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Isabel Schwinge

The Paradox of Knowledge-Intensive Entrepreneurship in Low-Tech Industries

Evidence from Case Studies of the German Textile Industry

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Foreword

This book attends to a highly innovative topic for social scientific innovation and entrepreneurship studies. It deals with conditions and deviation from innovation routines during the processes of knowledge-intensive entrepreneurship in so-called low-tech industries. Since the 2000s, research on the low-technology sector became an important field of research not only at the Chair of Economic and Industrial Sociology at TU Dortmund University but also in the area of European innovation studies. Several internationally and nationally funded research projects significantly contributed to a new understanding of innovation and restructuring of the economic landscape in the emerging debate on knowledge societies and economy. At the beginning of this debate, the central factor of knowledge was foremost based on new technologies and innovation based on R&D, while the sector of low-tech industries only received subordinated relevance with respect to coming social and economic development. In contrast to this view, low-tech research as a whole has clearly shown that low-tech industries are by no means technologically and economically stagnant. Rather, they play a decisive role in future economic and technological development of advanced countries.

However, until recently it remained unclear whether the low-tech sector also offers opportunities for far-reaching entrepreneurial activity developing new technologies and creating new market segments by using new knowledge. Following the current debate in innovation studies, this type of entrepreneurship is being termed as Knowledge-Intensive Entrepreneurship (KIE). At first glance, such entrepreneurial activity in low-tech sectors can be regarded as highly unlikely. Nevertheless, an internationally conducted research project entitled AEGIS (Advancing Knowledge-Intensive Entrepreneurship and Innovation for Economic Growth and Social Well-being in Europe) took up this issue. Embedded in a broader research agenda focusing mainly on KIE in high-tech and service sectors, the question for the opportunities and patterns of KIE activities in low-tech sectors has been raised. The project was funded from 2009 until 2012 by the 7th European Framework Programme in Social Sciences and Humanities. One of the project's premises was that KIE is highly industry-specific. Its features depend on the knowledge base, the main actors and institutions of an industry. For that reason, a specific work package dealt with the evolution and characteristics of KIE in the low-tech sector. Based on the expertise of research on innovation in low-tech industries, the Chair of Economic and Industrial Sociology implemented the work package in collaboration with five European research partners.

One of the outcomes of this work is the present study by Isabel Schwinge who was strongly involved in the research activities of the AEGIS project. This book is based on her PhD thesis finished in late summer of 2014. Isabel Schwinge links in her work the aforementioned unconnected fields of research in an empirical and a conceptual perspective: the low-tech innovation research that has delivered important contributions to the understanding of industrial innovation processes and the recent debate on KIE as a relevant mechanism for future economic growth and societal well-being. Because it has been primarily connected to the high-tech sector and start-ups, KIE seems a paradox phenomenon in technologically stagnating sectors like the industrial low-tech sector. In this research context, the gap of research and genesis of the book's main question for the emergence of KIE in the institutional environment of low-tech industries is placed. The author elaborately states the problem of this paradox and her seemingly contradicting research question. She solves conceptual inconsistences of both research strands referring to different innovation paradigms. In doing so, a broad and disparate base of literature is made accessible to the reader. How KIE emerges in the institutional environment of low-tech industries was conceptually and empirically not answered so that the author develops a broad framework. Starting point is that systemic concepts for explaining the emergence of KIE alone are not sufficient, given the assumption that the environment of low-tech industries does not offer opportunities to KIE. Willful actors need to be considered as well. Variant case studies in the German textile industry are the core of the book. They are based on a multilevel research design that is both quantitative- and qualitative-oriented and take into account the explorative character of the topic. In this way, the author is able to identify relevant determining factors and, in addition, mechanisms of KIE activity. Isabel Schwinge presents empirical paradox conditions for entrepreneurs: on the one hand the conditions in highly developed industries stimulate a few entrepreneurs for significant deviation from established technological paths and innovation routines, on the other hand the empirical results show that actors and institutional structures do not support this action. After thoroughly discussing these findings with the state of the art, Isabel Schwinge concludes that a systemically aligned opportunity for this rare phenomenon of KIE is not very likely in low-tech industries. Instead, institutional entrepreneurship activity becomes more likely for the successful implementation of deviating innovation. With these findings she deviates from disciplinary-constricted perspectives and contributes profound to the still undertheorized debate on KIE as a mechanism of industrial change.

Altogether, this book presents an elaborate theoretical and substantial empirical work about a subject area so far scientifically and innovation-politically insufficiently addressed. Isabel Schwinge succeeds in dealing critically with concepts from two different fields of research and opens up new perspectives for future research, as the differences in sectoral characteristics of KIE compared to the high-tech sector still deserve comparative studies. Her enriched approach of KIE offers a suitable and promising basis in this respect.

Hartmut Hirsch-Kreinsen

Preface

This book came into being because of my participation in the European large-scale project AEGIS "Advancing knowledge-intensive entrepreneurship and innovation for economic growth and social well-being in Europe" (2009-2012) for the work package on the sectoral dimension of low-tech sectors. The project gets in line with the recent debate on knowledge and the revival of entrepreneurship in economics. Its main idea is related to the perception of Knowledge-Intensive Entrepreneurship (KIE) as a necessary mechanism or agent of change mediating between the creation of knowledge and innovation and their transformation into economic activity. It seeks to move away from a person-centric view of entrepreneurship and considers entrepreneurs as generating and using knowledge, inserted in networks, systems, institutions and society and involved in dynamic processes of innovation and transformation. Entrepreneurship shapes and is shaped by the broader social context – including customs, culture, and institutions. Thereby knowledge does not necessarily originate from 'knowledge organizations' (universities, R&D organizations, etc.) alone but also from users and from related joint activities in production and use through different spillovers. Across sectors and countries the AEGIS project addresses competences and incentives that promote the generation of knowledge from suppliers, users as well as from related activities and its transformation into innovation, economic value added, and social benefits. For the first time the characteristics, scope and incentives of this specific form of entrepreneurship were not only examined in high-technology and service industries but also in low-technology industries.

Besides our first essay collection resulting from the work package on the low-tech sectoral dimension (Hirsch-Kreinsen/Schwinge 2014), this book offers rich insights in the interdisciplinary roots on the debate of knowledge-intensive entrepreneurship in the specific sectoral context of low-tech industries as well as in sophisticated empirical findings from profound case studies, using the example of the German textile industry; not least because the investigation of KIE case studies in this sectoral environment resulted in the insight that systemic and structural analyses are not sufficient to understand the process of KIE in such a context. Rather, sociological theory, like the actor oriented institutional approach, is suited to gain knowledge about the interrelation of KIE and its social environment, which is the specific contribution of this book.

Despite my interest and expertise in innovation and network studies, I was not able to make use of knowledge-intensive entrepreneurship and low-tech sectors when I heard about those young strands of research some years ago. I started my work as a greenhorn in this respect and faced troubles in linking these two fields of research, given their different interdisciplinary assumptions of innovation and entrepreneurship that seem to be paradox at first glance. However, the impartiality of a greenhorn par-

ticularly helped me to solve this conceptual paradox and empirically explore indeed paradox conditions for this deviating entrepreneurship from an established institutional environment. Considering the ongoing transformation not only of traditional industries but also of science towards transformative, transdisciplinary research, I am deeply grateful for this learning process and the people I met during this time.

For this reason, I would like to particularly thank my supervisor Hartmut Hirsch-Kreinsen who gave me the opportunity and time for this enlightening experience and work. Likewise, I would like to thank Carsten Kampe who introduced me to the world of science. I am also grateful for the work with my second supervisor Andreas Hack. Furthermore, I would like to acknowledge and thank my colleagues Katrin Hahn, Stephanie Steden and Jörg Abel and the colloquium of the Chair of Economic and Industrial Sociology at TU Dortmund University for their various support and inspirations. My further gratitude is directed at Bo Carlsson for his precious feedback during the DRUID Academy in 2012 as well as to the inspiring exchange and good times with my partners from the AEGIS project: Attila Havas, Bram Timmermans, Christian Østergaard, Esin Yoruk, Eun Kyung Park, Jon Mikel Zabala Iturriagagoitia and Slavo Radosevic. Particularly, I would like to thank my interviewees for their time and essential contribution to this work. With respect to the formal organization and editing of this book, I would like to especially thank Gundula Wilke and the student assistants from the Chair of Economic and Industrial Sociology for their proofreading, Jens Wilke und Olaf Erkens from the IT support of the faculty as well as Christian Rammer from the Centre for European Economic Research (ZEW) for the friendly provision with data.

Finally, my *Herzensdank* is directed at my family, mi compañero and my dear friends, especially Conny, for sticking by me during this time, and for your love and empathy that you showed me in all those words and little and bigger gestures.

Isabel Schwinge, Dortmund, June 2015

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List of abbreviations

AEGIS	Advancing knowledge-intensive entrepreneurship and innovation for economic growth and social well-being in Europe
AIF	Allianz Industrie Forschung
CEPS	Centre of European Policy Studies
CIRFS	Comité International de la Rayonne et des Fibres Synthétiques Européen
CIS	Community Innovation Survey
CPM	Costs per mille
DITV	Institut für Textil- und Verfahrenstechnik Denkendorf
EPO	European Patent Office
Eurostat	Statistical office of the European Union
GEM	Global Entrepreneurship Monitor
GER	Germany
High-tech	High-technology
IE	Institutional entrepreneurship
IGF	Industrielle Gemeinschaftsforschung
ILC	Industrial life-cycle
IPRs	Intellectual property rights
IVC	Industrievereinigung Chemiefaser
IVGT	Industrieverband Garne, Gewebe und technische Textilien
KEINS	Knowledge-based entrepreneurship: Innovation, Networks and Systems
KIE	Knowledge-intensive entrepreneurship
LMT	Low- and medium-low-technology
Low-tech	Low-technology
MIP	Mannheimer Innovationspanel (Mannheim Innovation Panel)
MUP	Mannheimer Unternehmenspanel (Mannheim Enterprise Panel)
NACE	Nomenclature statistique des activités économiques dans la Communauté Européenne
NICs	Newly industrialized countries
NIS	National innovation system

NTBF	New technology based firms
OECD	Organization for economic co-operation and development
POS	Point of sales
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RWI	Rheinisch-Westfälisches Institut für Wirtschaftsforschung
R&D	Research and development
SI	System of innovation
SIS	Sectoral innovation system
SME	Small and medium-sized enterprises
STI	Science, technology and innovation
TAL	Textile, apparel and leather
TIS	Textile innovation system
TITV	Institut für Textil- und Verfahrenstechnik Denkendorf
VC	Venture capital
ZEW	Centre for European Economic Research

1 Introduction – matching two strands of research

Analysing knowledge-intensive entrepreneurship (KIE) in low-tech industries may irritate researchers of entrepreneurship as well as low-tech innovation studies. It may even confuse them like the business idea of Birgit Mayer confused her former employer (a comb producer) and the executive director of her local savings bank. "Autoteile aus Pappe? Was für ein Quatsch!"[1] (Pollack 2007: 18) Mrs. Mayer got this reply from everyone. Today this new light material is running on the streets integrated, for instance, as wheel covers in cars from known automakers. Though no one had believed in her business idea at the beginning, Mrs. Mayer founded the Wabenfabrik and succeeded in making corrugated cardboards applicable for vehicle parts. The Wabenfabrik became one of the most innovative and experimental firms in the traditional cardboard industry (Nagel 2011).

This case illustrates an example of knowledge-intensive entrepreneurship (KIE) in the paper industry. The OECD as well as many researchers and policy makers would classify the paper industry as a low-technology (low-tech) industry because of its averaged little investments in R&D. Further classified 'low-tech' or 'medium-low-tech industries' are the food and beverage industry, the basic metal industry, the textile, clothing and leather manufacturing, the wood and furniture as well as the plastics industry. The 'low-tech sector' aggregates all of these low-tech industries. Low-tech innovation studies focus on innovation activities new to the existing low-tech firm and on process innovations optimizing the manufacturing process. This kind of innovation, like advancing specific steel alloys (Hirsch-Kreinsen 2005: 152), does not necessarily imply entrepreneurial activity. Consequently, entrepreneurship has not been part of this strand of research.

On the other hand, the young strand of research on KIE has overlooked the phenomenon in the low-tech industrial context. The research community has not agreed on a common concept of KIE. Some researchers use the term without specifying it. The phenomenon is related to new, innovative firms that appear in knowledge-intensive industries where the majority of firms permanently innovate and create new knowledge based on a high proportion of high-skilled professionals. It is linked to scientific or R&D based knowledge and to a highly dynamic technological environment. All these characteristics are usually not assumed for the low-tech sector. Accordingly, many researchers and policy makers do not deal with KIE emerging in low-tech industries because of these paradox assumptions.

[1] "Car parts made of cardboard? What nonsense!" (Translated by author)

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Researchers of the European AEGIS project[2] (2009-2012) considered KIE for the first time in the context of low-tech industries.[3] Here, KIE is understood as an important mechanism for transmitting knowledge into innovation and transforming industrial structures (Malerba 2010b: 3). This approach points to a dynamic industrial perspective on KIE that does not necessarily exclude the phenomenon from emerging in the low-tech sector as well. It agrees with Schumpeter's (1967) early concept of economic development where entrepreneurship has a constituent function for implementing an innovation relevant to industrial dynamics. Evolutionary economists rediscover entrepreneurship as an important mechanism for innovation and economic growth. So far, the low-tech context has been neglected by these scholars; but why should KIE not be an important mechanism for innovation and transforming activities in these low-tech industries just as well?

In the last decades, low-tech industries became rather known for concentration processes than for entrepreneurial growth processes. Indeed, they can be located in a matured industrial stage of technological development. Their growth rates are only moderate and the international competition is strongly pronounced. The transformation of these industries has been in full state but mainly in price and quality competition, without deviating from established technological or innovation paths. However, regardless of the low sectoral amount of R&D and regardless of the latest economic crisis, these low-tech industries still depict a persistent economic size concerning employment and income in Germany and Europe (Directorate-General for Enterprise and Industry 2013: 9; Hirsch-Kreinsen 2013). Low-tech industries will not disappear from our economies, since the manufacturing of and supply with groceries or metal components will be of vital economic and societal importance in the future. There will be no "satisfactory substitute" for the food industry (Mendonça 2009), for instance. All the more we ought to be interested in phenomena that sustainably transform and develop the matured industrial structures of the low-tech sector, as it could be the case for KIE.

Coming back to the example of Mrs. Mayer, it is notable that she developed flame retardant and water-resistant cardboards together with a team of tinkerers educated as craftsmen instead of high-skilled professionals. Almost every handcraft's trade was represented in her team for development activities from a joiner to a fitter, because there had been no specific profession for producing such innovative paper combs (Pollack 2007). Hence, this innovation in lightweight construction with several new fields of application for the industry was set up without any formal R&D, academics or cooperation with a university (Nagel 2011). This example illustrates specific characteristics of KIE in the low-tech context that neither KIE studies nor low-tech

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2 Advancing knowledge-intensive entrepreneurship and innovation for economic growth and social well-being in Europe; project co-funded by the 7th framework programme for research and technological development of the European Commission.

3 The author participated in work package 1.3: "Knowledge-intensive entrepreneurship and the sectoral dimension: Low-tech sectors" of the AEGIS project.

studies have identified so far. For that reason, the objective of this doctoral thesis is to better understand economic transformation processes in low-tech industries using the neglected perspective of entrepreneurship.

As this research topic links entrepreneurship and low-tech innovation research for the first time, a more detailed introduction into the context is given in the following chapters. First of all, the state of the art of low-tech industries (Chapter 1.1) and KIE (Chapter 1.2) is presented to start from a consistent understanding. Then the paradox of KIE in low-tech industries and related problems will be stated from which the main research question of this thesis is derived (Chapter 1.3). In the next step, I draw a conceptual approach of KIE for the specific analysis in the low-tech context (Chapter 1.4). Finally, this introducing chapter outlines the objectives and organization of the thesis (Chapter 1.5).

1.1 Low-tech industries

In this chapter the state of the art on low-tech industries is determined and classed with the ongoing debate in innovation research, referring to the perception of the characteristics and innovation activities as well as the knowledge dimension of these industries in the literature.

1.1.1 Definition and business conditions of low-tech industries

The term 'low-technology sector' stems from the OECD "classification of manufacturing industries based on technology" (e.g. OECD 2005: 181), which categorizes the technology intensity of manufacturing industries into 'high-technology', 'medium-high-technology', 'medium-low-tech' and 'low-technology' aggregates. This *definition* is based on the average ranking of 12 OECD member states measured by the indicators "R&D expenditures divided by value added" and "R&D expenditures divided by production" for the period between 1991 and 1999 (ibid.). This means that the degree of complexity of technology is not directly measured but rather a strong correlation of the measured expenditures on a technology, and its complexity is taken as a basis for using the categories high- and low-technology industry.

However, the cut-off points in this classification have been termed as clear between the marks of below 1% for low-tech industries, between 1 and 3% for the medium low-tech, between 3 and 5% for medium-high-tech, and more than 5% on R&D expenditures for high-tech industries. The industrial sectors allocated to these groups seem to remain constant over the decades measured in total (cf. Hatzichronoglou 1997; OECD 2003a; Potters 2009; Som et al. 2010), though national differences among these groups are pointed out. The sectors recycling, manufacturing not elsewhere cited, wood, pulp, paper, paper products, printing and publishing, food products, beverages and tobacco, textiles and textile products, leather and footwear are accounted to the low-tech industry category.

This OECD classification, especially the tags high-tech and low-tech, has become widely used among researchers and policy makers as well as in economy. Unfortunately this led to a shortcoming and misleading use of the original concept of technology intensity (cf. Robertson/Smith 2008: 97), for example that “investment in R&D is directly correlated with the degree of innovation in an industry and with its rate of growth” (Robertson/Jacobson 2011b: 4). Such reduced postulations have led to a very narrow focus on technology intensity and innovation only based on R&D indicators and finally to a “preferential treatment” (Kirner et al. 2009a: 447) of such high-tech industries to the disadvantage of low-tech industries (cf. Hirsch-Kreinsen et al. 2006; Robertson et al. 2009). Equating high R&D intensity with high innovativeness as well as the usefulness of this sectoral classification is meanwhile widely criticized (cf. Hirsch-Kreinsen 2005; Kirner et al. 2009a/b; Som 2012; von Tunzelmann/Acha 2005).

