities by wilful entrepreneurs will be considered. This structuration view allows understanding the occurrence of KIE even in the supposed absence of opportunities in the direct sectoral environment.
The first sectoral analysis points to structural incompatibility of the different opportunities and shows a fragmentation between the main actors. At the case level a broad variance of how KIE can emerge (as a spin-off, in cooperation or internal) in the textile sector is assessable. The mechanisms and determination of opportunities still remain to be analysed. To conclude, actor-oriented neo-institutional concepts are expected to contribute to the further explanation of the empirical findings.

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Knowledge-intensive entrepreneurship in a low-tech sectoral innovation system – using the example of cases from the German textile industry

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1. Introduction

Knowledge-intensive entrepreneurship (KIE) depicts an important mechanism for transferring knowledge into innovation and transforming industrial structures (Malerba 2010; Malerba/Mckelvey 2010). Therefore, KIE is analysed in the context of low-tech sectors which has been neglected by entrepreneurship as well as (low-tech) innovation studies so far. Thus, the intention of the thesis aims at a better understanding of transformation processes in these industrial sectors by using the example of KIE cases from the German textile industry. Starting point is the assumption that different sectoral systems of innovation have various effects on entrepreneurial performance and the organization of innovation activities due to different opportunities (Malerba 2005). Current research within the European AEGIS[1] project presumes that this is also the case for KIE and has recently started to explore sector-specific characteristics of KIE.

The term KIE is quite young and the literature review shows that it is tightly connected to innovation and economic development and going beyond ordinary founding activities. The knowledge dimension seems to play a constitutive role but especially in this respect the definitions by Groen (2005), Malerba (2010) and Malerba and McKelvey (2010) or Delmar and Wennberg (2010) remain vague. For instance, it is defined as a process that is "to a great extent based on relatively new (mostly academically derived) knowledge or technology" (Groen 2005: 70). Malerba stems from "new ventures […] that intensively use knowledge" (2010: 4). However, any economic action is hardly to imagine without referring to knowledge (Strulik 2007: 714). Furthermore, knowledge cannot be quantified in terms of a more intensive use and or normative in terms of a certain type of knowledge. Scientific knowledge, can hardly be more knowledge-intensive than other forms of knowledge (Smith 2002). Indeed, within an economic system knowledge can have different economic values, but scientific or R&D based knowledge cannot be placed over pragmatic or market knowledge in general. Moreover, Delmar and Wennberg's definition is based on 'high potential entrepreneurship' allocated to knowledge-intensive industries with a highly educated workforce on average (2010: 1/7). This concept seems also difficult to apply for the low-tech context. In contrast to this, Malerba and McKelvey (2010) explicitly include KIE appearing in low-tech sectors. But apart from an earlier concept by Malerba (2010), they exclude corporate entrepreneurship as an organizational form and focus on new, highly innovative firms instead.

In the context of weak or non-R&D intensive low-tech sectors with mainly incremental process innovations new to the firm and general low founding intensity (Heidenreich 2009; Kirner et al. 2009; Robertson/Jacobson 2011; ZEW) the term needs to be adapted and further specified. In this respect KIE in low-tech sectors is understood as (1) a rare phenomenon referring to Schumpeter's evolutionary entrepreneurship concept in place of a permanent condition as an knowledge-intensive firm; (2) it

[1] "Advancing Knowledge-Intensive Entrepreneurship and Innovation for Economic Growth and Social Well-being in Europe", funded by the Seventh Framework Programme of the European Commission since 2009.

can emerge in terms of a new firm or as corporate entrepreneurship (leading to a new business unit); (3) knowledge-intensive activities that create new problem solutions/innovations by no pre-defined established schemes or methods. This definition stems from literature about knowledge-intensive firms that explicitly distinguishes between knowledge-based (already existing schemes) and knowledge-intensive activities (Corell 1998; Kampe 2005). With reference to Deutschmann this creative activity is also to differ from learning. While the former points at the invention of new symbolic pattern, the latter refers to the communication of such pattern (2008: 107). The concept can be well related to Schumpeter's evolutionary understanding of entrepreneurship that excludes routine innovation and focuses on deviation of established practices (Schumpeter 1964: 100). Thus, the new combination may include scientific or R&D knowledge but is not necessarily reduced to it. Furthermore this rarely creative action by a minority of entrepreneurs is not reduced to inventors, scientists or higher educated people (ibid. 115/129). However, it still depicts a research gap in economics and economic sociology. While the economic theory still cannot adequately grasp the creative moment and risky, irrational decision making, the economic sociology prefers more dealing with recurring action pattern (Deutschmann 2008: 100). Moreover, in the course of raising network research in both fields the rejection of this phenomenon referring to a stereotyped heroic entrepreneur can be found (Edquist et al. 2010b; Köhler 2008; Rammert 2008). But dealing with this phenomenon and taking over the entrepreneur perspective by no means that the entrepreneurial process and setting up of an innovation is understood as solely done by one actor. Conversely, it has to be added that recent research by the cognitive social psychology and the knowledge sociology stress the social character of knowledge and connect individual with institutionalized knowledge structures (Drepper 2007). Cognition refers not only to an individual consciousness but is always part of a social context and is only comprehensible from this (ibid.). Therefore, KIE is here defined as generating an innovation that is new to the reference system of its corresponding low-tech sector or product field and is this way extending the corresponding sectoral knowledge base. A sectoral knowledge base consists of a set of shared knowledge within an industry or product field concerning specific scientific and technological parameters, a certain intellectual understanding of technical functions and performance features or regarding the use of materials and products (Robertson/Smith 2008: 99).

This sectoral knowledge base and related technological regimes are seen as an explaining variable in terms of powerful restrictions on entrepreneurial activities and the organisation of innovation and production activities (Malerba 2006). Radosevic in his systemic view on entrepreneurship in national innovation systems even goes so far that individuals are incapable to generate entrepreneurial activities without any sufficient entrepreneurial propensity of the system and structural opportunity (Radosevic 2010: 55). Just this propensity is denied regarding mature technological, routinized regimes as in case of low-tech sectors while from new emerging industries particularly more opportunities for entrepreneurship are expected following industrial lifecycle theory (Breschi/Malerba 1997; Spilling 2008). On the supposition that the sectoral innovation system of low-tech sectors does not support entrepreneurial opportunities for KIE, it should be explored, *how KIE nevertheless succeeds in generating an innovation in the institutional environment of a low-tech sector.*

In the following a conceptual framework and the methodological approach is outlined for this investigation. A first description of the sectoral innovation system of the German textile industry will be given as well as a presentation of the opportunities that can be identified at the three case studies. The paper concludes with the first preliminary results using perceptions from actor-oriented neo-institutional concepts.

2. Conceptual framework

2.1 The concept of sectoral innovation systems

The sectoral system of innovation (SIS) approach is especially suited for embedding the KIE cases because it offers "a way to examine the dynamics of sectors due to innovation and technological change and the coevolutionary process taking place among knowledge, technology, actors, and institutions." (Malerba 2005) Thus, apart from a single reduction to R&D it depicts a multidimensional and dynamic view on innovation in sectors in which KIE and its constituent dimensions can be integrated. Basically, an innovation system is characterized by certain stability and components related to each other and interacting together in an intended and unintended way in order to develop, diffuse and utilise innovation (Bergek et al. 2005).

More precisely Breschi and Malerba defined a SIS very close to technological systems as "a system (group) of firms active in developing and making a sector's products and in generating and utilizing a sector's technologies; such a system of firms is related in two different ways: through processes of interaction and cooperation in artefact-technology development and through processes of development and through processes of competition and selection in innovative and market activities" (1997: 131). Later Malerba refers explicitly to the knowledge dimension by conceptualising a sectoral system as "the collection of economic activities organised around a common technological or knowledge base in which individual enterprises are likely to be either actual or potential competitors with one another" (2004: 428) Malerba integrates different concepts like the industrial lifecycle theory or Pavitt's taxonomy of 'innovation' modes for understanding and explaining the differences of innovation in various industrial sectors. According to that big divergences in the conditions of innovation opportunities exist among industrial sectors concerning science, technologies and knowledge bases as well as the institutional context (Malerba 2006: 23) and have therefore also various effects on entrepreneurial performance and the organisation of innovation activities (Malerba 2005). In the same direction Pitt and Nelle (2008) argue for their study about improving the innovativeness and entrepreneurship in the Australian red meat industry. According to them, "the resulting entrepreneurial orientation, will impact on how problems and opportunities arising from changes in the external environment are perceived by the players in the sector" (2008: 4).

The literature and empirical studies according to SIS and technological regimes is not quite clear for allocating the entrepreneurial orientation of the German textile industry. Spilling (2008) for instance, differs between the two ideal types of entrepreneurial and routinized regimes. He describes the routinized regime in accordance to the Schumpeter Mark II system with large existing firms as the main innovators and a less accessible knowledge base based on R&D (ibid.: 147). Malerba and Breschi differ also between sectoral innovation systems referring to Schumpeter Mark I and II. But in their transnational sectoral analysis (using data from 1978 to 1991) they allocated the clothing and textile sector to a third category as traditional sectors with "many innovators […] with no specific knowledge spatial boundaries" (1997: 143 et seq.). Since that time the textile industry in Europe and in Germany has undergone a restructuration and concentration process whereas since around 2000 new innovation paths in terms of new functional and technical textiles emerged (Meyer-Stork 2006). This has probably led to a new industrial lifecycle removing the existing system. Thus, it is not that clear how to characterize this SIS. However, persistence of the mature system is to presume. According to this it is worthwhile to conduct a new analysis of the textile SIS referring to the period between 1999 and 2007 in consistent with the conducted case data. In particular the empirical analysis should focus on the entrepreneurial orientation of the SIS. For that reason the following hypothesis is deployed: The low-tech sectoral innovation system of the German textile industry is not entrepreneurial-oriented and does

either offer no or only low entrepreneurial opportunities. In other words, it does not support the emergence of KIE.

In addition, the boundaries of the SIS are outlined in accordance to Malerba who depicts a sector as a set of activities that has product groups for a certain demand and customary knowledge in common (2005: 385). However, this framework should be understood as a construct concerning the sectoral boundaries. In a broad sectoral system usually different innovation systems related to different product groups can coexist (ibid: 387) as it is also the case for the textile industry. For analytical reasons aiming at a low-tech sector level above all the sectoral and firm analyses refer to the textile industry (NACE code Rev. 1.: 17) in Germany and where it is possible to data from the subsectors to which the cases can be allocated. The main dimensions for a sectoral systemic framework are the *knowledge and technological domain, actors* and *institutions*. These conceptual dimensions will be extended by the *entrepreneurial* dimension referring to related functions that can be found at Bergek et al. (2005) and Edquist (1997). They listed, for instance, "experimental experimentation" or "institutions enhancing entrepreneurship" as functions of an innovation system. The entrepreneurial dimension is integrated into the other dimensions since it appears in terms of specific entrepreneurial knowledge, entrepreneurial actors and activities, and institutions.