As Paul Robertson et al. have already stated, the “role of low- and medium-technology (LMT) firms and industries in modern economies is complex and frequently misunderstood.” (2009: 441) Thus, the perception of low-tech industries in science and policy can be termed as divided. On the one hand, the vital economic meaning of the low-tech sector has been stressed by several authors. Regardless of the serious concentration processes that these industries have faced, they still substantially account for employment and the value added of the manufacturing sector (Hirsch-Kreinsen et al. 2008; Potters 2009; Robertson/Smith 2008; Som et al. 2010). For example, roughly half of the employees of the German manufacturing are still employed in non-research-intensive or low-tech industries (Som et al. 2010: 6). On the other hand, “[m]odern research and innovation policies often overemphasize the role of R&D in economic growth and underestimate processes of change and needs in those sectors of the economy with low R&D investments.” (Kaloudis et al. 2005: 72) This is justified with higher growth rates in research-intensive industries and connected to the expectation that the R&D intensity determine the state’s competitiveness and limited growth prospects of low-tech sectors (Hirsch-Kreinsen et al. 2008: 3; Kaloudis et al. 2005: 49; Som et al. 2010: 3).

However, equation of high R&D intensity and growth falls too short (Rammer et al. 2010: 18; Robertson/Smith 2008). Quite the contrary, several authors could not find any indications for the decreasing importance of low-tech sectors but assessed an unexpected persistence of these sectors (cf. Hirsch-Kreinsen 2009: 93; Robertson et al. 2009: 441; Som et al. 2010: 4 et seq.; 17). Indeed, these authors attest low-tech industries a decisive role for innovation in high-tech sectors (Hirsch-Kreinsen 2009: 95) and economic well-being in general (Robertson et al. 2009: 441) due to the demand for high-tech products or the supply with intermediate product and their contribution to the diffusion of such innovation (Potters 2009; Rammer et al. 2010: 18).

The *business conditions* and environment of low-tech sectors can be characterized with largely saturated and shrinking markets (Som et al. 2010: 5; Robertson/Jacobson 2011b: 7) that “are generally mature and may be slow-growing and subject to over-capacity and high levels of price competition” (Robertson et al. 2009: 441). In general, the products from low-tech industries are considered easier to substitute compared to products from research-intensive fields due to mostly lower product complexity (Som et al. 2010: 5). In this context the production processes and product design is standardized with low set-up costs, while the firms compete largely on price (Rammer et al. 2004; Robertson/Jacobson 2011a; Scarpetta/Tressel 2004 in Potters 2009). But as the low-tech sector comprises many (manufacturing) industries, some of “their products and production processes may be highly complex and capital intensive” (Robertson et al. 2009: 441).

The demand especially for consumer products is rather inelastic, since these products are “necessities” which are usually satisfied with higher income levels (von Tunzelmann/Acha 2005: 415). Moreover, most of the firms in low-tech industries are said to operate in locally or regionally zoned markets (Hirsch-Kreinsen et al. 2008: 13 et seq.). The competition is often based on brand loyalty by a market leader, which weakens competing in new product development (von Tunzelmann/Acha 2005: 415). Altogether, demand factors are said to be more important for innovation than technology in these industries (Potters 2009; von Tunzelmann/Acha 2005: 415). In this context the market environment is often described as technologically less dynamic (Rammer et al. 2005: 9; 17 et seq.), because “[t]hese are frequently ‘mature’ industries, where technologies and market conditions may change more slowly” (von Tunzelmann/Acha 2005: 408). Basic production technologies are rather used and applied than developed (ibid. 415; Potters 2009) so that some authors also characterize them as “receiving” or “using industries” (Heidenreich 2009: 493) rather than selling or creating technology (cf. Pol et al. 2002; von Tunzelmann/Acha 2005: 419).

In other words, the low-technology intensity in this sector springs from common product differentiation strategies looking for new user market niches and technology acquisition that usually requires little product development or R&D activities (Potters 2009). Altogether, the market conditions of low-tech sectors can be summarized as typical for mature industries with segmented markets where the “competitive advantage depends upon product differentiation, cost efficiency and control of complementary assets” (von Tunzelmann/Acha 2005: 413).

1.1.2 Sources of knowledge and innovation in low-tech industries

In the literature it is prominently referred to the importance of practical knowledge or application-oriented knowledge in low-tech industries because of the low investments in R&D on sectoral average (Hirsch-Kreinsen 2009: 94; von Tunzelmann/Acha 2005: 417). In this respect categories like internal and external knowledge bases are used that point to distributed sources of knowledge across different knowledge bases

(Hirsch-Kreinsen et al. 2008: 8). Keith Smith (2003), and Paul Robertson and Smith (2008) introduced the concept of distributed knowledge bases to research on low-tech innovation. Following this logic, the internal knowledge base of low-tech industries is primarily based on practical knowledge, whereas R&D-based knowledge and knowledge of new technologies arise from external knowledge bases. “Unlike scientifically and theoretically generated knowledge that rests on criteria such as theoretical relevance and universality, practical knowledge is generated in application contexts of new technologies and obeys validity criteria such as practicability, functionality, efficiency and failure-free use of a specific technology” (Hirsch-Kreinsen et al. 2008: 7). Moreover, practical knowledge “is created and reproduced through learning-by-doing, empirical trial-and-error and limited systematic training” (Hirsch-Kreinsen 2005: 153). It is based on “accumulated experience and well-established, proven, and tested routines for solving technical problems” (Hirsch-Kreinsen 2009: 94).

Besides sectoral and general applicable knowledge bases, the firm-specific knowledge base depicts a further level for assessing the knowledge content of an industry (Robertson/Smith 2008). At this firm level Hartmut Hirsch-Kreinsen et al. (2008: 9 et seq.) point to “a concentration of knowledge in the hands of a small group of managers and technical experts, while the more or less qualified production workforce is only responsible for carrying out tasks” (Hirsch-Kreinsen et al. 2008: 9 et seq.). Moreover, Kirner et al. (2009b) assessed an above average share of low- and unskilled employees at low-tech firms that led them to the assumption of alternative paths of knowledge generation and accumulation.

In general, *knowledge from internal sources* is supposed to be of great importance (Faulkner 1994 in Heidenreich 2009: 488), since the sensing and absorption of relevant external knowledge depicts a critical point. Wendy Faulkner (1994) indicates that it is rather difficult and knowledge-intensive for firms to extend their existing knowledge base into new areas. Especially technological paradigms of the surrounding sectoral knowledge base can “have a ‘powerful exclusion effect’, thus limiting the ability of firms to ‘see’ knowledge (including technological options) that is available outside” (Faulkner 1994: 441 et seq.). Paul Robertson and David Jacobson particularly identified this problem for the low-tech context (2011: 8): “[T]he main problem in knowledge use by LMT firms may be to find the knowledge in the first place. Even when valuable knowledge is available, this does not mean that organizations that could benefit from its use (problem holders) know where to find it or that recognized paths for locating knowledge are available”.

Despite this challenge, the “systematic application” of *external knowledge* sources and knowledge bases are considered as particularly relevant in low-tech industries (Hirsch-Kreinsen 2009: 94; Hirsch-Kreinsen et al. 2008: 8). This external knowledge can be practical as well as science-based knowledge. Consultants, machine builders and suppliers can provide, for instance, theoretically and scientifically generated knowledge incorporated in production technologies or materials, which contribute to process specialization (Hirsch-Kreinsen 2009: 95). Specialized service providers and research institutes have important knowledge about material testing or calculations and product design at command (Hirsch-Kreinsen et al. 2008: 12). But finally it stands to reason to what extent this external knowledge is internalized into the organizational knowledge base, or if it remains part of a division of labor between firms in an ordinary market relation along the supply chain.

Basically, *innovation* is linked to complex mechanisms of knowledge distribution (Edquist 1997b in Kirner et al. 2009a: 448). Scientists focus primarily on identifying specific modes or innovation patterns – as it is also the case for innovation in low-tech industries or low-tech firms (e.g. Heidenreich 2009; Hirsch-Kreinsen 2008; Kirner et al. 2009a; Som 2012). These are mainly identified through indicators like knowledge sources and input in innovation. Since the constitutive characteristic of low-tech industries is their low investment in R&D or formal low R&D activity, it is argued that particularly application oriented and practical knowledge are relevant for innovation activities in these sectors (cf. Hirsch-Kreinsen et al. 2008; von Tunzelmann/Acha, 2005: 417). Instead of a science and R&D-driven mode of innovation, a mode of doing-using and interacting is supposed to be prevalent in low-tech sectors (Heidenreich 2009: 483; Hirsch-Kreinsen et al. 2008: 7; von Tunzelmann/Acha 2005: 417). Thus, the innovation understanding that is taken as a basis here is that “innovation can take place without research and development (R&D)” (Jacobson/Heanue 2005: 315). Especially learning is stressed in this context that can happen “through acquisition of tacit and practical knowledge, and through formal and informal diffusion between firms” (ibid.). Innovations result in this context from incremental product development, customer-oriented innovations, or the optimization of process technologies (Heidenreich 2009: 483; Hirsch-Kreinsen 2008: 27). The relative meaning of R&D for the economic performance is also supported by the survey on German firms without R&D performance by Rammer et al. (2010: 17). They could not find any difference in the return of sales or any other indicators for determining the business profit between innovators with and without R&D activities.

Even though it was already outlined that low-tech markets grow and change slowly, “they are far from technologically stagnant” (Robertson/Jacobson 2011b: 4). Innovation is nevertheless of vital importance for many small and medium sized firms operating in this sector – especially because of low-wage competition from developing countries” (Potters 2009). Nevertheless, according to the German innovation report (Som et al. 2010: 7), low-tech industries not only have lower expenditures in R&D on average but also fewer innovation expenditures in total compared to research-intensive industries.

The character of most innovations emerging in this context is generally rated rather incremental than radical (Bender 2005: 89; Robertson/Jacobson 2011b: 4) in terms of improvements to existing products with only a minor contribution to the process or product technology (Raymond/St-Pierre 2010 in Som 2012: 8). “Process, marketing and organisation innovations are much more important than product innovations" (Heidenreich 2009: 487) for these industries. In their early stage, these industries particularly contributed to process innovation and the development of technologies for mass production (von Tunzelmann/Acha 2005: 420). The overall goal for innovation and technical developments was geared to continuously save time and labor by "raising throughput, reducing downtime, and improving the machinery so as to ensure the speedy throughflow in all stages of its operation" (ibid.) in order to receive so-called dynamic economies of scale.

Against this background, process innovation still remains the dominant type of innovation identified in low-tech sectors (Heidenreich 2009: 483; Robertson/Jacobson 2011b: 7; Robertson et al. 2009: 442; Som 2012: 8). The innovation activities of low-tech firms are directed to production efficiency but meanwhile also to the quality of the production process, product differentiation and specific customer-orientation for competing in global markets (Heidenreich 2009; Kirner et al. 2009a: 457; von Tunzelmann/Acha 2005). These quality and value adding strategies avoid competing only on prices (Som 2012: 5). "Process innovations generally take place in the context of ongoing operations and are mostly initiated and pressed ahead by the staff responsible for the ongoing functions, such as engineers, technicians, master craftsmen, and skilled workers on the shopfloor" (Hirsch-Kreinsen 2009: 94). Such innovations are "usually not the outcome of the latest scientific or technological knowledge" (Som 2012: 10). In this context learning by doing and using and producing are depicting the essential sources of innovation (ibid.; Heidenreich 2009: 483; also Hirsch-Kreinsen et al. 2008: 7). Thus, regarding the sources of innovation, there are many other sources to consider than R&D, e.g. technical as well as non-technical, physical and immaterial and firm-internal as well as firm-external sources (Som 2012: 349) referring to the mentioned distributed knowledge bases.

External sources are also important to less radical innovation like in low-tech sectors (Heidenreich 2009: 483). But – according to the recent German survey on innovation systems (Rammer et al. 2010: 14 et seq.) – external information sources like customers, universities, other research institutes or scientific journals and patents are, compared to R&D intensive innovators, of minor importance for non-research intensive innovators. Against this, consulting firms and suppliers are identified as slightly more important sources of innovation for this group (ibid.). These findings correspond with other perceptions in the literature. Here, especially the acquisition of innovative machinery, equipment and software technology is prominently emphasized as an important source of innovation for non-R&D-intensive firms (Arundel et al. 2008a; Bender 2005; Heidenreich 2009; Potters 2009). This implies that high-technology is also incorporated in low-tech sectors (Hirsch-Kreinsen 2008; Mendonça 2009), but it is supplied by high-tech industries while low-tech sectors purchase ready-to-use technology and adapt it sometimes (Potters 2009). For this reason, low-tech industries are often characterized as so-called supplier-dominated sectors according to Pavitt's technology based classification of industries (Pavitt 1984; Heidenreich 2009:

489; Robertson et al. 2009: 442). Accordingly, supplier dominated firms are expected to "make only a minor contribution to their process or product technology" (Pavitt 1984: 356). Heidenreich (2009) confirms this characterization of low-tech industries with data from 2004 and 2006 of the European Community Innovation Survey (CIS 4).

However, as it was already outlined "LMT industries resist easy classification" (von Tunzelmann/Acha 2005: 411). Particularly the indicators of the CIS have been questioned for their R&D focus in measuring innovation and have been under development in recent years (cf. Arundel et al. 2008a; Hahn 2009). The design of new indicators for innovation has been, for example, also part in the course of the development of the European 2020 Strategy (Som et al. 2010: 13). As initially referred to Robertson and Jacobson (2011) and Kirner et al. (2009a), the analysis of innovation cannot only be reduced to direct R&D expenditures or technology intensity, which can only led to a restricted picture of innovation in low-tech sectors (even if the indicators about technology intensity may be reliable). There is a risk that the innovativeness of low-tech firms may be underestimated (Hirsch-Kreinsen et al. 2006), because their contributions within relationships to partners (e.g. suppliers) are difficult to grasp statistically (Robertson et al. 2009: 447). Often only the formal R&D processes of their partner organization are measured (ibid.). "In this case official statistical credit for research intensity is given to the other firms, but the LMT inputs may still be profound and indispensable." (Robertson et al. 2009: 443) Such perspectives have not been sufficiently covered by the current innovation indicators yet, so the content validity is to be questioned and potentially determining factors of such innovations remain indefinite (Rammer et al. 2010: 18 et seq.). Against this, Hirsch-Kreinsen (2008; 2009) or Kirner et al. (2009a) and Som (2012) draw a more differentiated picture on innovation activities that point to more heterogeneity in low-tech industries.

Moreover, these authors have in common that they trace back innovation of firms in low-tech sectors to already existing knowledge by "external knowledge sourcing or formal cooperation with external partners, particularly with customers, suppliers and competitors" (Som 2012: 9). Hirsch-Kreinsen et al. (2008: 9 et seq.) argue that the "ability to effectively coordinate network relations across company borders, especially with other companies within the value chain, is a central precondition to successful LMT innovation strategies." Bender (2005: 95) refers in this respect to "innovation enabling capabilities" of firms to creatively integrate different distributed relevant knowledge. This way, (new) technical solution is adapted and reframed to a new combination. Von Tunzelmann and Acha (2005: 409) stress the significance of "knowledge search, identification and proof" for innovation in low-tech industries.

Even though it was earlier indicated that external information sources play a minor role in low-tech sectors than compared to high-tech sectors, there are nevertheless several indications in the literature for vital *organizational capabilities* in order to source external information. Som et al. (2010: 9), for instance, assessed in their innovation report that non-research-intensive firms can also be quite capable to build up a similar technologically absorptive capacity as research-intensive firms, if the technology development is highly relevant for the low-tech firm's competitiveness. Moreover, Kirner et al. (2009a: 457) observed that low-tech firms are able to "innovate their production processes at least as efficiently as medium- and high-tech firms".[4]

The state of the art of low-tech industries shows that innovation research still needs further development in its concepts, parameters and indicators to draw closer to the complex empirical phenomenon of innovation. This field of research is contributing to these attempts while applying a broad understanding of innovation awarding the diversity of innovation activities. Besides this important contribution entrepreneurship has been neglected in low-tech innovation research and depicts a gap of research. Empirical case studies like in the PILOT[5] project (2002-2005) or more recent work based on longitudinal surveys (Kirner et al. 2009b; Som 2012) focus only on established firms.

1.1.3 Prospective trends of low-tech industries

Finally different prospective trends of low-tech industries can be identified from the literature review. Though it has been more and more noted that they play still an important role for economic and innovation systems in developed industrial countries, the contribution of low-tech industries is still mostly outstanding (Som et al. 2010: 3).

In the last decades, low-tech industries in Western Europe have been facing considerable competition from low-wage countries and have been shrinking or relocating their business to Eastern Europe (Heidenreich 2009: 483; Potters 2009). Von Tunzelmann and Acha (2005: 411 et seq.) illustrate, for instance, the impressing catching up activities of the Asian NICs by their rising market share between 1970-1995 compared to Europe, the USA and Japan. This development has increasingly led to innovation pressure and investments in new technologies and materials (Potters 2009) oriented to value-added products or broader applications. However, von Tunzelmann and Acha (2005: 416) assess that "the declines in demand for the products of these industries have been less marked than might be expected" due to value-adding and higher quality strategies.

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4 Also, for the important aspect of absorptive capabilities for innovation in low-tech sectors, the established indicators are not adequately accurate so far (Rammer et al. 2010: 18 et seq.). Usually, innovation research is measuring R&D expenditures in this context or the share of high-skilled staffs. However, this way excellent absorptive capabilities or the ability of low-tech firms to cooperate despite the common low amount of high-skilled employees and low R&D expenses cannot be explained (ibid.).