As mentioned before a sectoral knowledge base describes a certain set of shared knowledge by the industrial actors of this sectoral system. Moreover, the SIS can differ in knowledge domains and technological regimes to other sectoral systems. Moreover, technological regimes can reach out or coexist beside other ones in a sectoral innovation system. Malerba further differentiates here between degrees of opportunity, accessibility and cumulativeness of knowledge for characterising a SIS (2005: 389). The diagnostic questions concerning the knowledge dimension are:

- What are the knowledge domains and what kind of opportunities for innovation do they offer?
- What are the main sources of knowledge and how is their accessibility?
- What is the degree of cumulativeness and appropriability of knowledge?
- Does entrepreneurial experimentation play a role regarding knowledge development?

The next dimension refers to the actors of the SIS. Though Malerba's sector and SIS definitions place the companies producing products/components from the same product group at the center other organisations and individuals are included as well. Malerba here explicitly refers to consumers, entrepreneurs, scientists, users, suppliers, universities, financial institutions, government agencies and industry associations which can differ in their importance and meaning to the system (2005: 385). With recourse to the knowledge and institutional dimensions these agents can be "characterized by specific learning processes, competencies, beliefs, objectives, or organizational structures, and behaviors, which interact through processes of communication, exchange, cooperation, competition, and command." (Ibid.) The diagnostic questions considered for this dimension are:

- Who are the actors mainly involved in innovation activities, knowledge production and technology development?
- Can entrepreneurs be identified among the innovators?
- Which dominant competencies and practices of the innovators can be identified?
- What kind of prevailing interactions can be assessed for innovation activities?

The actor's behavior and interactions are enabled by institutions – the third dimension. They are understood as norms, routines, common habits, established practices, rules, standards, laws et al. Thereby institutions can have different characters in terms of more or less binding/enabling, or on a formal or informal level. Finally they can be also shaped through interactions among agents as a recursive process. Malerba further differs between national and sector specific institutions, e.g. sectoral labor mar-

kets or sector specific financial institutions (ibid.). This dimension does not only shape actors but also depicts the sectoral knowledge base which is composed by certain accepted practices, rules and standards etc. The diagnostic questions in this respect are:

- Which sector specific institutions can be assessed for describing the sectoral knowledge base?
- Are there any institutions influencing the direction of knowledge or innovation development?
- Can any entrepreneurial orientation be assessed?
    - By the number of start-ups?
    - By institutions enhancing entrepreneurship through legitimising, mobilising of resources or providing free utilities (Bergek et al. 2005)?

Altogether these dimensions are strongly connected among each other and only separately considered for analytical reasons. However, it should be noticed that specific knowledge or new knowledge held by an actor of the SIS is neither automatically shared by all actors nor belongs necessarily to the sectoral knowledge base. For example, scientists doing applied research are holding knowledge that is maybe not established and commonly shared by the central actors or established in the sectoral knowledge base. The same holds true for individuals or organisations. Here the accessibility can sometimes be limited only to the individual (entrepreneur) or organisational level. In this regard knowledge has to be considered as distributed among different agents and also knowledge bases (Smith 2003). Robertson and Smith (2008: 99 et seq.) describe the knowledge content of an industry by distinguishing between such different levels of knowledge bases as firm-specific, sector or product-field-specific, and widely applicable knowledge bases. Finally institutions develop, maintain and distribute this knowledge (ibid.) and can provide entrepreneurial opportunities this way which is elaborated next.

2.2 The concept of entrepreneurial opportunities

The dominant perspective in entrepreneurship research stems from the nexus of an entrepreneurial individual and a valuable opportunity (Grichnik 2006; Radosevic 2010; Shane 2003). Nevertheless many authors criticise that this discipline has not succeeded in explaining this phenomenon adequately (Deutschmann 2008; Radosevic 2010). The following conceptual considerations refer to Radosevic's approach linking entrepreneurship with innovation systems (Edquist et al. 2010a; Radosevic 2010).

Radosevic's motivation of a systemic perspective on entrepreneurship is based on the assumptions that entrepreneurship is not randomly influenced by its environment and goes beyond a single entrepreneur. But so far this research gap misses a theoretical framework that he sees increasingly filled by a systemic and network based entrepreneurship research (2010: 52 et seq.; also Malerba 2010). According to this entrepreneurship is a „systemic (network) phenomenon, and emerges as an outcome of interaction (alignment) between technological, market and institutional opportunities" (Radosevic 2010: 53). Besides very few is known about the effects and dissemination of entrepreneurial opportunities in general (Radosevic 2010; Grichnik 2006) as well as for low-tech sectors. Radosevic expects to learn more about the dynamics of entrepreneurship by differentiating between market, technological and institutional opportunities. Yet these forms of opportunities were studied separately or conceptualised as substitutes. Particularly the role of institutional opportunities remained theoretically backward so far (Radosevic 2010: 64 et seq.).

For the concept of *technological opportunities* Radosevic refers to Schumpeter who understood them basically as infinite. But this does not count for innovation opportunities. Additionally, technological opportunities are seen as economically irrelevant as long as they cannot be implemented in an innovation. However, they are widely considered to be constitutive for realising product or process innovations. While opportunities for innovation are influenced by demand and termed as endogenous to the

economic system, technological opportunities are termed as exogenous springing from inventions outside this scheme (Radosevic 2010: 56). Besides there exists a sector-specific understanding of technological opportunities based on sector-specific research of technological regimes (e.g. Breschi/Malerba 1997). Here it is assumed that technological opportunities differ in space, time and sector respective to the technological regime (cf. Shane 2003, Freeman/Perez 1988, Breschi et al. 2000, OECD 2003 in Radosevic 2010: 57).

Market opportunities are based on uncertainties and information asymmetries that are differently sensed. Besides they can emerge in terms of products and resources that have not been valued adequately so far. However, information about prices or profits of new products can only be estimated in this respect. Market opportunities can only exist where needs and requirements have been articulated. This process of articulation is again deeply related to the existence or absence of institutional opportunities. Especially regarding changing industries and new technological fields this function of market development is usually underdeveloped (Radosevic 2010: 57 et seq.). Radosevic emanates in his approach from a multidimensional character of opportunities. The interrelation between market and technological opportunities is not necessarily understood as complementary, i.e. market opportunities alone do not guarantee the realisation of technological opportunities. Also market incentives and therefore institutional opportunities play another role (ibid. 58).