5 Policy and Innovation in Low-Tech (PILOT) – Knowledge Formation, Employment & Growth Contributions of the 'Old Economy' Industries in Europe, European research project (2002-2005) funded under key action "Improving the Socio-Economic Knowledge Base" of the European Commission's 5th framework program for Social Sciences and Humanities.

Against the competition from low-wage countries, some authors consider new advanced or high-technologies as a vital opportunity for the upgrading of products (Hirsch-Kreinsen 2005: 161; Rammer et al. 2010: 18) and innovation strategies in the low-tech sector (von Tunzelmann/Acha 2005: 415). They expect increasing investments in such technologies (Potters 2009; Hirsch-Kreinsen 2005: 161). While Hirsch-Kreinsen (ibid.) considers a high-tech environment as a ”central requirement for the development perspectives of low-tech enterprises”, Mendonça (2009: 470/471) specifically predicts a shift of paradigm to technological diversification also in low-tech industries that actively and crucially contribute to contemporary paradigm-changing technologies like ICT. Indeed, he refers to large leading firms in his investigation. Von Tunzelmann and Acha (2005: 415) at the same time relativize these high-technology driven opportunities, indicating that new technology based products alone do not imply economic success or meet the consumers' demand. They refer, for example, to genetically modified groceries that are rejected by many consumers in Europe (ibid.).

Altogether, the research on innovation in the low-tech sector "led to a new understanding of the restructuring of economic landscape of knowledge-based countries" (Hirsch-Kreinsen 2009: 95). Low-tech industries will neither disappear from this landscape nor be substituted by new industries. Following Hirsch-Kreinsen, the transformation process is carried out within the existing technical and sectoral systems based on "the combination and continuous recombination of high- and low-tech" (ibid.) and not as Mendonça predicted by "frontline technological knowledge" (2009: 470). If such restructuring processes continuously take place within the system can be questioned. Discontinuous disruptions and new path creation should also be taken into consideration, especially with regard to sustainable competitiveness and innovativeness of low-tech industries. The debate of the 'European paradox' shows clearly that high investments and performance in technology and R&D alone do "not automatically spillover for commercialization and economic growth" (Audretsch/Keilbach 2010: 286; European Commission 1995: 5). As Geoffrey Lancaster and Chris Taylor (1988 in Herbig/Kramer 1993: 4) stated, "Technology is not self-determining; it is not capable of autonomous action." Entrepreneurship is considered here as the "missing link" (Audretsch/Keilbach ibid.) or an "important mechanism" (ibid. 286) for commercializing new knowledge into economic growth. Hence, regarding the restructuring of low-tech industries, it is likely that (new) entrepreneurial actors from the periphery overcome the persistence of the established, path dependent innovation system (cf. Greenwood/Suddaby 2006). For this reason, knowledge-intensive entrepreneurship (KIE), defined as an "important mechanism for transforming industrial structures" (Malerba 2010b: 3), should be considered in this context.

1.2 Knowledge-intensive entrepreneurship (KIE)

The term ‘knowledge-intensive entrepreneurship’ (KIE) has a young research history. The literature review shows that no common definition has been established. In its place, several authors link it exclusively with start-ups (Heidemann Lassen/McKelvey 2012) emerging in so-called knowledge-intensive industries (Delmar/Wennberg 2010; Groen 2005; Neergard/Madsen 2004). The state of the art is introduced in the following going into different definitions, the relevance of KIE and first insights in the sources and conditions of this phenomenon.

1.2.1 Definitions and empirical relevance of KIE

Basically, entrepreneurship research is multidisciplinary and investigates “sources of opportunities, the process of discovery, evaluation, and exploitation of opportunities; and the set of individuals who discover, evaluate and exploit them” (Shane/Venkataraman 2000: 218). *Entrepreneurship* is understood as a “context dependent process, through which individuals and teams create wealth by bringing together unique packages of resources” (Brush et al. 2001; Ireland et al. 2001; Lyon et al. 2000 in Groen 2005: 69). It is an activity that aims at “creating something new; a technology, a product, an organization, a market” (Malerba 2010b: 6). Thus, it is widely connected to innovation and therefore entrepreneurial activities are additionally characterized by risk taking (ibid.).

Entrepreneurship researchers refer in this context to Joseph A. Schumpeter’s broad *innovation* approach (e.g. Delmar/Wennberg 2010; Malerba/McKelvey 2010; Morlacchi 2007; Spilling 2008). According to Schumpeter, innovation is the function of entrepreneurship defined as “carrying out of a new combination” even of existing resources and the “setting up of a new business” (Schumpeter 1967). It is to be distinguished from new firms that are established for juristic or franchise reasons without comprising any character of novelty or change (Garavaglia/Grieco 2005: 6; Malerba 2010b: 6). But entrepreneurship does not solely refer to innovative start-ups. Schumpeter and others have also included the transformation of an existing company (Schumpeter 1967; Malerba 2010b: 6).

Knowledge-intensive entrepreneurship (KIE) is especially bound to innovation, as it is attributed to the development and diffusion of knowledge and to “the leading edge of innovation practices” (Delmar/Wennberg 2010: 27). Aard Groen, from the Dutch Institute for Knowledge Intensive Entrepreneurship, (2005) defines KIE by the entrepreneurial process of sensing, developing and exploiting a business opportunity, if “these processes are to a great extent based on relatively new (mostly academically derived) knowledge or technology” (2005: 70). The knowledge-intensive character is explained in accordance to technological strategic changes that alter product fields, market actors and structures, and “the rules of the game, both on local as well as global levels” (Groen 2005: 70 et seq.). Notable in this definition is that it is focused on new scientific knowledge and technology. According to Groen’s own account, he is particularly interested in high-tech entrepreneurship (2005: 83), which does not seem adequate to investigate the phenomenon in the low-tech sector.

Also, Frédéric Delmar's and Karl Wennberg's (2010: 1/7) definition of KIE is based on 'high potential entrepreneurship' allocated to knowledge-intensive industries with a highly skilled workforce on average. They argue to move with this concept of KIE from the "all forms of entrepreneurship are good" view "towards a more nuanced view where 'high-potential entrepreneurship' is what matters for economic development" (Delmar/Wennberg 2010: 1). Furthermore, they consider KIE as "[e]ntrepreneurial activities in the knowledge intensive economy [that] are of particular interest, because they provide a link between the production of new technological knowledge and its eventual commercialization" (ibid.). Hence, they clearly restrict this phenomenon to a certain sector and to specific knowledge. If we recall the initially introduced case with Mrs. Mayer and her team of handicraftsmen in the cardboard industry, it could not be explained by such a concept.

In contrast, Franco Malerba's remarks on "knowledge-intensive entrepreneurship and innovation" (2010b) are more detailed in an essay collection based on the KEINS project[6]. First he gives a general definition of KIE as "new ventures that introduce innovations in the economic systems and that intensively use knowledge." (2010b: 4) The determination of 'knowledge-intensive' still remains vague here. But he introduces three complementary definitions of KIE (2010b: 5) in order to encompass the essays' different approaches: KIE can be set up by "new firms in sectors that are highly knowledge intensive", "academic inventors" or "new innovators in a technology/sector". This last category can be finally also applied to low-tech sectors. Moreover, this broad termination also includes new firms as well as "established firms active in a process of technological diversification" (ibid.).

In the following AEGIS project, Malerba and Maureen McKelvey (2010) explicitly consider KIE in diverse sectors. Furthermore, they try to distance themselves from the focus on technological and scientific knowledge (2010: 7/9). However, they center on new knowledge-intensive firms in a management perspective considering business model concepts and explicitly exclude corporate entrepreneurship (2010: 9 et seq.). This implies that they understand KIE not as a phenomenon but as a condition, namely as permanent knowledge-intensive firms, which "have significant dimensions of knowledge intensive in their activity" (Malerba/McKelvey 2010: 7). Again the approach of KIE as knowledge-intensive firms is difficult to apply on low-tech industries. Moreover, the characteristic 'knowledge-intensive' remains quite abstract and indistinct.

[6] Knowledge-based Entrepreneurship: Innovation, Networks and Systems (KEINS). European research project (2004-2007) funded by the European Commission's 6th framework program, priority 7: Citizens and Governance in a knowledge-based society.

In order to distinguish this new concept of entrepreneurship from existing concepts or ordinary start-ups, Malerba and McKelvey argue that KIE goes further than the characteristic of a new venture. Additionally, compared to corporate entrepreneurship KIE does not remain internal to the existing organization (2010: 9). Moreover, distinct from new technology based firms (NTBF) that are characterized by “the translation of scientific and technological assets into economic value creation […] KIE also focused upon the impacts on innovation system” (ibid.).

While Malerba and McKelvey’s approach reaches beyond the scientific and technology focus and includes the low-tech sector, other exclusion factors seem hard to connect to innovation in the low-tech context as it was introduced earlier. Namely, they explicitly exclude innovation in existing firms, which “focus upon standard (or well established) goods and services, without elements of novelty in the product, process, organization, service, etc.” (2010: 9) and which is based on “repetitive and routine as well as well-known and established science and technology” (ibid.). However, many innovation activities described in the low-tech literature particularly refer to such incremental or routinized activities.

Though Astrid Heidemann Lassen and McKelvey (2012) acknowledge the importance of knowledge of existing firms just as well, they align to the previous concept as they spring from “a particular type of start-up company” (2012: 6) in their literature review for the AEGIS project. They stress “the role of different types of knowledge, its commercialization into products, processes and the impact upon economic renewal and growth” of KIE. However, they cannot offer a more comprehending and specific concept of knowledge intensity.

After this first review of definitions to understand what is meant with KIE in the scientific debate, next the *relevance and meaning* of this phenomenon should become clearer. Against the background of the recent debate on the knowledge economy, especially in econometric literature, it seems that the term ‘entrepreneurship’ receives new attention by the term ‘knowledge-intensive entrepreneurship’. “Entrepreneurship takes on new importance in a knowledge economy, because it serves as a key mechanism by which knowledge created in one organization becomes commercialized in a new enterprise.” (Heidemann Lassen/McKelvey 2012: 6)

As one of the current works referring to several authors, Malerba (2010b: 3) outlines the role that KIE can have for innovation and especially for the “transformation of the industrial system end economic growth”, because it implements new products and processes into the economy by using, absorbing and creating new knowledge. Malerba calls these vital activities the “backbones of the international competitiveness of countries” (ibid.). Especially relevant for the low-tech context is that KIE “rejuvenates technologies and industrial structure” (ibid.). For this reason, KIE receives much attention by policy makers (ibid.). Hence, the analysis of KIE in low-tech sectors could also raise the policy makers’ attention to those neglected industries.

Empirical evidence for the meaning of KIE has been mainly proven under specific conditions and contexts due to the focus on start-ups in knowledge-intensive industries or high-tech sectors. Malerba (2010b) refers in this respect, for instance, to Audretsch and Keilbach (2006) who analyzed “high-tech entrepreneurship” in high-tech sectors; they found a positive effect for the economic performance of regions in Germany. Malerba concludes that “[h]igh knowledge intensity (i.e. high-technology sectors or ICT) affects entrepreneurship by providing more entrepreneurial opportunities. In turn entrepreneurship affects economic performance through increase in competition and in diversity” (Malerba 2010b: 23). Knowledge intensity is here determined by high-tech sectors. Applied on low-tech sectors, this argument could imply to assume low entrepreneurial opportunities because of the low technology intensity according to the common criteria.

Moreover, Malerba refers to quantitative measurements for the relevance of KIE. He and Camerani (2010) analyzed firms patenting for the first time (Malerba 2010b: 14). They found out that “the relevance of new innovators in terms of total number of patents is much less significant. Innovative entrants start innovating with very few patents and are smaller than incumbent innovators: this is similar across technologies and across countries.” (Malerba 2010b: 15) Actually, this is a good example to illustrate the limits of such common indicators for the relevance of KIE. Further quantitative analyses focus on academic entrepreneurship (ibid.) operationalized as academic start-ups or academic patenting as contributions to innovation activity (ibid.). Finally, Malerba refers to a survey of knowledge-based entrepreneurship in Western and Eastern Europe (KEINS project). KIE is used synonymously and measured here in “new firms that innovate within a very short time after their establishment and are both knowledge-based (i.e. active in science-based and science-driven sectors) and technology-based (i.e. patenting in sophisticated and dynamic technological contexts)”. (Ibid. 17) What is finally notable about these examples is that KIE was firstly again measured based on typical quantitative high-tech indicators, which limits its application on the low-tech context. Secondly, KIE is not easy to measure with these indicators, and seems not to be a prevailing, statistically significant phenomenon. According to Malerba and McKelvey, “the analysis of the relevance of KIE at the sectoral, regional and country level requires quantitative indicators.” (2010: 33) But at the same time they admit that “[t]hese indicators are not easily available, nor does a comprehensive indicator exist” (ibid.). In this respect, they refer to specific databases from the micro and meso level for linking KIE to the macro level. The problem is that these databases often exist only for specific countries or industries and mostly not for low-tech industries (cf. for example Eurostat or reports on the German innovation system or on entrepreneurship activity).

With recourse to the *conceptual perspectives* of this research history it is remarkable that the broad concepts by Malerba et al. indicate at least to depart from the prominent person-centric view on entrepreneurship and to take into account several actors and embedding networks of cooperation as well as institutional settings (Malerba 2010b: 3; Neergard/Madsen 2004). KIE should be considered in multidimensional ways as context dependent (Groen 2005) and integrated in innovation systems at the national, sectoral or local level (Malerba 2010b: 3 et seq.). However, the definitions introduced earlier rather point to a focus on the organizational level instead. Indeed, Heidemann Lassen and McKelvey (2012: 6) admit that there exist no "comprehensive unified conceptual framework" regardless of several studies in the general entrepreneurship field and knowledge management that have been used for KIE so far. Furthermore, their literature review resulted in the insight that various perspectives exist on KIE "which reflect the current unstructured nature of the field. While most studies of KIE focus on high-tech industries, literature also demonstrates that KIE is a relevant aspect in a variety of different settings; high-tech, low-tech and service alike." (Ibid. 2012: 69)

1.2.2 Sources of KIE

The main categories of sources for KIE could also be identified in the broad entrepreneurship literature on determining and success factors of innovative start-ups. According to this human capital of the entrepreneurs, financial sources, intellectual property rights (IPRs), cooperation and networks with other firms and other institutional actors (Lenzi et al. 2010: 179 et seq.) are considered as the main sources (ibid.). However, this research is mostly based firstly on start-ups (not including corporate entrepreneurship) and secondly conducted in technologically highly dynamic contexts, excluding low-tech industries.

Entrepreneurs as one of the most important sources for KIE, however, are out of the question. They "represent an important source of variation in the economic system by introducing new types of goods and services and/or new ways of organizing the productions of such" (Schumpeter in Delmar/Wennberg 2010: 1). Entrepreneurs are "knowledge operators, dedicated to the utilization of existing knowledge, the integration and coordination of different knowledge assets, the creation of new knowledge, and engaged in the development of new products and technologies." (Malerba 2010b: 6et seq.; Heidemann Lassen/McKelvey 2012: 69) Their intellectual assets, personal talent, skills as well as their educational and professional experiences build a bundle of sources that determine the success of the entrepreneurial process (Lenzi et al. 2010: 180/194). Here, also the social capital of the founder, e.g. experiences and network relations made at previous employers, can depict an important source (cf. Lenzi et al. 2010: 180; Neergard/Madsen 2004). The survey of the KEINS project, which conducted a large number of firms in the high-tech sectors biotechnology, electronics and medical devices in Western, Central and Eastern Europe, found a high level of human capital in their cases with a majority of founders having a PhD or master's degree (Malerba 2010b: 18). Camilla Lenzi et al. (2010: 180) assume "the higher a founder's intellectual assets the greater the chances of a new venture success in terms of both survival and economic performance".

Besides this internal factor, external sources like the national or sector-specific *funding*, e.g. venture capital (VC) is also considered as vital (Ben-Ari/Vonortas 2005; Lenzi et al. 2010; Malerba 2010b). Regarding the approach to analyze new firms in high-tech sectors such as ICT or biotechnology, the significance of venture capital is not a surprise. But not only financial aspects are important; it is also pointed to “the provision of technical and managerial know-how” (Barry et al. 1990; Kaplan/Strömberg in Lenzi et al. 2010: 180) of the VC consultants especially for inexperienced entrepreneurs in these fields. However, the KEINS survey also shows sectoral differences. For medical devices, for instance, banks are more used as a funding source, while venture capital is more important in biotechnology in Germany and Northern European countries (Malerba 2010b: 18).

Also national or sectors-specific configuration of *intellectual property rights* and patents are indicated as typical assets for such venture creation (Lenzi et al. 2010: 181). Moreover, KIE can derive from users or the demand side as well as from the supply side (Malerba 2010b: 10). Above all, established firms quite often support and affect KIE (Mamede et al. 2010). The spin-offs from these established firms source considerable knowledge about technologies, products and markets from them (Malerba 2010b: 9) or receive financial support. The KEINS survey shows, for example, that biotechnology spin-offs used knowledge about products from their previous employer, while spin-offs in electronics and medical devices obtained knowledge about customers (Malerba ibid. 18).

Similar to innovation sources of low-tech firms (Hirsch-Kreinsen et al. 2008; Som 2012) *networks and cooperation* with external “knowledge institutions” are found among the important sources for KIE (Groen 2005: 70; Lenzi et al. 2010: 181; Malerba 2010b: 13). Lenzi et al. (2010: 181) refer with recourse to Ronald Burt (1993) and Walter Powell and Stine Grodal (2005) to the increasing need for agreements with other actors “to collect and exchange resources and, ultimately, to coordinate the innovative activities and produce more and more sophisticated and knowledge- and technology-intensive products and services”. They explain this trend with the “increasing complexity of knowledge-intensive sectors” and their “increasing dispersion and distribution of resources, knowledge and competencies among different actors” (ibid.). This argument reminds of the distributed knowledge bases that Robertson and Smith (2008) applied on innovation in low-tech sectors. Groen (2005) also points to growing multi-disciplinarity of innovation and the embeddedness of KIE entrepreneurs in heterogeneous networks for implementing such innovations. Therewith “networks of socio-economic institutions” (e.g. public and private research institutes) have an effect on KIE through technology development (2005: 70). In line with this, the KEINS survey identified R&D as the main field of cooperation for KIE (Malerba 2010b: 18). Overall these actors, whether new firms or established firms, or corporations with so-called knowledge institutions, have in common that they all contribute to KIE by using existing knowledge, (re-)combining different knowledge assets or creating new knowledge (Heidemann Lassen/McKelvey 2012: 69). Hence, most of the different sources presented entail specific knowledge so that knowledge is understood as the general and constituent source of KIE.