Until now *institutional opportunities* have been hardly theorised with respect to entrepreneurship. However, Radosevic ascribes a central importance to them for matching technological and market opportunities. The fabric of market opportunities and entrepreneurial action is embedded in a web of values, norms, beliefs, traditions as well as formal and informal relations. Here also expectations and the conformity of entrepreneurs' and business partners' conjectures are cited (ibid. 62). Radosevic broadly defines institutional opportunities as those promoting entrepreneurs or innovation adherents in general. They occur in the course of the functionality of institutions that structure interdependencies between actors and mediate at the coupling of market and technological opportunities (ibid.). In his understanding of institutions Radosevic refers to Schmid (2004) who defines them as „human relationships that structure opportunities via constraints and enablement. A constraint on one person is opportunity for another" (Schmid, in Radosevic 2010: 61). Moreover, institutions function within further determining factors of technical change like relative prices, firm- and industry-specific routines, market structures, irreversible technological paths and lock-ins (ibid.)

With regard to the interrelations among these three opportunities it further has to be added that Radosevic stems from complementary components in that way that the absence of one can lead to matching problems. In this systemic context entrepreneurship is basically not understood as "the result of scarcity of entrepreneurial talent" but as a "binding agent" (Radosevic 2010: 66). According to this scarcity of entrepreneurship is not a result of shortcomings but of mismatch (ibid.). Thus here entrepreneurial activities are linked with a sector's entrepreneurial propensity and the structural features of an innovation system. The entrepreneurial propensity is thereby conceptualised by entrepreneurial opportunities (market, technological and institutional) and the entrepreneurial experimentation (Radosevic, unpublished concept) within the innovation system. Misarrangements regarding the combination of opportunities are referred to the underdevelopment, wrong orientation (e.g. anti-business orientation of a SIS) or problems of compatibility due to an isolated development of one of the opportunity components (ibid.). According to this view entrepreneurs are not able to conduct successful entrepreneurial activities in the case of a structural incompatibility of the opportunity components and insufficient entrepreneurial propensity.

2.3 Connecting the sectoral with the entrepreneurial dimension

Recalling the starting assumption that the low-tech SIS offers no or only low entrepreneurial opportunities, KIE had to be excluded according to the systemic view on opportunities. In favour for explaining the occurrence of KIE even in the absence of opportunities in the direct environment, however, a structuration view is needed. The entrepreneurial process is understood as a recursive interaction considering entrepreneurs who are not only discovering but also creating opportunities (Garud/Karnøe 2001; Sarason et al. 2006). The application of a structuration view allows emanating from wilful actors who are able to either sense or match distributed opportunities from other sectoral knowledge bases or other SIS. This implies that the analysis differentiates – apart from Radosevic's concept – between opportunities from different SIS. The NIS would be a too general frame for analysing the opportunity environment and often concentrates on some leading economic industries (Breschi/Malerba 1997). In contrast low-tech sectors have been mostly neglected as a unit of analysis so far (Hirsch-Kreinsen/Jacobson 2008). The analysis at the sectoral level in a first step will consider general entrepreneurial opportunities while their occurrence and interplay for KIE is investigated in more detail using the example of three different case studies. Here it is asked for the background of each opportunity component. The following diagnostic questions are considered:

- What kind of technological, market and institutional opportunities can be identified?
- To which knowledge base (entrepreneur, firm-specific, sectoral) and to which innovation system can be each opportunity related (textile, other SIS or NIS)?
- And –finally – how were the opportunities matched?

3. First empirical findings

The first empirical findings conducted at the sectoral and firm level are based on multiple sources. The analysis of the SIS aims at characterising the structure and innovation practices in the German textile sector for understanding the deviation of generic KIE cases. For that reasons quantitative data from the Mannheim Innovation and Enterprise Panel (ZEW) and Destatis/Eurostat are used. Additionally industrial innovation reports as well as primary data from conducted expert interviews with representations of industrial and research associations, consultants have been analysed. The quantitative data covers mainly the period between 1997 and 2006 where it is possible also until today. The primary data deals with cases of KIE that occurred between 2000 and 2006 and was conducted in 2009 and 2010 as explorative case studies.

3.1 Sectoral analysis: innovation system of the German textile industry

In the nineties the textile industry suffered worldwide overproduction and saturation of consumer demand. This trend was followed by a declining international competitiveness of the German industrial production. Textile commodities close to the consumer are almost marketed as prefabricated imports at the domestic market (Meyer-Stork 2006). Especially in the German textile industry the number of firms decreased significantly from 5,162 in 1999 to 3,921 in 2007. In the same time the number of employees was reduced from 138,308 to 97,558 by nearly 30 percent (Destatis/Eurostat). The turnover did not break down as the former numbers: it went down by 15 percent to 15,040.6 million Euros in 2007. Contrary to this general shrinking there is growth in the field of technical textiles that points to a change and improvements in the economic situation (Rwi 2010: 260).

The *Knowledge Dimension*

The textile sector can be roughly divided into the subsectors of home textiles, clothing and technical textiles. Many processing steps along the textile supply chain like fiber processing or textile refine-

ment are based on chemical knowledge. The most established *knowledge domains* can be mainly located to the traditional sectors of home textiles and clothing whereas the domain of technical textiles offers more innovation *opportunities*. In contrast to textile commodities close to the end-user that aim at visual and haptic changes with a low innovation gravity and short development cycles, innovation processes of technical textiles are characterised primarily by functionality and deeper development efforts. Even the research is differentiated systematically from the traditional textile development activities (Meyer-Stork 2006:42). In many cases the textile material is used as a component in combination with other materials or elements. The resulting interactions are complex and their optimisation is long (ibid. 50). Though innovations in these component segments are hardly notable in products by consumers they can be mainly characterised by creative destruction in terms of substituting or extending materials in new fields of application (RWI 2010: 240). Leading themes at this time have been product innovations with increasing customer value in the fields of protective textiles and clothing, bio-functional textiles or textiles combined with electronic as well as environmental and economic process technologies, transport technologies and the optimization of textile care and sterilisation (Begemann 2003: 262 et seq.). The knowledge connected to the opportunities of these themes is mostly distributed among other high-tech sectoral knowledge bases like biotechnology, medical engineering, electronics or micro system engineering.

According to van Delden (2006) the industrial lifecycle of technical textiles can be meanwhile suited in a maturity stage as well. Primary requirements as fire and temperature resistance, lightfastness or chemical resistance have been already implemented at the market (2006). The focus is rather on the production of secondary products with features like low processing costs and prices, low weight, or increasing durability whereas the grade of innovation regarding raw materials diminishes gradually. The focus of R&D is rather lying on the downstream process in terms of new functionally improved end products while employing established, proved process technologies and raw materials (ibid. 17 et seq.). While considering information sources for this knowledge it becomes obvious that this is mainly created by research institutes. From the companies' perspective sources for innovation differ clearly against this. According to data between 2000 and 2008 from the Mannheim Innovation Panel (ZEW) the main *information sources* are the own company and customers. Moreover, suppliers are clearly less important which is in contradiction to the common assumption about low-tech firms as supplier-dominated firms (e.g. Heidenreich 2009). However, the importance of customers agrees with the new industrial customer markets from which the textile firms need to source information. Technical fairs are another important source. In contrast R&D service providers, public research institutes and universities were rated very low as information sources as well as industrial associations, patents and standards. Besides more than 50 percent of the textile firms constantly have not created any research and development knowledge since 1998. At least the number of firms with occasional R&D and also continuous R&D activities has increased slightly until today (ZEW). The *accessibility* to this knowledge is not quite clear yet.

With regard to the degree of *cumulativeness* and *appropriability* of knowledge it is rather obvious that the accumulated knowledge for process optimisation and quality improvements alone will not be sufficient for the mostly traditional firms that have survived so far. Against this, the new technical textiles have cumulativeness for secondary or end products at command while the newly developed materials have diverse, compatible and flexible features for application (Meyer-Stork 2006). *Entrepreneurial experimentation* shows up here in terms of the exploration of a variety of new technologies and different types of application in the sense of Bergek et al. (2005). However this is mainly not achieved by entrepreneurs but probably by research institutes where the economic exploitation remains open.

The Actors Dimension

A rising trend of innovation activities in course of the identified opportunities cannot be assessed among textile firms. As the main actors involved in innovation activities first all textile firms performing in new technical textiles, especially the producers of intelligent fibers, are to mention as the "winners in the development of technical textiles so far" (Knecht 2003: 14). According to the Mannheim Innovation Panel (ZEW) the share of innovators among textile firms is rather stable at around 50 percent. Since a peak in 1999 the trend has been rather declining. Also the innovation intensity of firms has remained more or less stable between two and three percent since the nineties. The share of R&D expenditure in value added in the textile industry amounted around two percent between 1999 and 2007 (Destatis/Eurostat). Taking into account the dominant *competencies* and *practices* for innovation at the firm level, several sources prove general low R&D activities. The ZEW data shows slightly increasing numbers of textile firms with occasional and continuous R&D compared to a clear majority of firms without any R&D (ZEW). There can also be no increasing trend identified at the share of high skilled employees. The share of R&D employment in the number of persons employed for textile industry amounted constantly around one percent between 1999 and 2007 (Destatis/Eurostat). The average of manufacturing industry amounted around four percent compared to this (ibid.).

Apart from common low-tech characteristics the share of product innovators is significantly higher for the textile industry even compared to the clothing industry. The rate of process innovators of both sectors is constantly below the one of product innovators (ZEW). The share of cost reduction has remained more or less constant but on a low level. Sales increase due to improvements in quality improved from 2002 to 2006. Up from this time it significantly declined from 3.6 percent to one percent in 2010 (ibid.) which obviously points to the limits of the quality strategy. Most of the firms within the Mannheim Innovation Panel indicated for the period between 2000 and 2008 that product development was mainly done internal. The fewest firms let their products mainly develop by third parties whereas the development together with a third party has considerably increased (ibid.). Regarding protection practices most firms prefer the advantage of a temporal headstart, secrecy and trademarks. Registered design lately increased while patents are less important in this respect. In general the application of different mechanisms has increased from 2000 to 2007. Experiences with the violation of intellectual property rights in the course of the international market liberalisation have been a serious, determining factor.

The innovation statistics do not allow identifying the share of entrepreneurs among the innovators at this sectoral aggregation level. The sectoral founding intensity (absolute foundations per 10,000 employees) by the Mannheim Enterprise Panel remained between 1997 and 2006 at 0.05 on average for the textile industry and for clothing at 0.03. Compared to this the average of all sectors in Germany in this time accounted for 46 (ZEW). Besides this very low sectoral founding intensity no increase in spin-offs from research institutes was noticed by the Confederation of the German Textile and Fashion Industry. In the expert interviews the industrial representatives rather pointed to the form of corporate entrepreneurship which is quite hard to measure in statistics. Thus, in the textile industry many traditional firms survived by learning to diversify their business or set up new business following the market development. When the new business unit has been successful, it is sometimes outsourced or even substitutes the former main business after a while.