Related to the different sources of KIE, there are also different types of *knowledge* indicated as relevant for KIE. The most prominent type which is referred to in the KIE literature is scientific technological knowledge. Malerba (2010b) explains this with the increasing significance of this knowledge for innovation referring to Paul David and Dominique Foray (2002). In connection with this, the “scientifically educated workforce has risen continuously over the past three decades in almost all the European countries”, which also increased the opportunities for new fields of applied research such as material science, gene technology or information sciences (Malerba 2010b: 6). Accordingly, KIE is ascribed to “coordinate [and] integrate external scientific knowledge with the internal one” (Malerba 2010b: 7). In addition, Malerba points to practical industrial knowledge “needed for developing complex products, modularity in product design and openness in the interfaces [as] […] very important elements that shape entry and competition.” (Ibid. 8) He refers here to incumbent firms as the usual coordinator for such “system integrations” (ibid.). Moreover, KIE actors have to decide about internalization and externalization of knowledge, organizational and artefact domains, whereas knowledge can have enabling as well as impeding character (ibid. 7). Strikingly, the argumentation on KIE often refers to entrepreneurial activities in context of an existing organization or corporate entrepreneurship.

The above described entrepreneurial activity of using, combining and creating knowledge leads over to *capabilities* of “integrating the developments in knowledge with the reconfiguration of resources, organizational skills and external links” (Malerba 2010b: 7) that are comparable with the ‘innovation enabling capabilities’ introduced to the low-tech industries (Bender 2005: 95). Also Lenzi et al. (2010: 180) stress the “high level of competences” needed for successful KIE. Interestingly, Malerba underlines with recourse to a study of Johan Brink and McKelvey (2010) “the ability to reconfigure assets” and “integrate knowledge” as a key competence of the firm instead of “technological competences and scientific competences per se” (Malerba 2010b: 21). Brink and McKelvey found in the high-tech biotechnology industry that “firms which draw benefits from knowledge integration and local learning, rather than from radical innovations, can prosper and grow. They do so even without being radical innovators and without being highly science intensive.” (Ibid.) This is an interesting observation, because it widens the conceptual discussion on KIE to broader concepts and indicators also adequate for the low-tech industries.

1.2.3 Environmental conditions and institutional influences

The creation of new knowledge and emergence of KIE also depend on environmental conditions and specific institutional influences. Thereby, research especially takes into account the so-called learning environment. It is generally assumed that the learning environment influences the occurrence of new entrants and innovators in a technology or sector (Breschi et al. 2000; Malerba/Orsenigo 1996 in Malerba 2010b: 8). In particular, specific technological and scientific opportunity conditions, “the cumulativeness of the advancements, and the rules and regulations” affect the “type and intensity” of KIE (Malerba 2010b: 23). Low conditions of appropriability and cumulativeness together with high scientific and technological opportunity conditions are expected to positively affect the rate of new innovators (ibid. 8). Moreover, it was found that the investments in new ventures increased with high technological opportunities and weaker intellectual property regimes (Godinho/Mamede 2005 in Malerba ibid.).

Further *institutional influences* with stimulating character on KIE can be found in public policy programs for business planning or institutional training of entrepreneurs (Heidemann Lassen/McKelvey 2012: 27). These should provide the use and creation of knowledge about markets but also technological and scientific knowledge (ibid. 30). Christian Garavaglia and Daniela Grieco (2005: 37) consider efficient and effective educational systems as a particular determining factor for “the level of scientific and technological knowledge in a country and the individual abilities to develop interpretative frameworks that constitute the prior knowledge held by entrepreneurs in creating, identifying and pursuing the opportunities.” However, to what extent KIE should be supported by public policy – in general or focused on the expected successful ones, is critically discussed (Heidemann Lassen/McKelvey 2012: 30). Finally, the “legal framework of academic careers” (e.g. positions available), the regulation of patent and intellectual properties or the sharing of license earnings are indicated as institutional influences on KIE in terms of academic spin-offs (Godinho/Mamede 2005 in Malerba 2010b: 10). Furthermore, KIE is said to face specific institutional conditions regarding financing. The difficult evaluation of innovations implemented during the process of KIE and the linked “extensive assets” particularly inhibit the access to external financing (Ben-Ari/Vonortas 2005 in Malerba 2010b: 11). Guy Ben-Ari and Nicholas Vonortas found out that different financial actors can play a role to different times (ibid.). Venture capital is especially important for the start-up and early stage, while debt financing or government grants are needed to enable the venture capital funding. This is due to the focus “on large and safer deals” of venture capital, whereas the public actor is responsible for the risk framing and provision of information for KIE in specific technologies or sectors of economic interest (ibid.).

Empirical studies of KIE have shown that the conditions and institutional influences differ across industries. Main factors identified for the differences are the type of knowledge, the knowledge base, the “competences necessary for market success”, the customer structure, and also the “relationship with the previous employer” (Malerba 2010b: 18). The “key characteristics, resources and linkages […] to activate and exploit in the early stages” can considerably differ among industries (Lenzi et al. 2010: 181).

So far, *sectoral characteristics of KIE* have been mainly analyzed for high-tech sectors, which refer to the origin or source of KIE above all. For example, in biotechnology new firms are often spin-offs from university “with a great command of science and strong links with a network of large firms and research laboratories” (Malerba 2010b: 14). In machine tools, however, spin-offs rather spring from existing firms with knowledge based on “experience and publications” (ibid.). Contrarily, in the software industry open sources and “user-producer relations” are of importance for new firms (ibid.). Another study by Annaleena Parhankangas and Pia Arenius (2003) analyzed 50 Finnish technology-related firms in seven industrial sectors – among them also low- and medium-low-tech-tech sectors like rubber and plastics or printing and publishing. They conclude that the type of new venture depends on the sector. The type of firm developing new technologies is typical for high-tech sectors such as biotechnology, optical technologies, electrical components, or medical devices. The firms serving new markets are characteristic for specialized industrial machinery and components or software services and IT systems. Whereas corporate ventures restructuring core business are mainly found in low-and medium-low-technology sectors like metals, standardized industrial components (Malerba 2010b:14). Malerba (ibid.) derives that “spin-offs occur more frequently in sectors in which product proliferation and market segments are relevant, scale economies are limited and human capital is important.” In other words, academic spin-offs or new firms, exploiting new markets, are not expected to occur in low-tech sectors (for restructuring them) but in the form of corporate ventures.

However, as a more general starting point it can be assumed in line with Malerba and McKelvey (2010: 8) that *national and sectoral innovation systems* play a decisive role in shaping the type and intensity of KIE differently. According to Malerba, the effects of sectoral innovation systems on KIE have been less analyzed so far (2010: 13). Additionally, he demands “deeper analyses of the different dimensions of KIE and their links with innovation systems […] in particular agent-based models of KIE, innovation and industrial dynamics have to be produced.” (2010: 24). But such systemic links between knowledge, innovation and entrepreneurship address a quite complex set of issues to be analyzed (Heidemann Lassen/McKelvey 2012: 54).

In conclusion, the conceptual shortcomings of the term KIE that show up in this review are comparable with the preceded term of ‘knowledge-based entrepreneurship’, which is partly used synonymously. Garavaglia and Grieco (2005: 39) criticize the widespread use of knowledge-based entrepreneurship without any clear “specific delimitation”. What is knowledge-based and knowledge-intensive still remains vague. It is called for “more systematic and transparent measures of knowledge-based resources” (Heidemann Lassen/McKelvey 2012: 55). Especially the indicators for the almost exclusively quantitative research on KIE show limitations and shortcomings in the measurement of this complex phenomenon. Malerba and McKelvey (2010: 34) acknowledge the limitations of the widespread used patent indicator. And if the indicator for human capital were applied in terms of the “skills of the members of the new ventures [it] is usually not available" (ibid.). In most cases, empirical studies focus on a limited number of indicators such as patents or academic spin-offs. This is difficult to compare with data in low-tech sectors, because they are often not collected or available.

1.3 The paradox of KIE in low-tech industries

The literature review of both strands of research reveals some controversial assumptions on innovation and knowledge-intensive activity that impedes studying the emergence of KIE in the low-tech sector. For instance, concepts that exclusively bond KIE to knowledge-intensive industries could not be used for low-tech industries (Delmar/Wennberg 2010; Groen 2005; Neergard/Madsen 2004). The same holds true for approaches that solely define KIE as start-ups (Heidemann Lassen/McKelvey 2012). These concepts of KIE are explained with expected economic growth in these industries and firms. This is not a scientifically but rather a normative argument. As we learned from Robertson and Jacobson (2011b: 4 et seq.) or Kaloudis et al. (2005), the growth rates of high-tech sectors compared to low-tech are to be questioned. A similar logic is applied to innovation that is assumed to be of a low technology character in so-called low-tech industries. Since KIE is mainly connected to high-tech innovation, it is not supposed to occur in the little growing and low research-intensive sectors. This simple logic bears no scientific argument but is unfortunately widespread in innovation and entrepreneurship policy and research.

On the other hand, there are notable commonalities regarding relevant knowledge types and capabilities in both fields of research. Indeed, recent research for the AEGIS project does not exclude KIE from emerging in low-tech industries (Malerba/McKelvey 2010; Hirsch-Kreinsen/Schwinge 2011; 2014). However, as it is basically emanated from differences in sectoral innovation systems, there is also reason to assume sectoral varying forms of KIE. Yet, research has just started to deal with low-tech specific characteristics of KIE (Hirsch-Kreinsen/Schwinge 2011; 2014). The benefit of dealing with this phenomenon in low-tech industries is to contribute initially to insights in KIE processes and secondly to extend knowledge about restructuring processes in the low-tech sector applying an economic and industrial sociological perspective.

Taking research history on industrial dynamics into consideration, it becomes clearer why KIE in low-tech industries has depicted a research gap so far. Besides the differences in terms and understanding of innovation in the concepts of KIE and in the low-tech sectoral context, the answer can be referred back to the widely known view of industrial life-cycles (ILC) and alternating Schumpeterian innovation modes (often called Schumpeter Mark I and II) (Malerba 2005a; Spilling 2008). Following these views, KIE emerging in low-tech sectors seems to be a paradox at first glance, because in mature industries – which low-tech industries represent – innovation is not considered to take place in entrepreneurial regimes but in routinized regimes (ibid.). In other words, applying the maturity argument to industries from the low-tech sector, entrepreneurship is not expected to be the dominant pattern of organizing innovation in these industries.

The *industrial life-cycle theory* occurred in "search for regularities in the aging patterns of different industries" (Peltoniemi 2011: 349). It seeks to explain change in industry structure by technological developments (ibid.). Furthermore, it offers a "perspective on the relationship between industry characteristics and the rate of firm formation" (Shane 2003: 129). In other words, this theory enables a first general theoretical link of the research object's dimensions of industry and entrepreneurship.

Conceptually, the ILC theory distinguishes between two eras along the development of an industry: the 'era of ferment' and the 'era of incremental change' that are explained by technological discontinuities and dominant designs (e.g. Murmann/Tushman 2001). To each era typically either start-ups or established firms are allocated as major actors for innovation. Low-tech industries are situated in the era of incremental change. In this stage, "incumbent firms have built up capabilities to refine the dominant design in line with the requirements of existing users. […] [and] it is very difficult for entrepreneurial ventures to match dominant firm's capabilities." (Murmann/Tushman 2001: 193 et seq.). Contrarily, in times of technological uncertainty (era of ferment) entrepreneurs have more opportunities founding a venture, because radical new innovations are not expected from established firms that are used to "incrementally refining the dominant design of the previous technology cycle" (ibid.).

With advancing age of an industry, the nature of innovation obviously changes. First product innovation is prevalent and shifts to process innovation (Peltoniemi 2011: 355) and scales of economies, while the product variety is decreasing (ibid. 350). This is fully consistent with the innovation activities already described in the low-tech chapter (cf. Heidenreich 2009: 487; von Tunzelmann/Acha 2005: 420), namely the improvement of existing products or process innovations gaining continuously at optimal throughflow times and costs reductions in order to receive "dynamic economies of scale" (von Tunzelmann/Acha ibid.). The maturity of an industry becomes finally visible by the 'shake-out' in firm numbers (Peltoniemi 2011: 352), which is explained by several reasons. On the one hand, it is argued that increasing expenditures in R&D for process innovation do not have the size advantage anymore compared to product R&D. These strong cost-spreading effects lead to firm exits and rare entries (cf. Cohen/Klepper 1996; Klepper 1996 in Peltoniemi 2011: 352). Generally, a shift from "widening" to "deepening" innovation activity (Breschi et al. 2000; Malerba/Orsenigo 1996 in Peltoniemi ibid.) is assumed. In the course of shrinking market growth, remaining firms rather need to develop their capacities besides R&D activities, since "market shares are reallocated to the most capable producers" (Peltoniemi 2011: 354). "Firms that are unable to move towards greater product standardization and process innovation will not succeed in competition against those who make the transition." (Ibid.) This shake-out stage can be observed in the majority of low-tech industries, which faced an enormous contraction process over the last decades. Hence, the previously described incremental process innovations in low-tech sectors can be explained by these reflections. Besides this, firms exited the domestic market and relocated production to low-cost countries. With regard to profit and innovation strategies of low-tech firms, Holm-Detlef Köhler (2008: 6) likewise refers to life-cycles and Schumpeter's category of creative accumulation prevalent "in more developed mature industries with established hierarchies and high entrance barriers for newcomers", whereas creative destruction is related to entrepreneurs in new sectors due to low entrance barriers (ibid.). In this sense, KIE – understood as a new entrant destroying existing products and structures by creative innovations – is not assumed in low-tech sectors.

A further argument which indicates against any incentive for entrepreneurs entering mature industries, like low-tech industries, is that "the growth of most industries slows as markets become saturated, and also that this maturity is often accomplished by a reduction in the rate of innovation" (Utterback 1994 in Robertson/Jacobson 2011b: 6). Contrarily, "[i]nnovations that open up new technological avenues create new industries, emerge during an era of ferment, and tend to be produced by new entrants" (Peltoniemi 2011: 351). This is said to take place in so-called entrepreneurial regimes. New entrants have an advantage compared to established actors, because they "are not held back by the established division of labour and communication between different departments institutionalized around refining a stable architecture effectively" (Henderson/Clark 1990 in Peltoniemi 2011: 351). Large, established firms are considered as the major innovators in established industries (Spilling 2008: 149; Winter 1984: 297) where they pursue creative accumulation in 'routinized regimes'. They predominately tend to perform innovations that "solidify the status quo" (Peltoniemi 2011: 352) instead of creative destruction. In this type of regime, innovations "are termed incremental (Anderson/Tushman 1990; Henderson/Clark 1990; Tushman/Anderson 1986) or regular and niche creation innovations (Abernathy/Clark 1985; Clark 1985) [meaning] movements down the design hierarchy and signify refinement or extension to higher-order concepts and reinforce existing commitments." (Peltoniemi 2011: 352 et seq.)

The two ideal alternating regimes, entrepreneurial and routinized, explain different industrial dynamics in industrial evolution (Spilling 2008: 147). Beside the simple distinction in new entrepreneurial firms as the main source of innovation on the one hand, and established large firms as innovators in the routinized regime on the other hand (Winter 1984: 295; Spilling 2008: 144), also differences in the nature of knowledge are assumed for these regimes (Malerba 2005a; Spilling 2008). Above all, the knowledge dimension refers to technological and R&D based knowledge. Routinized regimes are characterized "by a high importance of basic sciences and relatively low importance of applied science" (Heidenreich 2009: 484), while the latter is referred to entrepreneurial regimes (Breschi et al. 2000 in Heidenreich ibid.). This is the next indication beside the characteristic of large firms that routinized regimes do not fully agree with the characteristics of low-tech sectors. Low-tech sectors are usually dominated by small and medium sized firms, and these spend ordinarily only little on R&D – be it for basic research or applied research. Instead, this is rather done by public research or industrial research communities in Germany, like the AIF (Arbeitsgemeinschaft für industrielle Forschung) or suppliers of medium or high-tech sectors (e.g. machinery and equipment, ICT).

Furthermore, the nature of the knowledge base of the routinized regime is explained based on trajectories directed to the exploitation of economies of scale or the "mechanization of manual work" (Peltoniemi 2011: 352 et seq.). This corresponds with the nature of innovation described with the era of incremental change and in low-tech industries before. Established technological regimes determine the potential and constraints of a given technology. For instance, these trajectories influence the engineers' attention to specific directions of development (Nelson/Winter 1977 in Peltoniemi ibid.). Under these circumstances, rather "knowledge internal to the industry becomes valuable for keeping up with technological developments, and past learning-by-doing gives an advantage to incumbents over entrants" (Gort/Klepper 1982 in Peltoniemi 2011: 353). Also, David Audretsch and Max Keilbach (2010: 289) with recourse to Sidney Winter (1984) describe the knowledge conditions in routinized regimes as favorable for large incumbent firms. The "continuously innovating and accumulating technological and innovative capabilities" (Spilling 2008: 149) disadvantage potential new entrants here (cf. also Shane 2003: 130). This builds another argument against KIE occurring in a routinized regime if solely defined as new a firm. In conclusion, given that low-tech sectors were classified as routinized regimes (despite the few mentioned inconsistencies), KIE in low-tech sectors must be considered as a paradox, since innovation is not organized through entrepreneurship in such routinized regimes.