According to the customer market the textile industry has broadly opened up to other sectors. Besides the traditional customers of producers in the field of home textiles and clothing also national economic important industries like automotives, aerospace and even machinery and plant engineering could be enlisted for the new textile materials. But also the traditional customers have benefited from this development with innovative products and services for maintaining and extending the client base as well as in new product supply chains (RWI 2010: 245). The articulation of new demand at consumer mar-

kets compared to this is still weak due to the fact that the innovative textile components have rather improving or substituting functions in existing end products.

The same way the sector has undergone a concentration process the industry associations were affected. They refer about no entrepreneurial or specific innovation programs and seem to be less important for innovation activities. Their main function is the distribution of the latest results and information of the textile research board. The tasks of this central actor – that already has been existing for more than 50 years – is to promote the development of the textile research and its industrial application, to mediate between textile industry and research and to prove their cooperation economically as well as scientifically (Begemann 2003). According to the board, research institutes play a decisive role due to the small and medium-sized structure of the textile and clothing firms that have hardly own research capacities available (ibid. 268; Meyer-Stork 2006). Besides also qualified experts from the industry are involved in the committees. The industrial research is mainly based on public funding by the consortium of industrial research associations (AIF) and the Federal Ministry of Economics and Technology as well as the Federal Ministry of Education and Research. Promoted projects are those with several actors from science and industry, especially SMEs, but they refer still to a pre-competitive stage. Though the scientific research infrastructure seems to be in a good position in Germany, weaknesses in the transfer of research results have been assessed by the chairman of the German textile research board (Meyer-Stork 2006). According to him this is due to the difficulties for medium-sized companies in finding the right middle course between pre-competitive joint development and a permanent distinction of an own market niche (ibid. 50). A consulting expert stated in this respect that more far reaching industrial innovation activities without public promotion and research hardly exist in Germany anymore. The permeability of knowledge along the dissected textile supply chain is traditionally limited. Often the specialised textile firms have no more far reaching knowledge than certain knowledge of their direct business partners which could be a serious barrier for sensing opportunities from distributed knowledge bases.

With regard to financing institutions only a few sources have been reviewed so far. The ZEW data for public funded innovators has been fluctuating from 2000 to 2008 between eight to 25 percent. A report about “opportunities and challenges for financing innovation in the European textile and clothing industry” within the European project NetFinTex investigated firms and financing experts from Germany among other European countries. The study concludes with assessing a considerable gap between the textile entrepreneurial community and the investors. Reasons for this are seen in an underestimation of the growing potential in textiles by both groups accompanied by a rather negative image of the sector as a whole, scarce familiarity with the financial instruments at the entrepreneurial side as well as “unfamiliarity with IPR approaches and opportunities, especially in the case of accession to equity capital.” (Netfintex 2007: 37) In particular a lack of information sources regarding cooperation with venture capitalists and business angels was assessed. Finally also the industrial supply chain and the capital market are characterised as fragmented (ibid. 38).

The relevance of cooperation along the whole value chain has been stressed by several experts (Knecht 2003; Begemann 2006), nonetheless, several empirical sources support the general low cooperation performance in the textile sector on the European level (Heidenreich 2009; Hollanders/Arundel 2005) as well as on the national level (ZEW). Cooperation with customers was slightly more often indicated by the firms. The collaboration with universities and research institutes was again lower rated (ZEW data between 2000 and 2008). In the minor case of cooperation, however, the RWI evaluation of the industrial community research found that the orientation of the textile firms was decisively stimulated by research institutes and the research board which also established contacts to neighbouring sectors (2010: 244).

The Institutional Dimension
Connected to the introduced actors above a *specific institution* in this industry is the stable fragmentation of R&D activities between research and industry without leading to assessable increasing spin-off activities or rising investments in their exploitation on the industry side. Firms on the other hand still develop products mainly internally in line with the limited knowledge flow along the value chain that is shaped by suspicion and divergent pressure of profit margins.

The German textile research board with its industrial and research members can be seen as the most important formal institution influencing the *direction of knowledge and innovation development.* Rammert terms industrial joint research as an institution that evolved to control the destructive power of innovation (Rammert 2000: 167) which seems to be still the case in the textile SIS. Besides the market liberalisation and connected to this the price competition and catching up of emerging markets has led to more technology orientation. But also industrial customer markets like the automotive or aerospace industry contribute to a market pull and influence the direction of innovation activities.

Regarding the sectoral labour market and *specific financing institutions* it is preliminary to state that their peculiarity lies in being neither innovation nor entrepreneurship-oriented. Also the number of start-ups does not show an entrepreneurial orientation. Only the emergence in terms of corporate entrepreneurship, indicated by experts, points in this direction but is hard to quantify. According to a textile association and the German research board no sector-specific *institutions enhancing entrepreneurship* exist. Public supporting programs used for innovation have rather a general character aiming at interdisciplinary technologies.

All in all these preliminary results further confirm the character of a low-tech sector where the majority of firms is not or low investing in innovation and R&D. Though the science and technology side is distinct in Germany, no linear innovation model can be identified. Thus on the one hand research is following the market and industrial customers on the other hand it delivers orientation and promotes ideas (Meyer-Stork 2006). Other industrial experts confirmed this but also stressed the firms and customer markets as innovation drivers. Despite the industrial orientation of research, a broad interaction with the industrial environment cannot be assessed. In place of cooperative interactions fragmentation prevails between actors from science, industry and investors. The SIS seems to offer no incentives to researchers for spin-offs whereas corporate entrepreneurship seems to be more common for industrial actors following innovation trends. The impression arises that the SIS is oriented to scientific precompetitive knowledge production while lacking knowledge and institutions for its economic exploitation. Thus the textile SIS differs clearly from entrepreneurial regimes in the sense of Schumpeter Mark I pattern and could be a sectoral peculiarity which needs further validation. Finally these first results refer rather to a structural incompatibility of within the SIS with underdeveloped market and underdeveloped and wrong oriented institutional opportunities.