Further arguments against the occurrence of KIE in low-tech sectors can be found in *entrepreneurship research*, too. Scott Shane (2003: 118-144) in his "General theory of Entrepreneurship" also refers to industrial life-cycles for explaining "industrial differences in entrepreneurial activities": "When industries are young and pre-paradigmatic, they have few existing firms and new firm formation is relatively common. As industries age and develop, they tend to become composed of a larger number of firms, and new firm formation becomes relatively less common." (Shane 2003: 129) According to this, the "level of entrepreneurial opportunity" is influenced by the respective stage of industry life-cycle (ibid). Several reasons are indicated that mature industries, like low-tech industries, offer reduced opportunities for new firm formation (ibid. et seq.). Market growth shifts from upward and growing adoption downward to declining adoption in aged industries (ibid.). Moreover, the increasing demand is rather met by existing firms than by new firms (ibid. 130) and finally, at a certain stage opportunities of demand are too low to incite new firm creation.

In addition, Shane with recourse to Breschi et al. (2000) points to the industrial knowledge base. When an industry matures, the knowledge base becomes stable and firms conduct learning-by-doing. Shane also stresses here that “new firms lack the opportunity to develop these learning curve advantages” (ibid.). In contrast to this, firm formation is rather expected to take place in “growing industries, because high growth rates generate excess demand that established producers cannot satisfy, and because high growth rates make it possible for new entrants to avoid competing directly with established producers for customers” (Shane 2003: 127). Additionally, firm formation is more likely in large, segmented markets and younger industries (ibid. 143) that “have not yet converged to a dominant design” (ibid.). Shane states with recourse to empirical evidence that firm creation is “more common in industries that are more profitable, have lower cost inputs, are less capital intensive and […] are less concentrated and have lower average firm size” (ibid. 144). In case of low-tech industries, for most of these aspects the opposite is the truth (except from the average firm size and partly the segmentation). Instead, low-tech sectors are generally characterized by high capital intensity and market concentration as well as low growth and profit rates. Hence, it has to be assumed that these sectoral conditions do not favor any firm formation so far.

Against these theoretical deliberations of industrial dynamics and entrepreneurship research it can be assumed that entrepreneurial opportunities and activities are expected to be near to the ground in low-tech industries. Based on this assumption, analysing KIE in low-tech sectors seems to be a paradox, which explains why this phenomenon has not been investigated in this context so far. Thus, the main problem of this thesis deals with the question:

> *How does KIE emerge in the institutional environment of low-tech industries?*

Why is it nonetheless worthwhile to deal with this question? The response can be found in further considerations of ILC theory as well as in the limits of its theoretical findings. First of all, as Spilling (2008: 144) state, the “shift from one mode to the other does not mean that entrepreneurs are a threatened species: ‘They survive in a number of niches, sometimes in competition and sometimes in symbiosis with research-intensive giants’ (Winter 1984: 295)”. Hence, entrepreneurial innovation is also conceivable outside from entrepreneurial regimes. Empirical entrepreneurship studies have been mainly based on quantitative population-level investigations (cf. Shane 2003; Peltoniemi 2011). However, Fritsch (2011: 376) points out that particularly “highly innovative new businesses is a rather rare event”, which is difficult to identify and measure accurately. This can be certainly assigned to the phenomenon of KIE as well. In addition, the two innovation modes (Schumpeter Mark I/II) depict ideal categories (Winter 1984; Spilling 2008). This dichotomous view does not take into account “the fact that industries and firms are multi-product and the technological regime may differ importantly among products” (Winter 1984: 317). This way, the empirical and theoretical findings about the industries’ evolution and their innovation activities are mostly based only on the investigation of a dominant technological regime that cannot be equalized with a single industry (Malerba 2005b). “The dichotomous Mark I and II categorizations may be too restrictive to portray the main pattern of evolution of different industries” (von Tunzelmann/Acha 2005: 424).

On closer inspection, ILC theory offers an interesting starting point to solve the outlined paradox. Theorists of the life-cycle view do not only spring from the displacement of an entrepreneurial regime by a routinized regime along an industry’s evolution. Likewise, a routinized regime can be replaced by an entrepreneurial regime creating a new industrial cycle (which the metaphoric term of a cycle actually implies). “In this case, a rather stable organization characterized by incumbents with monopolistic power is displaced by a more turbulent one with new firms using the new technology or focusing on the new demand” (Henderson/Clark 1990; Christensen/Rosenbloom 1995 in Malerba 2005a: 383). Such developments are archetypal and explained with the discontinuous development of innovation (ibid.). Thus, such new cycles can also be theoretically assumed for matured low-tech industries. Transferred on the low-tech context KIE would not be necessarily considered a paradox anymore but a mechanism to transform industrial structures (Malerba 2010b: 3). In conclusion, the ILC theory and the modes of innovation regimes can help describing existing industrial structures and the environment in which KIE occurs. However, the findings from industrial and entrepreneurship literature need not necessarily be true for the rare phenomenon of KIE in low-tech sectors. Rather, the indicators do not seem to sufficiently explain the phenomenon.

In addition, *economic sociological deliberations* on cyclical economic development explain the paradox of KIE in the low-tech industries. After the stage of path creation and establishment, the third stage is characterized by institutionalization that leads to a paradigm or dominant design and finally to lock-in of the established technological path (Deutschmann 2008: 111). Paradoxically, this state of lock-in uncovers the limits of the prevailing paradigm and stimulates new ideas that become “Ausgangspunkt neuer pfaderzeugender Erfindungen”[7] (ibid.). Even if only a minority of entrepreneurs senses this lock-in as an entrepreneurial opportunity, a new cycle can occur this way (ibid.). Applying this argument on the low-tech environment, the characterization of these industries’ evolution cannot be clearly allocated to a routinized or entrepreneurial regime and remains to be newly determined. It has to be assumed that the embedding knowledge and innovation conditions for KIE range somewhere in between in these sectors. Generally, the industry context affects the entrepreneurs’ decision

[7] … starting point for new path creating inventions (translated by author).

on exploiting an opportunity (cf. Shane 2003: 118). For the low-tech context it still needs to be clarified, if low-tech industries favor or hinder such opportunity exploitation. Particularly for KIE, Delmar and Wennberg (2010: 15) assess that only “little research to date has investigated how these contextual sources interact or how they shape entrepreneurial behaviour across levels of analyses.” They assume that opportunities, individual entrepreneurs and the emergence of entrepreneurial firms depend on these contextual conditions like temporal and spatial factors (ibid.). In addition, tensions have to be assumed for the process of KIE that starts embedded in “established economic structures, but at the same time changes them” (Groen 2005: 69). Concretely, resisting actors and systems need to be considered within the established structures (cf. ibid.). Likewise, the mechanisms and agents that stimulate KIE are not clear for low-tech environments.

1.4 Approaching KIE in low-tech industries

The introduced reviews of innovation research on the low-tech sector and KIE concepts lead to the first conclusion that the existing definitions of KIE cannot be simply applied on the low-tech context. Several reasons can be found for the conceptual adaptation of the existing KIE definitions. First of all, in most of the introduced KIE concepts KIE is defined by bounding its occurrence to knowledge-intensive industries that have a high innovation rate and high rate of high-skilled people (cf. Delmar/Wennberg 2010; Groen 2005). Low-tech industries are categorically excluded from these because of their low investments in R&D and low amount of high-skilled employees (cf. Kirner et al. 2009b). However, if KIE is understood as a mechanism of change (Malerba 2010b; also Malerba/McKelvey 2010), the phenomenon is also conceivable as revitalizing for traditional low-tech industries. Schumpeter (1967) once used the phenomenon of entrepreneurship for explaining discontinuous change. He has no specific industry in mind for his concept of entrepreneurship explaining economic development, but his deliberations are in many respects useful for our perspective on KIE in the sectoral context.

In the following the problem of inconsistent assumptions of the two fields of research (conceptual paradox) are solved by developing a more adequate concept for the analysis of KIE in low-tech industries. More precisely, a broader concept of innovation and entrepreneurship is necessary as well as a more precise definition of the term knowledge-intensive to distinguish it from neighboring terms.

1.4.1 Broadening the understanding of innovation

The basic difficulties in applying the existing KIE concepts on the low-tech sector context lie in the fact that they are obviously based on another innovation paradigm. On the one hand it does not enable researchers to consider entrepreneurial innovation in low-tech industries and on the other hand it is not fully consistent with the developmental entrepreneurship perspective according to Schumpeter. It stands out of question that KIE is especially connected with innovation. However, depending on which innovation paradigm is applied and what is understood by innovation, KIE can be measured in the low-tech context or not.

The existing KIE definitions use mainly quantitative R&D and patent indicators (Camerani/Malerba 2010; Malerba/McKelvey 2010) and refer to scientific or R&D based knowledge (Delmar/Wennberg 2010; Groen 2005) above all. In doing so, an innovation understanding according to what Chris Freeman and Luc Soete (2009: 587) call the innovation paradigm of the 20th century becomes obvious. Accordingly, innovation is mainly considered in terms of corporate R&D activities at the firm level. Because firms in low-tech sectors are known for their low in-house R&D activity (cf. Heidenreich 2009, Kirner et al. 2009a; Som 2012), a broader concept of innovation is necessary. Several researchers of innovation studies on the low-tech sector (Hirsch-Kreinsen 2008; Som 2012; Robertson/Smith 2008), but also independent from low-tech studies (Arundel et al. 2008a/b; Godin 2008; Smith 2005), criticize the R&D focus. They acknowledge that innovation is more than based on R&D activity and highly skilled staff. In this respect, Som (2012: 109) argues with recourse to Freeman and Soete's (2009: 587) shifts in innovation paradigms that, although meanwhile a paradigm of the 21st century has been proclaimed that centers on the systemic and inter-organizational collaborative aspects of innovation, most innovation studies still follow the previous "in-house corporate R&D" innovation paradigm. The reason for this is that "R&D data still represents one of the most reliable and easily available measures to assess firms' innovation activities." (Som ibid.) But neither firm nor R&D indicators can sufficiently measure KIE activities in the low-tech sector. The example of Mrs. Mayer's innovation of the flame-retardant paper combs, from the introduction, is a highly innovative application in the field of car bodies. It was neither based on formal R&D activity nor on a formal, highly educated workforce. Applying the indicators of the widespread innovation paradigm from the 20th century, this innovative venture could not have been identified.

In response to this conceptual problem, a broader understanding of innovation should be used apart from the common indicators. In search of this, Schumpeter's entrepreneurial perception of innovation put itself forward. He describes five cases of "new combinations of productive means" (1967: 66), which covers new product and process innovations, the disclosure of new markets, new sources of supply as well as organizational innovations. These kinds of innovations are not bound to any R&D activity or technological innovation. Schumpeter explicitly indicates that the entrepreneur, who is the one carrying out this new combination, is not necessarily the inventor of any new means (1967: 88/89). This broader innovation understanding is more useful for our approach. However, the broad range of innovations is nevertheless specified by the necessary requirement that the innovation process has to be characterized by discontinuity (Schumpeter ibid. 66). Innovation for economic change in the sense of Schumpeter does not “grow out of the old by continuous adjustment in small steps” (ibid. 65). This might imply growth, “but neither a new phenomenon nor development in […] [his] sense” (ibid. 65 et seq.). Schumpeter explicitly excludes incremental innovations that are actually characteristic for low-tech industries. In its place, he stresses the disruptive deviation from existing routines (ibid. 80). Freeman and Soete (2009: 587) call this entrepreneurial innovation understanding the innovation paradigm of the 19th century. It helps to bypass the prevalent narrow innovation understanding of the previous concepts on low-tech and KIE, while it encloses the function of KIE as a mechanism of change. Finally, with this Schumpeterian understanding, the innovation activity of KIE can be discriminated from investigated incremental innovation activity in low-tech industries.

The innovations’ character of newness is derived from its social context meaning that “the innovation must be considered new to members of the social system” (Herbig/Kramer 1993: 5). In this approach, a low-tech industry depicts this social system and builds the frame of reference for the deviation from routines. Knowledge or artifacts that have existed in another industrial system before can nevertheless be considered as innovative, if it is varying from the members’ common knowledge base of the considered social system. Accordingly, not every change within an organization is a Schumpeterian innovation, since the frame of reference applied here refers to the industrial environment and not solely to the firm.

1.4.2 Widening the understanding of entrepreneurship

The Schumpeterian innovation paradigm also helps in dealing with the entrepreneurship term of KIE. A wider concept of entrepreneurship is additionally needed, because KIE is almost exclusively investigated in terms of a new firm creation so far (cf. Delmar/Wenn-berg 2010; Groen 2005; Heidemann Lassen/McKelvey 2012; Malerba 2010a). Though Malerba (2010b: 5) firstly included “either de novo entrants or established firms active in a process of technological diversification” and with an “entrepreneurial spirit” (ibid. 4) at command for defining KIE, in a later approach this form of corporate entrepreneurship is explicitly excluded (Malerba/McKelvey 2010: 9 et seq.), while the foundation of new firms is highlighted (ibid. 7). The exclusive focus on new firms involves some difficulties especially in the low-tech sector (cf. Chapter 1.3). The exclusion of corporate entrepreneurship might have to do with the operationalization of KIE for empirical research. New firms can be identified easier than the phenomenon of corporate entrepreneurship. But the foundation of a new firm alone does not necessarily imply innovative activity (Malerba 2010b: 6; Sharma/Chrisman 199: 13). For KIE, however, innovation depicts a constitutive component (cf. Malerba ibid.; Delmar/Wennberg 2010).

In the KIE literature, further ambiguous arguments for and against the phenomenon emerging in new firms as well as in established firms as corporate entrepreneurship can be found: Delmar and Wennberg (2010: 150), for instance, acknowledge that the phenomenon observed as new firms in knowledge-intensive industries showed only limited growth and "little impact on the industry and the economy at large" despite their ability to seize given technological opportunities. These start-ups seem to invest even less in R&D than established firm as well as to "produce fewer patents and fewer products and technologies" (Delmar/Wennberg 2010: 14). And, compared to established firms, new firms are disadvantaged in accessing external sources of relevant actors due to missing legitimacy (cf. Lenzi et al. 2010: 180). Moreover, Godinho and Mamede (2005) found in their investigation for the KEINS project that spin-offs from established firms profit from the access to knowledge of the parent firm and other sources (in Malerba 2010b: 9/18). Hence, corporate entrepreneurship can solve problems that young entrants may face in aged industries. However, arguments against corporate entrepreneurship can be found as well. Especially established low-tech firms face problems in overcoming widespread "Tayloristic structures" with their "strictly-defined division of labour" (Hirsch-Kreinsen 2005: 158). The organizational environment of highly "repetitive tasks" leads employees in low-tech firms rather "to hide their knowledge of the trade or to use it for little innovations only unofficially in order to gain more freedom" (ibid.) instead of highly innovative entrepreneurial activity.

Although new KIE firms are said to perform generally less good than incumbent firms according to R&D and patent indicators (which are not exactly necessary for implementing a significant innovation), "the quality of their innovation is on average higher" according to Delmar and Wennberg (2010: 14). This is because new, independent firms are expected to better succeed in linking "generally new sources of knowledge [with] economically relevant knowledge" (ibid. 28). Contrarily, for established firms it is quite difficult to extend their existing knowledge in new areas (cf. Faulkner 1994: 441). They acquire knowledge cumulatively and path dependent in fields that are familiar to them (ibid. 441 et seq.). Especially technological paradigms of the surrounding sectoral knowledge base can "have a 'powerful exclusion effect', thus limiting the ability of firms to 'see' knowledge (including technological options) that is available outside" (ibid. 442).

These inconsistent arguments underline once more the initially introduced paradox situation of KIE in low-tech sectors. Following the industrial life-cycle (ILC) theory, on the one hand new firms could face serious entrance barriers in mature low-tech industries (Köhler 2008: 6) due to the required high capital intensity in these industries. Additionally, they have to deal with established actors that seek to hold on to the status quo (cf. Peltoniemi 2011). On the other hand, varying innovation is not expected to be carried out by established firms embedded in their routinized innovation regimes (Murmann/Tushman 2001). In eras of ferment with technological uncertainty, entrepreneurs have more opportunities founding a venture, because radical new innovations are not expected from established firms that are used to "incrementally refining the dominant design of the previous technology cycle" (Murmann/Tushman 2001: 193et seq.). In fact, low-tech sectors have faced huge shrinking processes

(Robertson et al. 2009; Robertson/Jacobson 2011a) and can be rather characterized by a shake-out stage (Peltoniemi 2011; Shane 2003), whereas more firms exit than enter the market.

The theory of ILC tells little about the specific *setting* of entrepreneurship in the transition stage from an era of incremental change to a new era of ferment where established actors are displaced by new firms (cf. Christensen/Rosenbloom 1995; Henderson/Clark 1990 in Malerba 2005a: 383). Particularly with respect to low-tech industries, it is even harder to anticipate, if this transition is carried out mainly by new independent firms or in established firms as corporate entrepreneurship. Parhankangas and Arenius (2003) have found that corporate ventures are mainly restructuring new business in low-tech sectors. Though this study did not especially refer to KIE, corporate entrepreneurship should not be excluded as an organizational form of KIE. All in all, it remains difficult to expect KIE activities solely taking place as either new firms or as corporate entrepreneurship at established firms. Likewise, none of both forms can be excluded for the low-tech environment. Moreover, this is likely to vary significantly among the several low-tech industries. That is finally why in response to this open question a new explanatory approach shall be receptive to the broadest variance of possible cases. Consequently, KIE is conceptualized to emerge in the context of low-tech-sectors in both ways: as new firm creation as well as corporate entrepreneurship at an established firm.

In the following investigation, KIE can include independent entrepreneurship, if "individuals or a group of individuals [are] acting independently of any association with an existing organization" (Sharma/Chrisman 1999: 18) as well as corporate entrepreneurship, if these individuals "create a new organization or instigate renewal or innovation" with an existing organization (ibid.). However, KIE is to be distinguished from Pramodita Sharma's and James Chrisman's (1999: 18) general understanding of entrepreneurship insofar that entrepreneurship in this low-tech approach here does not necessarily require the creation of a new organization but of an innovation, while the authors contrarily consider "the presence of an innovation […] as a sufficient condition for entrepreneurship but not a necessary one". This can be explained by their focus on the creation of a new organization that can also be founded in absence of an innovation. Moreover, they argue that innovation varies in its degree and that its uniqueness is difficult to specify (ibid.). But exactly this is the point where KIE is to be differentiated from ordinary entrepreneurship concepts or simple founding activities. Innovation is a constitutive element of the KIE concept as it has already been stressed by several authors. More precisely, corporate entrepreneurship shall be understood here "as the presence of innovation plus the presence of the objective of rejuvenating or purposefully redefining organizations, markets, or industries" (Covin/Miles 1999: 60). This perception then fully consists with the necessary requirement that KIE "rejuvenates technologies and industrial structure" (Malerba 2010b: 3) and the perspective that is considered in this work.

This perception can also be aligned with the Schumpeterian innovation paradigm. Indeed, Schumpeter states with regard to the organizational setting of entrepreneurship that these “new combinations are, as a rule, embodied, as it were, in new firms which generally do not arise out of the old ones but start producing beside them” (1967: 66). But at the same time he admits that it “may happen – that the new combinations could be carried out by the same people who control the productive or commercial process of which is to be displaced by new.” (Ibid.) Moreover, these new combinations are not immediately taking the place of the old ones “but start producing beside them” (ibid. 101). In other words, Schumpeter acknowledges that innovation can also emerge in an existing organization as a form of corporate entrepreneurship. According to the innovation meant here, the entrepreneurial process “may result in the creation of a new organization, it does not necessarily have to do so“ (Sharma/Chrisman 1999: 13).

1.4.3 Specifying KIE

Taking Schumpeter’s entrepreneurship perception as a basis has further advantages considering another conceptual problem of the existing KIE concepts. That is the common operationalization of KIE as ‘knowledge-intensive firms’ (cf. Groen 2005; Malerba/McKelvey 2010). The term ‘knowledge-intensive firm’ is closely related to permanent innovation activity and a highly educational level at the firm (ibid.). In respect to firms in low-tech sectors, the conceptual inconsistency is composed by the management literature that categorically distinguishes knowledge-intensive firms from manufacturing firms (Corell 1998) as they are common for low-tech sectors. Distinct to knowledge-intensive firms they are characterized as ‘capital-intensive’, i.e. that human capital alone can never be the only success criterion for such manufacturing firms (cf. Corell 1998: 22). Nevertheless, knowledge is not absent in these industrial ventures and can be an important size as well. The economic success of manufacturing firms rely first of all on real capital, whereas the competitive advantage for knowledge-intensive firms is said to be the superior knowledge above all (ibid.).

The common approach for investigating the knowledge intensity in this research field is to measure the educational level of the firm. In this respect, William Starbuck (1992: 719) suggests to define knowledge-intensive firms by one third of personnel with expert status, i.e. with a formal education and experience comparable with a doctoral degree. Hence, the degree of knowledge intensity shall be identified by the amount of employees with a formal academic degree. Carsten Kampe and Herbert Oberbeck (2005) indicate two points of criticism against this. Firstly, it cannot be excluded that the main performance of a firm with a high educational level of employees like an IT firm, for example, nevertheless consists mainly of routine work (ibid. 20). Secondly, formal education, especially in highly dynamic innovation fields, is not given or much slower in adapting to new knowledge before it can be representatively measured at the firm level (cf. ibid.). This was, for instance, observable for the early stage of the IT industry and also in the low-tech example of the Wabenfabrik Mrs.

Mayer could not find someone with a specific formal profession for her innovation idea (cf. Pollack 2007: 18). This is because creative or superior knowledge that leads to an economic advantage is going beyond the level of general education (Corell 1998: 25). Therefore, creative knowledge is also characterized as “esoteric” (ibid.), which means uncommon in this context. It is not sufficient to have ordinary knowledge at command, which was acquired in a formal education (ibid.). Some authors put creativity even in conflict with formal knowledge, since creativity becomes mostly important when conventionally methods are not enough for solving a problem (Alvesson 1993 in Corell 1998: 26). Or, in other words, if a problem can be solved by ordinary knowledge, most people do not see any reason for creativity (Corell ibid.).

Coming back to the reviewed concepts of KIE, the phenomenon is mostly operationalized as a knowledge-intensive firm and also measured by the educational level of the employees (cf. Delmar/Wennberg 2010; Lenzi et al. 2010; AEGIS Survey). Knowledge intensity is broadly equaled with innovation performance and creativity, and exactly this is expected from people with a formal, high educational level as a clear, measurable indicator in principle. Lenzi et al. (2010:180) go so far to claim that “the higher a founder’s intellectual assets the greater the chances of a new venture success in terms of both survival and economic performance”. However, for new firms Heidemann Lassen and McKelvey (2012: 55) notice that the “skills of the members of the new ventures is usually not available” in statistics, which particularly holds true for data about the low-tech sector. Moreover, the indicated criticism by Kampe and Oberbeck (2005: 22) considering the sufficient validity of the formal educational indicator for knowledge intensity can be taken over for this KIE concept. In particular, the industries in the low-tech sector traditionally have a very low amount of highly skilled employees. As mentioned earlier, Kirner et al. (2009b in Som 2012: 10) assessed an above average share of low- and unskilled employees at low-tech firms that led them to the assumption of alternative paths of knowledge generation.

Again it can be observed that the use of the term ‘knowledge-intensive firm’ points to the firm level and R&D indicators known from the persisting innovation paradigm of the 20th century. If we apply once more Schumpeter’s understanding of entrepreneurial innovation, we can at least solve the contradictions at the firm and educational level for the low-tech context. Before Schumpeter proceeded to the institutionalized innovation activity within the firm in his later work (Schumpeter Mark II; 1942/1950), innovation had been the function of entrepreneurship (Schumpeter Mark I; 1967). Moreover, the entrepreneurship phenomenon he describes is of economic significance and therefore a “specific process” (1967: 79) “as a rule not a lasting condition” (ibid. 78). This consideration excludes knowledge-intensive firms by definition. After the entrepreneur carried out the new combination, he loses his/her character as an entrepreneur again (cf. ibid.). Hence, Schumpeter emanates from *a rare phenomenon* of discontinuous deviation from routines (cf. 66/80), while it is nonetheless of economic significance. In addition, the entrepreneur is neither necessarily the inventor of new combinations (ibid. 88/89) nor the founder of a new firm (ibid. 78), nor is he or she specified in his/her educational level by Schumpeter. In consequence, springing from this broad Schumpeterian entrepreneurship concept expands the field of investigation and seems this way more appropriate, as a temporary phenomenon can take place either in association with a new firm or at an established firm in the low-tech sector. Anyway, necessary creativity and collaborations for KIE do basically not follow hierarchy and the control of an organization (Deutschmann 2008: 144). Organizations can provide room for creativity, but they cannot command creativity or be creative themselves (ibid.).

After these clarifications on innovation and entrepreneurship understanding finally the last but most discriminatory element of the KIE *knowledge intensity* needs to be specified. It has been theoretically related to creative innovation activity. Economic theorists generally struggle to deal with this complex creative phenomenon, because it cannot be explained by rational theory or caught in an algorithm (Deutschmann 2008: 99 et seq.). Knowledge intensity occurred in economic science related to the terms ‘capital- or labor-intensive’ to distinguish between different types of firms and their most decisive factor (cf. Kampe/Oberbeck 2005: 20; Corell 1998: 19). Accordingly, knowledge depicts the most important size for so-called knowledge-intensive firms instead of their capital intensity (cf. Cramer 2002: 12; Heidenreich 2002: 1; Starbuck 1992: 715; Strambach 1999: 7 in Kampe/Oberbeck 2005: 20). The difficulty is to measure knowledge as the central factor. Particularly in this respect the reviewed KIE concepts remain vague or not useful for the low-tech context. KIE is determined, for example, as knowledge-intensive firms which “have significant dimensions of knowledge intensive in their activity” (Malerba/McKelvey 2010: 7) or to “processes [that] are to a great extent based on relatively new (mostly academically derived) knowledge or technology” (Groen 2005: 70). But how can “a great extent” or “intensive use” of knowledge be measured? Knowledge is generally hard to quantify (cf. Kampe/Oberbeck 2005). Some authors try to deal with this problem by considering the type of knowledge and valuing scientific or R&D based knowledge higher than other types of knowledge. Basically, any economic action is hard 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 types 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. Usually scientific knowledge that is originally created on purpose of research is independent from any specific use (Hirsch-Kreinsen 2005; Som 2012). Instead, it has to fulfill academic conditions like reliability and validity, and this makes it theoretically transferable to a broad range of applications and contexts (Hirsch-Kreinsen ibid.), whereas knowledge, developed in the industrial context, is mainly focused on the solution of a specific problem and application that limits its transfer and value (ibid.). However, the broad appropriability of scientific knowledge does not imply automatically a higher economic value or intensity of knowledge. Innovation encompasses many more types of knowledge than approaches determined on scientific or technological knowledge can offer (cf. Jacobson/Heanue 2005: 315). The creation of new scientific knowledge alone cannot explain how it is commercialized in an innovation and create economic value.

The sociologists Christoph Deutschmann and Jens Beckert emanate from a systematically underexposed role of creativity in economic science (Beckert 1996; 1999 in Deutschmann 2008: 100). Likewise, such rare phenomena are not in the center of economic sociology that generally deals with recurring action patterns. Distinct from this, Schumpeter highlights the creative moment of entrepreneurship. Referring to entrepreneurs' deviation from routines he laid the ground for a more realistic and socialized concept for explaining change and innovation. For this outstanding view on entrepreneurship he is still today considered an outsider (Deutschmann 2008: 107; Morlacchi 2007: 342). Anyway, Schumpeter's approach also lacks central terms to analyze innovation as a social process based on communication and knowledge (Deutschmann 2008: 100). He is criticized for focusing mainly on the entrepreneur as an individual and his/her leading skills (Deutschmann 2008; Dopfer 2006). Kurt Dopfer (2006: 23) remarks, for instance, that Schumpeter "viewed the individual one sidedly only as an energetic personality, not as a knowledge and information processing agent. Though active, the agent he describes is not involved in any systematic way in knowledge creation, knowledge adoptation or knowledge communication."[8] For this reason, Schumpeter's evolutionary entrepreneurship concept alone is not sufficient to explain KIE in a certain sectoral environment. Overall, "[d]ie wirtschaftstheoretischen Konzeptionalisierungen der Figur des Unternehmers pendeln zwischen einer objektivistischen und einer personalistischen Sichtweise, ohne zu einer befriedigenden Lösung des Konflikts zwischen den konträren Positionen zu gelangen."[9] (Deutschmann 2008: 100)

Against the economic view Deutschmann's sociological view stresses the *creative skills* of the entrepreneur. The entrepreneurial action does not solely depict an information advantage or better illustration of data, as the Kirznerian School argues (cf. Kirzner 1983 in Deutschmann 2008: 107). Instead, it is pointed to the transformation of constructions of data as the creation of new preference structures and cognitive

[8] In the course of raising network research there is a rejection of this phenomenon as referring to a stereotyped heroic entrepreneur (Radosevic et al. 2011; Köhler 2008; Rammert 2008; Som 2012). But dealing with this phenomenon and taking over the entrepreneurial perspective does not mean that the entrepreneurial process and setup of an innovation is solely carried out by one individual. Conversely, it has to be added that recent research by the cognitive social psychology and the knowledge sociology stresses 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.).

[9] The economic theoretical concepts of the entrepreneur oscillate between an objectivistic and a personalistic view without giving any satisfying solution for the problem of these contrary positions (translated by author).

orientation (Deutschmann ibid.). Deutschmann is extending beyond the creative skills that refer not only to reactive problem solving but to the perception and definition of the problem as well as the perception of needs and cognitive structures for developing solutions (ibid. 107 et seq.). In addition, he emphasizes the open, playful and spontaneous character of creativity, which is not only typical in arts but mostly not sufficiently appreciated in the business context (cf. ibid. 107). The sociological view on the transforming role of the entrepreneur reaches beyond Schumpeter insofar that the main performance is not the implementation of a new combination but points to the skills to "establish local orders and control social arenas" for this transforming role (Deutschmann 2008: 107 et seq.). Likewise, Dopfer refers to the development and communication of "generic rules" (2006: 13) or paradigms as Deutschmann equals it with recourse to other authors (Choi 1993; Peine 2006 in Deutschmann 2008: 108). Such a new paradigm can become a rule beyond the local level (ibid. Deutschmann). This way, the social structuring of knowledge creating processes (ibid. 108) is taken into consideration. Similarly, Groen (2005: 70 et seq.) describes KIE as altering product fields, market actors and structures, and "the rules of the game, both on local as well as global levels".

In this respect to change, Deutschmann clearly distinguishes creativity from learning: While creativity refers to the invention of new symbolic patterns, learning deals with the communication of such new symbols (2008: 107). In this sense, the considered creative innovation activities differ from the systemic view on innovation that broadly refers to learning activities or creative accumulation at the so-called learning organization (Ben-der 2005; Cohen/Levinthal 1990; Köhler 2008; Lundvall 1992). In other words, this organizational learning is related to already existing firms and knowledge but not to the specific case of knowledge-intensive entrepreneurial innovation.

Garavaglia and Grieco (2005) describe the process of creativity for the case when "entrepreneurs do more than they know, going beyond the existing knowledge" (2005: 11). This can be anticipated to occur in low-tech industries just as well. The new creation "differ[s] from the expertise previously developed by the incumbent firms, and from the know-how linked to existing products and production processes" (Garavaglia/Grieco 2005: 36). But in their view the creative process depicts only one condition to explain knowledge-based entrepreneurship. The second necessary element in their definition is science-based knowledge (ibid. 10 et seq.). The 'knowledge-based entrepreneurship' has often been used synonymously (cf. Malerba 2010a), but the second necessary element cannot be taken over for the concept of KIE in the low-tech context.

The new approach for the low-tech context should overcome these conceptual inconsistencies by leaving the technology or "science-based view" (Garavaglia/Grieco 2005: 11) as well as formal educational indicators (Groen 2005; Delmar/Wennberg 2010) aside. Instead, *knowledge-intensive activity* shall be specified qualitatively by discriminating it from knowledge-based activity. This discrimination refers back to

Andre Corell (1998) and Kampe and Oberbeck (2005).[10] Creativity and innovation play an important role as explanatory factors for knowledge-intensive activity, but this time in a more qualitative way. Kampe and Oberbeck (2005: 22) describe Corell's distinction between knowledge-based and knowledge-intensive activities as the most radical. The distinction is important, because knowledge is present in any economic field in fact (cf. Strulik 2007: 714) as well as an underdeveloped concept in management literature (Smith 2002). Knowledge-based are called all those activities which use mostly standardized and sometimes but not necessarily highly complex knowledge (Corell 1998 in Kampe/Oberbeck 2005: 22). Kampe and Oberbeck illustrate knowledge-based activity by referring to doctors who use standardized knowledge and methods for their diagnostic analyses. Their solutions may be sophisticated but do not need to be creative. In the same manner it is referred to lawyers or auditors. Most of the economic literature would denote these activities knowledge-intensive professions or ascribe them to knowledge-intensive industries because of the high educational level. However, the central idea of this discrimination is that such knowledge-based activity is not considered a creative process, because it proceeds along solving schemes which exist already before any performance is implemented (Kampe/Oberbeck ibid.). Distinct from this, knowledge-intensive activity creates new knowledge or solving schemes that cannot be anticipated beforehand (ibid.). Hence, the constitutive element of knowledge-intensive activity is going beyond knowledge-based processes, because they manage complex problems that cannot be (optimal) solved by conventional means. In this way, knowledge-intensive activity is a contingent, creative process of problem solving (Corell 1998: 26; Kampe/Oberbeck 2005: 22), which requires outstanding knowledge regardless of which type and creative skills (ibid.).

Summing up the new preliminary definition for approaching KIE in the context of low-tech industries: (1) Entrepreneurship is understood as a rare phenomenon of deviation following Schumpeter (distinct to knowledge-intensive firms that permanently innovate and create new knowledge); (2) KIE can emerge in the entrepreneurial setting of new firms as well as in established firms in terms of corporate entrepreneurship, because a dominant setting cannot be anticipated from the existing literature; (3) KIE is based on knowledge-intensive activity that goes beyond pre-defined knowledge schemes (distinct from knowledge-based activity); instead, it constitutes a creative process in which new (problem solving) knowledge is just being created; (4) The necessary creative skills cannot be sufficiently measured by the formal educational level of the entrepreneur or share in a firm. Finally, (5) the resulting innovation is not necessarily R&D-based or a high-tech application, but it needs to be new to the reference system of the corresponding low-tech sector or product field. In conclusion,

[10] Indeed, they use it in the context of knowledge-intensive firms and services. For the specific dimension of entrepreneurship in this work knowledge-intensive activities will be considered apart from the firm level.

KIE deviates from established (innovation) routines of its sectoral environment and extends the sectoral knowledge base. This sectoral perspective is distinct from previous research on low-tech innovation which considers innovations new to the low-tech firm above all (cf. Köhler 2008; Bender/Laestadius 2005; Hirsch-Kreinsen 2008). In this sense, KIE can be integrated into the low-tech context, if the prevalent view on innovation and entrepreneurship is left aside.

1.5 Objectives of the thesis

In general, the thesis seeks to shed light on sectoral innovation dynamics in matured industries as "it is most likely that, if anything, our findings underestimate the true breadth and depth of entrepreneurial change in mature businesses in recent times" (Mendonça 2009: 479). Besides this uncommon but promising entrepreneurial perspective, the investigation aims at contributing to a better understanding of how new knowledge is transferred into innovation and economic value in low research-intensive industries. This way, the thesis can finally contribute to the first research on sectoral differences and characteristics of KIE.

The introduction discloses that KIE can emerge in low-tech industries, though it sounds paradox against the background of the state of the art on KIE and innovation in low-tech industries. In the previous chapter (Chapter 1.4), conceptual inconsistencies were initially clarified and adjusted to the low-tech environment in order to start the analysis of KIE in low-tech industries with a common analytical understanding. Although KIE is a neglected field of research in entrepreneurship and low-tech innovation studies, both strands of research generally agree on varying sectoral influence on entrepreneurial and innovation activities. This depicts the starting point to answer the main research question, *how KIE emerges in the institutional environment of low-tech industries*, as research on specific environmental effects of low-tech sectors on KIE has just started (cf. Hirsch-Kreinsen/Schwinge 2011; 2014).