In the context of mature fields with stable structures resistant to change, institutional theory would not expect entrepreneurs being successful in radical change but in premature fields with unfolded institutional order (Pacheco et al. 2010: 986). Somehow both can be found in the analysis of the textile SIS. The following case analysis will give a short overview of KIE in such an environment.

3.2 Case study analysis: entrepreneurial opportunities

In order to understand the knowledge-intensive deviation from the SIS the opportunities of these cases are considered in more detail. The three selected cases show a broad variance of how KIE can emerge (as a spin-off, in cooperation or internal) in the textile sector. The case data was conducted within the

case study research for the AEGIS project. Because KIE has been firstly explored in low-tech sectors the case study research was based on an explorative research design. Data concerning the background of the emergence, determining factors, market development et al. was broadly conducted as well as content analysis and secondary data to trace back the innovation and entrepreneurial process. This data pool should enable identifying the diverse backgrounds of the opportunities as well as the contribution by the entrepreneurs. The low number of cases is irrelevant in so far that the main point is to identify structural opportunities or not in which the cases are embedded. Moreover, the main objective of this work is to grasp the scope of the field of study without making a claim to be complete.

The first case was recommended within an expert interview with a representative of the German Textiles and Fashion Industry Association. It is about a spin-off from a research institute in the field of preparation and spinning of textile fibers. It was founded in 2005 with the legal form of a public limited company (PLC). For the establishment a 100 percent subsidiary (Ltd.) of the institute, a company for materials testing, holds the main share. Both are located in a former industrial district for man-made fibers. Knowledge-intensive entrepreneurship showed up in this case in terms of introducing new functional cellulosic fibers applied in different consumer products to the market. Thus the exploitation and commercialisation of this new technology and material build the knowledge-intensive activities. The production of the innovative fibers is based on a technology that was developed and patented by the institute and is therefore deviating from the knowledge of cellulosic fiber production and usual application according to the product's field knowledge base. This *technological opportunity* can be drawn back to former contract research for a monopolist of cellulosic fibers in the German market. The discovery of the technology that enables cellulosic fibers to absorb certain additives without losing its strength, however, happened by coincidence. Hence, the knowledge of the technological opportunity had not been integrated into the sectoral knowledge base but could be allocated to the scientific knowledge base within the textile SIS. The monopolist located mainly in the chemical industry was not interested in the high-priced niche market of these new cellulosic fibers since it is a mass producer of man-made fibers above all. This disinterest can be seen as the *institutional opportunity* for a new entrant. The development of the process application of the fibers was conducted by the institute which can be also considered as another institutional opportunity within the textile SIS. The development activities were funded by national and regional public innovation programs that depict further institutional opportunities but offered by the NIS. At this time the market for functional textiles was emerging with different technologies nevertheless often aiming at similar functionalities, e.g. anti-bacterial or climate regulating. Some first successful product innovations and raising interest for prototypes at fairs indirectly showed market demand for these functionalities. But the market niche of functional cellulosic fibers had not been explored this way before so that it is considered as a *market opportunity* within the textile SIS.

Already during the development process some interested processors of the fibers could be attracted and participated in the funded projects. But after this and despite all these opportunities the institute did not find any potential buyer. Finally due to certain expectations by political investors the spin-off was founded with the institute's director as the chairman. For the successful marketing and commercialisation an experienced entrepreneur could be won where the scientists had failed. He has no academic degree but founded 14 companies mostly in the electronic sector. After negotiations the entrepreneur became the second chairman and organised further investors from his social network. Due to his capabilities and creativity two consumer products were created with the innovative fibers. Not before the fibers were applied in this consumer products their value and potential was understood by potential customers and could be marketed.

Notable for this case seems that established industrial actors from the textile SIS were neither willing to risk nor able to exploit the new scientific knowledge for this market niche despite these opportuni-

ties within the SIS. In this context it is referred again to Radosevic who stressed that in changing industries and new technological fields market articulation is usually underdeveloped (2010). However, this kind of mismatch was overcome by the developed consumer product innovations that created new market opportunities in the field of cleaning products and in the textile SIS. Moreover the occurrence of this case can be explained by recurring to neo-institutional theory. According to this the set up of the significant innovation stems from the fringes of the sectoral field (Dolata 2011; Greenwood/Suddaby 2006). Applied on the SIS the integration and socialisation of central actors by the sectoral institutions prevent them from recognizing alternative practices. In contrast actors from the periphery, like the institute's director and the entrepreneur as a lateral entrant, are less familiar with these institutional practices and expectations and therefore more likely to question them and promote change (Pacheco et al. 2010: 986). Also the innovation at the beginning of the textile supply chain is consistent with this.

The second case was identified through internet research as it was awarded for pioneering activities in the textile industry. The traditional family business has already existed since 1956 and started with bedding clothes. Then it diversified in the field of medical textiles for hospitals and is operating in decoration fabrics and curtains. This case shows KIE in terms of corporate entrepreneurship. The patented innovations in the fields of conveyor belts and workwear led to the foundation of a subsidiary in 2004 because both new product fields should not be marketed together with the two existing product families. The family business and subsidiary together employ 40 full-time and 20 part-time employees. Both firms are independent of bank capital or any other form of debt capital. For about 20 years there have been efforts made by conveyor belt as well as marketing firms to produce advertisement on conveyor belts but without any success. The textile manufacturer developed a new process technology and patented it. Therefore not only textile expertise was needed but also expertise from other fields as chemistry. These had to be newly combined and applied. The product's extreme requirements were quite challenging and depicted problems which had not been seized and solved before. Then the processing was implemented with a traditional conveyor belt producer and is now marketed with an integrative operator concept.