The subordinate objectives are to gain insights in:

1. Environmental conditions of an exemplary low-tech industry to understand the deviation of KIE from it.
2. Characteristics of KIE in this industrial context with respect to specific opportunities, resources and mechanisms of KIE.
3. Influences of the institutional low-tech environment during the emergence of KIE.

These objectives structure the organization of the thesis in the following. A consistent conceptual frame is drawn from promising concepts of innovation, entrepreneurship and institutional theory (Chapter 2). The main analytical dimensions and diagnostic questions will be derived from the selected concepts. The methodological chapter outlines the specific approaches to implementation and analysis of the empirical investigation (Chapter 3). The multidimensional approach seeks to combine the evaluation of sectoral quantitative data with qualitatively gathered data from case studies. The German textile industry is exemplarily selected as the unit of analysis for the empirical investigation. Once the textile industry was one of the leading industries during the industrial revolution, then it became a typical low-tech industry (cf. von Tunzelmann/Acha 2005: 425). Economic transformation and technical changes in the last decades makes the textile industry interesting for the analysis of KIE. The empirical analysis starts specifying the institutional environment of the German textile industry (Chapter 4). Broad sectoral data helps to identify the industry's dominant practices of organizing innovation. As statistics and panels usually provide limited data on rare phenomena, three case studies of KIE are presented with regard to their specific opportunities, resources and mechanisms (Chapter 5). The case data is mainly based on explorative case study research from the AEGIS project. The case studies describe the whole process of KIE, enabling insights in environmental influences. Subsequently, the empirical results from the sectoral and case study analyses are combined and discussed in light of evidences and insights for the outlined objectives (Chapter 6). Finally, conclusions from the discussion on results of the textile industry are drawn on the emergence of KIE in low-tech industries (Chapter 7). Additionally, more general conclusions should be drawn on KIE's contribution to transfer new knowledge into innovation in these industries. This way, the thesis can contribute first empirical insights in sectoral differences and characteristics of KIE. At last, limitations and further questions from the investigation provide a research outlook.

2 Conceptual frame of reference

Whether in case of independent new firms or corporate entrepreneurship, socio-structural conditions have an effect on the emergence of entrepreneurial activity. This correlation can be cross-disciplinarily found in economic and industrial sociology as well as entrepreneurship literature. That context matters for KIE just as well can be found, for instance, at Groen (2005) or Delmar and Wennberg (2010: 152): "[I]nitial conditions at birth both in the surrounding context and specifically at the firm level have a path-dependent effect on firm evolution." The industry's contextual influence on entrepreneurial decision making was generally stressed by Shane (2003: 118): "Many researchers have shown that the propensity for people to engage in opportunity exploitation through new firm formation differs significantly across industries." Thereby, Shane basically distinguishes between industry context "that favors opportunity exploitation through firm formation" (ibid.) and the one "that hinders opportunity exploitation through firm formation" (ibid.). The conceptual frame of reference seeks to find out more from existing deliberations about the relation between context and entrepreneurs that can help to understand and analyze the emergence of KIE in low-tech industries.

As a general starting point, the assumption of Malerba (2005a) and Malerba and McKelvey (2010: 8) is used that national and sectoral innovation systems (Chapter 2.1) play a decisive role in differently shaping the type and intensity of KIE. These systemic links between knowledge, innovation and entrepreneurship address a quite complex set of issues to be analyzed (Heidemann Lassen/McKelvey 2012: 54). For that reason, the effects of sectoral innovation systems on KIE have been less analyzed so far (Malerba 2010b: 13). In addition, Malerba demands "deeper analyses of the different dimensions of KIE and their links with innovation systems […] in particular agent-based models of KIE, innovation and industrial dynamics have to be produced." (2010: 24).

The following frame of reference addresses such a comprehensive consideration of KIE deriving relevant diagnostic questions from systemic, entrepreneurship and actor oriented institution theories. First of all, the concept of sectoral innovation systems (Malerba 2005a/b, Breschi/Malerba 1997) is introduced, which considers established knowledge and innovation practices as well as actors in a sectoral system (Chapter 2.1). For specifying the research dimension of the entrepreneurial level, Slavo Radosevic's concept of differentiated entrepreneurial opportunities is additionally applied (Chapter 2.2). This systemic concept links entrepreneurial activities with technological, market and institutional opportunities of a national innovation system. However, systemic approaches do not allow considering rare, deviating and creative activity like KIE. According to this theoretical perspective, entrepreneurs would not be

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able to conduct entrepreneurial activities successfully in case of insufficient entrepreneurial opportunities of the innovation system. But, especially this low entrepreneurial orientation must be assumed regarding the maturity and low technology intensity of low-tech industries. For this reason, the conceptual framework is extended by the concept of institutional entrepreneurship (Chapter 2.3). It emanates from willful entrepreneurs who are able to disengage from their social context and change it (DiMaggio 1988). Consequently, the systemic concepts are linked with an actor oriented institutional concept (Chapter 2.4) to explain the emergence of KIE in low-tech industries.

2.1 The concept of sectoral innovation systems

The sectoral system of innovation (SIS) approach is especially qualified for embedding KIE, because it applies a sectoral and broad multidimensional view on innovation (Geels 2004: 914; Pitt 2007: 127). Likewise, Malerba (2010b: 3 et seq.) emanates from influences of sectoral innovation systems on KIE that contribute at the same time to their transformation.

Basically, innovation system approaches were designed to "take all important factors shaping and influencing innovations into account" (Edquist 1997a: 2). Apart from focusing one-sided on R&D indicators and distant from any linear development model, the approach emphasizes the "social nature of innovation processes" (Wolfe 2011: 13). It is pointed to the systemic and interactive nature of relationships between science, technology and economy (Edquist 1997a: 1; Wolfe 2011: 45). The narrow view on innovation of the innovation paradigm from the 20th century is overcome by this systemic innovation approach. Freeman and Soete (1997) call it the innovation paradigm of the 21st century. Likewise, this perspective is called a "Neo-Schumpeterian perspective on innovation" (Wolfe 2011; Malerba/Orsenigo 1996) with which the low-tech approach of KIE from above is compatible. An innovation system is constituted by certain stability and components that are mutually related to each other "to develop, diffuse and utilize innovation." (Bergek et al. 2005: 4). This interaction can happen in an intended as well as unintended way (ibid.). In order to reach their common goal of innovation, the system's set of components "share a common boundary" (Wolfe 2011: 45).

Originally, the concept of sectoral innovation systems provides an analytical framework to grasp inter-industry differences in innovation that national or regional innovation system approaches cannot offer (Köhler 2008: 6). Close to the concept of technological systems, Breschi and Malerba (1997: 131) define a sectoral innovation system (SIS) as "a system (group) of firms active in developing and making a sector's products and in generating and utilizing a sector's technologies". Distinct from national or regional system approaches, this analytical approach figures out "specific organizational and institutional features, which are the product of the historical path-dependent trajectory along which the sector has developed.” (Wolfe 2011: 48) This is based on the assumption that each sector has a specific (technological) knowledge base, learning patterns, actor networks and institutions (e.g. norms, standards, established practices, etc.) that shape a sector-specific mode of innovation (Köhler 2008: 6). For instance, innovation in the science-based pharmaceutical industry differs from the machine tool industry that is rather based on specialized practical knowledge (cf. Nelson/Winter 1977; Malerba 2004 in Köhler 2008: 6). Similarly, socio-technical theorists refer to sectors or industries as ideal types of artificial categories and consider them as “sozioökonomische Felder mit distinkten Regelungsmustern, Akteurfigurationen und Interaktionsbeziehungen, die sich um einen definierten ökonomischen Leistungsbereich […] konstituieren.”[11] (Dolata 2011: 18). Malerba (2004: 9) terms an industry as “a set of activities that are unified by some related product groups for a given or emerging demand”. With regard to the sector’s boundaries he emanates from dynamic and fluent boundaries (Malerba 2005a: 385). Additionally, it has to be pointed out that in a sector different innovation systems can coexist related to different product groups (ibid. 387). Consequently, this framework is understood as an analytical construct (Bergek et al. 2005: 3).

Following Malerba (2005a), the main analytical dimensions for building a systemic sectoral framework are knowledge and technological domain, actors and networks as well as institutions. These dimensions can be found again in the socio-technical perspective that considers industries embedded in specific economic and technological core structures and core actors, which in turn are shaped by institutions like social conventions and routines, for example (cf. Dolata 2011: 18. et seq.).

Next, the different dimensions are presented in more detail in order to determine the characteristics of a low-tech institutional environment for KIE.

2.1.1 The knowledge dimension

Malerba conceptualizes a sectoral system referring to the knowledge dimension as ”the collection of economic activities organized around a common technological or knowledge base in which individual enterprises are likely to be either actual or potential competitors with one another” (Malerba 2004: 428). A sectoral knowledge base describes a certain set of shared knowledge by the industrial actors of this sectoral system. The SIS can differ to other sectoral systems in *knowledge domains* and technological regimes (Malerba 2005a: 385). There are, for example, industries where science is the key driver of knowledge production, while other industries are determined by improvements and learning by doing (ibid. 387). Furthermore, Malerba basically distinguishes knowledge domains that are based on specific scientific knowledge and technological regimes for innovation activities and such domains that

[11] ... socio economic fields with distinct pattern of regulation, actor’s figurations and interacting relations that are constituted around a defined economic field of performance (translated by author).

address customer specific applications (ibid.). In other words, variances are related to specific types and applications of knowledge.

Furthermore, an SIS can be specified by prescribing the accessibility, opportunity and cumulativeness of knowledge (Malerba 2005a: 389). Regarding the access to knowledge, different *opportunities* can be assessed. There are opportunities to gain knowledge from the industry, but also from outside the industry. Gaining knowledge from outside the industry depends on the one hand on the level and origin of scientific and technological opportunities and on the other hand on the firms' perception of technological domains and learning regimes (ibid.). Thereof, the sectoral environment can determine firms in terms of human capital with certain skills or in terms of scientific or technological knowledge from non-profit organizations. Scientific breakthroughs can be considered as an example for sources of such technological opportunities. In other industries, users or suppliers as well as improvements in R&D or technical equipment can be sources of technological opportunities (ibid. 388; 2006: 27). Beside the accessibility to opportunities, different sources of cumulativeness of knowledge are distinguished. Cognitive learning processes and organizational capabilities as well as market feedbacks are considered as sources for accumulating knowledge (Malerba 2005a: 388). Here, firm-specific capabilities are regarded as "highly path-dependent" (ibid.). Altogether, huge sectoral differences exist regarding science, technologies and knowledge bases that condition opportunities for innovation and built a varying institutional environment (cf. Malerba 2006: 23).

In the last decades, knowledge has gained a lot of attention from evolutionary and economic researchers that lead to the debate on the knowledge economy. Along with this went the observation of a discontinuous change in knowledge accumulation and distribution processes that have "redefined existing sectoral boundaries, affected relationships among actors, reshaped innovation process, and modified the links among sectors" (Dosi 1997; Lundvall 1992; Lundvall/Johnson 1994; Metcalfe 1998; Nelson 1995 in Malerba 2005a: 387). Exactly this development can be considered as a new chance for the matured low-tech sector as well as for knowledge-intensive entrepreneurial activity in these industries.

In the case of established industries, Robertson and Smith (2008: 101) have referred especially to distributed knowledge based outside the firm and industry. Similarly to Malerba's argument that a technological regime and opportunities can exceed a sectoral innovation system, Robertson and Smith argue that relevant knowledge for an industry can be "distributed across a range of technologies, actors and industries." (ibid. 100) Especially firms in low-tech industries are said to rely on such distributed knowledge bases across industries to keep up in innovation and competition (ibid. 101 et seq.; Hirsch-Kreinsen et al. 2006). Coming back to the required comprehensive analysis of the social structuring of processes for *knowledge creation* (Deutschmann 2008: 108) the question is, how well knowledge is combined and diffused in low-tech sectoral innovation systems (Bergek et al. 2005: 9). Moreover, which knowledge processes might have changed in the last decades. Following the dynamic perspective of SIS concept identified patterns of a system cannot necessarily be considered as optimal (ibid. 14), because a system usually cannot immediately react and adapt to change. Changes in the sectoral knowledge base can have consequences for the organization of innovation and on sectoral boundaries (Pitt 2007: 127). They stimulate new actors "to complement the existing knowledge base and knowledge obsolescence produces changes in industry leadership" (ibid.). Hence, the SIS approach is not only useful to describe established practices for understanding KIE's deviation from it but also dynamics of the innovation system. The SIS analysis can also give first hints for structurally upcoming entrepreneurial opportunities in a matured industry.

Christine Anne Pitt (ibid.) concludes from the relevant, interdisciplinary distributed knowledge bases for innovation the importance of diverse actors' interaction because of their "complementary resources and competencies" (ibid.; also Wolfe 2011: 43). This leads over to the next analytical dimension of actors and networks.

Diagnostic questions concerning the knowledge dimension:

- *What are the knowledge domains of the industry?*
- *What kind of opportunities for innovation do they offer?*
- *How are the relevant sources of knowledge accessed?*

2.1.2 The actor dimension

At the centre of the SIS concept are companies producing products/components from the same product group (Breschi/Malerba 1997: 131; Malerba 2004: 9; Wolfe 2011: 48). However, an SIS is composed by heterogeneous actors (Malerba 2005a: 385). For that reason, Malerba points to consumers, entrepreneurs, users, suppliers, financial institutions as well as to non-profit organizations like universities and scientists, government agencies and industry associations. All those actors can differ in their importance and meaning to the system (ibid.).

Firms play a key role for the creation, adaptation and use of new technologies (Malerba 2005a: 390). Basically, it is assumed that firms of an industry use similar technologies and processing methods with common, related knowledge bases (ibid.). It is taken at a basis that these firms are embedded in the same institutional context and share common organizational and behavioral characteristics and learning patterns (Nelson/Winter 1982 in Malerba 2006: 23). Accordingly, firms from the same industry have several characteristics in common, but at the same time they can be considered as heterogeneous (Malerba 2005a: 385). This heterogeneity is manifested in firms' specific beliefs and expectations, their objectives and *competences*, or in their organizational form. Low-tech literature (Kirner et al. 2009a: 447; Som 2012) also addresses this heterogeneity. There is a considerable mix of low-tech and high-tech firms within low-tech industries, but also low-tech firms exist within high-tech industries (Kirner et al. ibid.). This insight is an important premise to explain the emergence of KIE in low-tech industries as such ventures or innovators might differ from the majority of low-tech firms.

Generally, firms are supposed to permanently accumulate knowledge and learn. System innovation theorists like Bengt-Åke Lundvall or Charles Edquist especially emphasized inter-organizational learning for innovation (Lundvall 1992: 1; Edquist 1997a: 4). This was based on the supposition that firms do not innovate in isolation (Edquist ibid. 7). With this perspective, the shortcomings of the corporate view on innovation (paradigm of the 20th century) are overcome. But the focus on learning organizations is not sufficient to identify and explain the emergence of KIE.

Beside the industry's key actors, suppliers and customers can be important for such inter-organizational interactions for innovation. They are supposed to contribute to the boundaries of the sectoral innovation system while steadily influencing them as well (Malerba 2005a: 385). Universities – already indicated as sources for technological opportunities – can be another relevant actor. They generate scientific knowledge that contributes to technological change and are therefore often considered the main source for innovation (Malerba 2005a). Additionally, universities are responsible for the education of R&D staffs in firms and scientists carrying out patents later on (Malerba 2005a: 391). For specific industries like biotechnology or electronic industry, they are also regarded as incubators for new firms (ibid.). Apart from this, *entrepreneurs* are not especially treated as actors in Malerba's SIS concept (2004; 2005a/b; 2006).

The role of financing organizations in an SIS differs related to the developmental stage of the industry. Here, it is referred again to the industrial life-cycle concept. "When industry matures or large firms are relevant, capital constraints become lighter and much investment is self-financed." (Malerba 2005a: 391) In the case of new industries, emerging firms are usually weakly positioned in self-financing so that venture capital firms play a significant role (ibid.). This has also been indicated in the literature review of KIE (cf. Lenzi et al. 2010; Ben-Ari/Vonortas 2005; Malerba 2010a/b). Pitt (2007: 126) refers to the relevance of different actors with regard to the stage of the industrial life-cycle. "As sectors respond to change, there is a tendency towards greater heterogeneity of actors. New categories emerge to assume new roles in the organization of innovation activities" (ibid.).

The "nature of systemic interaction between key actors" (Wolfe 2011: 43) builds another central point of the SIS concept (ibid: 48). Beside the indicated cooperative and competitive relationships (Malerba 2005a: 385; Breschi/Malerba 1997: 131) also *interaction processes* of vertical integration, formal and informal interaction between profit as well as non-profit organizations are considered (Malerba 2005a). For industries where the knowledge base is becoming more scientifically based, interactions with scientific organizations will become especially vital for firms (Pitt 2007: 127). This presupposes the firms' ability to effectively interact with such actors (ibid.).

Finally, the SIS approach is not geared towards sheer market based exchange relations. It is "composed of webs of relationships among heterogeneous agents with different beliefs, goals, competences, and behavior, and these relationships affect agents' action." (Malerba 2005a: 392) Accordingly, Malerba applies a relational, network based perspective for determining the structure of an industry apart from common industrial economics (ibid.). This way, he takes account of networks as a source for innovation for the integration of distributed complement knowledge, capabilities and specializations.