The peculiarity in this case is that actually no opportunity can be identified in the direct environment of the SIS. One day, the owner drew his attention to a dirty conveyor belt in the supermarket and thought of a more hygienic and visually appealing belt. When the *market opportunity* was analysed the firm realised that promotion at the area of the checkout counters does not exist in this way. Thus it is allocated outside the textile SIS in the marketing and metal producing sector (to which the production of conveyor belts belongs). A *technological opportunity* in a wider sense can be seen in the firm-specific knowledge base related to the manufacturing of decoration fabrics. *Institutional opportunities* neither in terms of enhancing entrepreneurship nor in terms of absent constraining institutions could have been identified yet. After the product launch it became apparent that the textile firm occupied a new market niche in the supply chain between retail and branded companies. The instituionalised practices and power structure for the German market became a serious barrier for the new entrant in this field. However, such institutional constraints do not exist in several Eastern European sales markets where the textile firm could easily introduce the belts. A constitutive prerequisite of the operator concept, beside the technical reliability of the product, was to provide belts regionwide to a supermarket chain as well as product-related service on site. In other words the firm built an infrastructure in all these countries without referring to any existing network before.

First of all it is interesting that this central actor diversified in a field out of its common business environment. Moreover, despite missing opportunities of the textile SIS and institutional barriers at the

new customer market the firm succeeded in sensing opportunities in other markets. The entrepreneurial capabilities of the firm and risk-taking of the owner can be considered as the most important factors.

The third case was also identified by internet research as the firm was awarded for its pioneering innovation. It is about a cooperation between a traditionally yarn producer and an innovation service provider. The company was founded in 1953 as a family business. Right from its beginning the company specialised in elastic threads for surgical stocking. There are 83 employees, mostly skilled and semi-skilled, working at the company. KIE emerged in terms of a new elastic conductive thread that had not existed before according to the sectoral knowledge base. The patented innovation led to the establishment of a new business unit.

Also in this case no technical invention had existed for being discovered as a *technological opportunity*. The field of variable electronics had already existed when the innovation process started. But within this new technological path other technologies focusing on fabrics or fibers were pursued. No one had thought of integrating conductive wires in the yarn construction so far which opened up several new fields of application due to unique features. Then the rented scientists of the service provider came up with this idea. The expertise and firm-specific knowledge base in elastic thread production was combined with the cross-sectoral creative thinking of the service provider who is specialised in technical innovation processes at SMEs. The *market opportunity* was sensed because of first industrial attempts in the emerging field of variable electronics. It can be allocated to the textile SIS but also to the electronic SIS. With the help of the service provider who conducted patent and market analyses this opportunity was sensed. Here again the direct articulation of demand by customers was still missing and led also to the development of product applications for demonstrating market opportunities to potential buyers. Also *institutional opportunitie*s in terms of research funding by public programs of the NIS were identified by the service provider.

However, the initiative of these innovation activities is traced back to the managing director of the textile firm. After a new shareholder had taken over the firm and invested in the location and equipment there have been also expectations of further going innovation activities. While the product lifecycle of the surgical stockings did not promise innovation opportunities anymore, the managing director decided to open up a new business field. Preceded attempts to win research institutes had been unsuccessful. The innovation process was mainly moderated by the service provider then. The only restrictive condition by the firm was that the innovation should be processed with the new equipment so that the field of elastic thread production was maintained. In the end a new material was created that opened up several new technological and market opportunities for the textile SIS. The deviation from established innovation practices at the textile firm was mainly overcome by the external view of the development partner and the promotion of the managing director.

4. Interim conclusion

In this first conceptual and analytical outline it became obvious that KIE occurs under specific circumstances which are hardly to explain by identified previous concepts and sectoral investigations. For that reason Radosevic's concept distinguishing between market, technological and institutional opportunities was applied to the framework of the sectoral innovation system. The system framework was extended by a structuration perspective justified by the starting assumption of a low likelihood of discovering opportunities in a mature low-tech sector.

The sectoral analysis showed that the changes in the textile SIS since the beginning of the new century cannot easily allocate to neither a routinized nor entrepreneurial innovation system. Technological opportunities and scientific knowledge production could be assessed but on the industrial and also research side rather hesitating attitudes prevail instead of an entrepreneurial propensity which point to structural incompatibility of opportunities in the SIS. Apart from entrepreneurship in terms of start-ups corporate entrepreneurship seems to be an established innovation practice.

Though the discovery of an entrepreneurial opportunity in a highly routinized environment with deeply anchored institutions is rather unlikely (Pacheco et al. 2010) illustrative cases of KIE could be found. A first investigation and allocation of the entrepreneurial opportunities showed a variety of sources within and outside from the SIS as well as various ways of matching these opportunities. Institutional opportunities supporting KIE could be rather ascribed to the NIS. The industrial entrepreneurs created their own technological opportunity instead of accessing the scientific knowledge base from the textile SIS. However, it seems to be no coincidence that two cases refer to new textile material located at the beginning of the textile supply chain close to material research and the chemistry sectoral knowledge base. Also actors from the SIS periphery or outside (rented scientists) as well as knowledge from other sectoral knowledge bases obviously play a role for KIE in this low-tech sector.

However, the circumstances of the cases and mechanisms for matching or completing the opportunities by the entrepreneurs' action could only be raised in a first step and deserve, with regard to the structuration perspective, further detailed analysis. In each case the implementation and market introduction of the innovation required enormous efforts by the entrepreneurs who mainly had to deal with hesitating and resisting potential development partners, customers, employees and investors.

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