Diagnostic questions concerning the actor dimension:

- *Who are the actors mainly involved in innovation activity, knowledge production and technology development?*
- *Can entrepreneurs be identified among the innovators of the SIS?*
- *Which dominant competencies of the innovators can be identified?*

2.1.3 The institutional dimension

The actors' behavior and interactions are enabled by institutions – the third analytical dimension of the SIS conception. Broadly institutions are understood as norms, routines, common habits, established practices, rules, standards, laws and others (Malerba 2006: 29; Edquist/Johnson 1997). Apparently they can exist in varying industry-specific forms and influence the SIS in different ways (Bergek et al. 2005: 13; Pitt 2007: 128). Such effects can be characterized more or less binding or enabling and at a formal or informal level (Malerba ibid.). Innovation system theorists acknowledge, for example, that a complex set of non-market institutions determine innovation and market forces of an industry (Edquist 1997a; 2005; Soete et al. 2009 in Wolfe 2011: 43). Analysts need a broad perspective to identify the relevant institutions (Bergek et al. 2005: 8). This might explain that the "study of the role of institutions in sectoral systems is still considered to be in its infancy." (Pitt 2007: 128)

In turn, institutions can be shaped through interactions among agents as a reciprocal process (Malerba 2005a; Pitt 2007). "At the sectoral level, these specific institutions may arise due to the planned and deliberate actions of firms or other organizations through such means as industry codes of practice." (Pitt 2007: 128) Likewise, institutions "may also emerge as unintended consequences of the interactions between actors such as in the division of intellectual property rights in collaborative R&D projects." (Ibid.) *Industry-specific institutions* can differ from national institutions. Malerba distinguishes, for example, between industrial labor markets or industry-specific financial institutions (Malerba 2005a: 385/394.). Additionally, he assumes interrelations between institutions from the national and industry-specific level. National institutions may impede development or innovation in certain industries or lead to mismatches with industry-specific institutions and their actors (ibid.).

Again, entrepreneurial activity is not especially treated in the institutional dimension of Malerba's SIS concept (2004; 2005a/b; 2006). In general, the SIS perspective is more oriented to existing firms and their interactive learning activities (Wolfe 2011; Edquist 1997b) than to entrepreneurial activities. However, in his later work Malerba describes KIE as affected by innovation systems (2010b: 3 et seq.). But the role of industry-specific institutions in this respect has remained open so far. Other innovation system theorists have included the entrepreneurial aspect as institutions "enhancing entrepreneurship" (Edquist 2005) or "entrepreneurial experimentation" (Bergek et al. 2005; Carlsson/Jacobsson 2004). For Christine Anne Pitt and Susan Nelle, a key function of innovation systems is to facilitate and promote the entrance and survival of new firms and innovative SME (Chaminade/Edquist 2005 in Pitt/Nelle 2008: 9). Also, Anna Bergek et al. (2005: 15) emphasize the role of new entrants in their analytical considerations about dynamics of technological innovation systems. Behind these approaches lies the assumption that an increasing number of new entrants raise the chances for innovation and resource mobilization (Carlsson 2003 in Bergek et al. 2005: 15). The increase in actors in the SIS again entails that established firms have more opportunities to learn from entrepreneurial experiments and to contribute to knowledge development through knowledge diffusion (Bergek et al. ibid.). Moreover, new entrants are supposed to "influence the direction of search" (ibid.) and to contribute to the legitimization of upcoming new innovation systems (ibid.). This should be especially considered for KIE as the function of low-tech sectoral innovation systems' transformation. On the other hand, new firms usually face problems with their own legitimization and resources. Consequently, institutions that provide *legitimizing and mobilizing resources* as "free utilities" or "positive externalities" improve entrepreneurship in the innovation system (ibid.). This way, the belief in the growth potential of a new field can also be enforced.

It is more than worthwhile to investigate entrepreneurial experimentation in an SIS, because it depicts a specific form of knowledge development[12] (Bergek et al. 2005: 15). Entrepreneurial innovation is able to alter the established "direction of search"[13]

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12 Basically, Bergek et al. (2005: 15) consider R&D, learning from new applications, imitation and especially entrepreneurial experimentation as sources for knowledge development.

13 Further mechanisms influencing the direction of search within the SIS: "different competing technologies, applications, markets, business models etc. These factors are not controlled by one organization. They represent the combined effect of: visions, expectations, belief in growth potential (demographic trends, climate debate, growth of SIS in other countries), actor's perceptions of the

(ibid. 10 et seq.) of the SIS and keeps it from lock-ins, since it secures the variety of new combinations. Following Bergek et al. (2005: 17), an innovation system "without any vibrant experimentation will stagnate". Entrepreneurial experimentation is to be distinguished from R&D activities, because it additionally reduces uncertainty effects of testing new technologies and applications of which some can fail and some succeed (Bergek et al. 2005: 15). Furthermore, they (ibid. 415 et seq.) explicitly emphasize that the variance of entrepreneurial experimentation is not exclusively achieved by new actors but by many different types.

> *It should be noted that the word 'entrepreneurial' does not refer only to new or small firms, but to the more general Schumpeterian notion of an 'entrepreneurial function' (i.e. making new combinations). This function may be filled by any type of actor, including large, established firms diversifying into the new technology. (Ibid. 416)*

This notion converges well with the preliminarily outlined approach of KIE in low-tech industries as corporate entrepreneurship.

Pitt and Nelle (2008) have used a broader term to link industry-specific institutions with entrepreneurial activity. They investigated the entrepreneurial orientation of the Australian red meat industry as a function of the sectoral innovation system to improve the innovativeness of this low-tech sector. Accordingly, the institution of *entrepreneurial orientation* determines "how problems and opportunities arising from changes in the external environment are perceived by the players in the sector. This, in turn, will determine how proactively the sector responds." (2008: 4) Thereof, the propensity of firms to engage in entrepreneurship reveals on the one hand their innovativeness, risk taking, and pro-activeness (Lumpkin/Dess 1996 in Pitt 2007: 118) as well as their educational and practical learning capabilities and motivation (Hindle 2002 in Pitt ibid. 119). On the other hand, these firm-specific aspects are influenced by the industry's "prevailing cultural perception regarding the social legitimacy of entrepreneurship" (Pitt 2007: 119). Entrepreneurial experimentation can be integrated in the term 'entrepreneurial orientation' as an appearance of the firms' entrepreneurial propensity. According to Bergek et al. (2005), likewise, institutions legitimizing entrepreneurship and mobilizing resources as free utilities can be considered as an expression of the sector's cultural perception of entrepreneurship.

In sum, the components' interplay within the SIS affects entrepreneurial firms. Their capabilities to sense and exploit opportunities arise from those interactions (Johnson/Van de Ven 2002; Shane/Venkataraman 2000 in Pitt 2007: 130). The entrepreneurial opportunities for innovation are distinguished from industry to industry due to the indicated industry-specific conditions (Malerba 2006: 23). Apart from the sectoral differences at all these levels, matured industries also need to undergo transformation processes in order to gain competitive advantages (Pitt/Nelle 2008: 2). Dynamics in sectoral systems are the result of co-evolutionary processes of their vari-

relevance and different types of knowledge, regulation and policy, articulation of demand, technical bottlenecks, crises in current business" (Bergek et al. 2005: 16 et seq.).

ous elements, involving knowledge, technology, actors, and institutions (Malerba 2005a: 396). They "are likely to change over time" (Bergek et al. 2005: 14). This dynamic perspective implies that an innovation system is not necessarily optimal (ibid). The innovation performance of a system can be basically understood as a coordination problem of the system's components that need to be aligned.

In conclusion, although the "industry sector is not a common level of analysis in the study of entrepreneurship" (Pitt 2007: 133), it should have become obvious that innovation and entrepreneurship activity are "context sensitive" for the industry and firm level. The industry's entrepreneurial orientation affects how actors perceive entrepreneurial opportunities and how, in turn, their exploitation of opportunities helps the industry or SIS to proactively respond to changes (ibid. 149). A great advantage of these deliberations is that not only the sectoral structure and recurrent practices can be analyzed to understand KIE's deviation from it, but also the transformational situation of low-tech industries can be better mapped than by industrial life-cycle theory.

Diagnostic questions concerning the institutional dimension:

- *Are there any industry-specific institutions influencing the direction of knowledge and innovation development?*
- *Can any entrepreneurial orientation be assessed in terms of entrepreneurship enhancing institutions legitimizing or mobilizing resources?*

2.2 The concept of systemic KIE

Radosevic et al. (2011) are one of the first scientists linking KIE with the concept of innovation systems. Moreover, they apply an extended concept of entrepreneurial opportunities going beyond technological opportunities, which makes it valuable for the investigation of KIE in low-tech industries.

The integration of entrepreneurship and innovation system perspectives turned out difficult, because Schumpeter's entrepreneurship as well as the following person-centered view on entrepreneurship neglect systematic interrelations with the institutional environment (Radosevic 2007: 8), and on the other hand, innovation system theorists largely ignore routine-breaking entrepreneurial activity. They rather focus on institutions that stabilize individual behavior (ibid. 5). Against this background, Radosevic et al. (2011) developed a concept of entrepreneurial propensity of innovation systems. Their analytical framework seeks to explore the relationship between KIE and national innovation systems (NIS) as well as the systemic properties of KIE (ibid. 4).

Radosevic's motivation of a systemic perspective on entrepreneurship is based on the assumption that entrepreneurship is not randomly influenced by its environment, i.e. why it goes beyond a person-centered perspective. This research gap has missed theoretical framing that Radosevic sees increasingly filled by systemic and network based entrepreneurship research (2010: 52 et seq.; also Malerba 2010b). Accordingly, entrepreneurship is understood as a „systemic (network) phenomenon, and emerges as an outcome of interaction (alignment) between technological, market and institutional opportunities“ (Radosevic 2010: 53). An opportunity is basically understood as a situation that newly combines resources for a potential profit (cf. Shane 2003: 10; Grichnik 2006). As only little is known about the effects and dissemination of entrepreneurial opportunities (Radosevic ibid. 55; Grichnik 2006: 1308; McMullen et al. 2007: 281), Radosevic expects to learn more about the dynamics of entrepreneurship by integrating market, technological and institutional opportunities. These types of opportunities were studied separately or conceptualized as substitutes (Radosevic 2010: 64). Particularly, the role of institutional opportunities has remained theoretically backward (ibid. et seq.). The three different types of entrepreneurial opportunities are regarded as particularly relevant to identify the entrepreneurial orientation or propensity of an innovation system (Radosevic et al. 2011: 4).

In their understanding of innovation systems, Radosevic et al. (2011) closely refer to the common broad definition that innovation systems comprise "all important economic, social, political, institutional and other factors that influence the development, diffusion and use of innovations" (Edquist 1997b; Edquist/Hommen 2008 in Radosevic et al. 2011: 11 et seq.). In particular, the mutual interaction process is stressed for the out-coming innovation (ibid. 12). Apart from the traditional focus on the systemic components (Lundvall 1992; Nelson 1993), they prefer focusing on a dynamic perspective by asking what happens in the system (Bergek et al. 2005; Edquist 2005) and concentrating on activities instead of the system's components (Radosevic et al. ibid. 10 et seq.). The national innovation system's effects on KIE build the center of their analytical framework. A national innovation system (NIS) is defined as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman 1987 in Radosevic et al. ibid. 12). Based on this framework, the nature of KIE as a "multi-dimensional phenomenon" (ibid. 5) and its systemic properties should be systematically studied (ibid. 4).

Following Malerba and McKelvey (2010), KIE is defined as "new firms, innovators and knowledge operators that are involved in systematic, problem solving processes" (Radosevic et al. ibid. 7). Since they understand KIE as a "largely distributed phenomenon" (ibid. 4), it is not excluded from the low-tech sector (ibid.7). However, following the AEGIS project, corporate entrepreneurship in terms of established firms older than eight years is explicitly excluded from their approach (ibid.). KIE is further conceptualized as imbedded in innovation systems with heterogeneous actors and networks and formed by institutions (Radosevic et al. 2011: 5; Malerba 2010b). Similar to Bergek et al. (2005), Radosevic et al. (ibid.) consider entrepreneurship and KIE as a function and one of the “core properties” of an innovation system. In this respect, KIE activity is contributing to structural, institutional and societal dynamics referring to Schumpeter’s “agent of change” (ibid. 9).

The concept of systemic KIE seeks to assess the entrepreneurial propensity of an innovation system expressing the extent to which the innovation system encourages entrepreneurship (ibid. 22). It is conceptualized by entrepreneurial opportunities (market, technological and institutional) and entrepreneurial experimentation that in turn are moderated by activities of the innovation system (Radosevic et al. 2011: 16). In the following, the systemic entrepreneurial opportunities and entrepreneurial propensity of an innovation system for KIE are introduced in more detail.

2.2.1 Systemic entrepreneurial opportunities

Entrepreneurial opportunities spring from the paradigm of entrepreneurship research that is the nexus of an entrepreneurial individual and a valuable opportunity (Grichnik 2006; Shane 2003; Casson 2005). Thereof, different, competing perspectives on the interrelation of the two elements exist in the scientific discourse: a discovering (Schumpeter 1967) and creative (Kirzner 1973; 1997) perspective (cf. Grichnik 2006; Radosevic 2010; Pacheco et al. 2010). In recent literature, integrative approaches can indeed be found (cf. Edelman/Yli-Renko 2010; Pacheco et al. 2010; Tracey et al. 2011).

The correlation between environment and individual causes has not adequately been analyzed, in particular the different types of opportunities (Grichnik 2006: 1308) or the prevalence of specific characteristics of opportunities (McMullen et al. 2007: 281). McMullen et al. (ibid.) trace this back to weaknesses of economic and management theory that cannot sufficiently explain the sources of relevant knowledge and knowledge spillover and the emergence of new firms in this respect. In economic entrepreneurship research still the notion prevails that the entrepreneurial process starts with the sensing of an already existing opportunity (cf. Shane 2003; Kirzner 1983; Radosevic 2010: 53) and an objective, independent factor from the entrepreneur (cf. Casson 2005: 424). Contrarily, other authors emphasize “the manifest ability and willingness of the individuals, on their own, in teams, within and outside organizations to perceive and create new economic opportunities” (Wennekers/Thurik 1999: 46). In addition, the value of an opportunity is quite problematic. Delmar and Wennberg (ibid. 11) describe opportunities as fuzzy, because their value depends not only on the individual’s skill for identifying and communicating it to others, it also offers many ways of combinations for products and services (Shane 2003 in Delmar/Wennberg ibid.). Thereof, their economic value is hard to anticipate. By implication, opportunities have a socially constructed nature and can hardly be isolated from the exploiting individual (McMullen et al. 2007: 273).

Similarly, Radosevic et al. (2011: 16) assume that entrepreneurial opportunities are in general not terminable, because the results depend on the disciplinary scope of inquiry and level of analysis at the firm, industry or country level (ibid. et seq.). They assume that "entrepreneurship is driven by complementarities arising from the favourable interaction of all three types of [technological, market and institutional] opportunities. In the absence of one of these, entrepreneurial opportunities cannot be realised" (ibid. 5/17). In this regard, three views on entrepreneurship of Kirzner (1983), Schumpeter (1942) and List (1909) and their different driving factors are integrated into one concept of entrepreneurial opportunities (ibid. 17). These types of opportunities should be described in more detail in the following.

For the concept of *technological opportunities*, Radosevic refers to Schumpeter's entrepreneurship concept (Schumpeter 1942 in Radosevic 2010: 56). In this respect, the exploitation of an untapped technological opportunity to one of Schumpeter's manifold forms of new combinations (for product, process, market or organizational innovations) depicts the entrepreneurial process. Accordingly, technological opportunities are constitutive for product and process innovation. Schumpeter differs between technological opportunities and those for innovation. Technological opportunities are considered infinite in contrast to opportunities for innovation that are influenced by demand and termed as endogenous to the economic system. Technological opportunities are exogenous emerging from inventions outside this scheme. They are economically irrelevant as long as they cannot be implemented in an innovation at the economic system (Radosevic ibid.). A technological opportunity cannot be simply reduced to a technological invention in Schumpeter's sense. The "innovation which it is [sig.] the function of entrepreneurs to carry out need not necessarily be any invention at all. It is therefore not advisable, and it may be downright misleading, to stress the element of invention as much as many writers do." (Schumpeter 1967: 88) Indeed, Schumpeter used the expression "new possibilities" for new combinations of productive means. For him, "[t]hey are always present, abundantly accumulated by all sorts of people. Often they are also generally known and being discussed by scientific or literary writers. In other cases, there is nothing to discover about them, because they are quite obvious." (Ibid.) At the same time it should not even be the part of the entrepreneur to "'find' or 'create' new possibilities." (Ibid.) In sum, technological opportunities are an "unlimited pool of inventions and relevant knowledge" (Oakley 1990 in Radosevic 2010: 56/72), which do not necessarily arise from new technological or scientific knowledge or any researcher (academic entrepreneur).

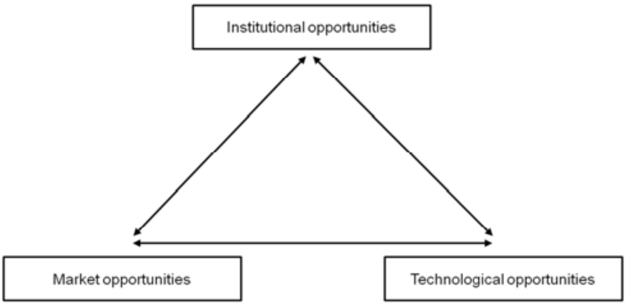
Later, Schumpeter's work was allocated to specific periods, for instance in the industrial life-cycle theory (Radosevic et al. 2011: 18). The focus on technological opportunities became widely common. Pavitt (1984), for instance, explained sectoral differences in innovation modes primarily through technological characteristics. Further sector-specific research on technological regimes (cf. Breschi/Malerba 1997; 2000) established a sector-specific understanding of technological opportunities. Nowadays, it is widely interdisciplinarily assumed that technological opportunities differ in space, time and sector respective to the technological regime (cf. Breschi et al. 2000; Freeman/Perez 1988; OECD 2003b; Shane 2003 in Radosevic 2010: 57).

Moreover, entrepreneurship literature points to differences in technological opportunities for established and new firms (cf. Shane 2003: 12). New firms usually cannot afford R&D to identify technological opportunities and then commercialize new technologies like large firms or established firms can do. The new firms “cannot endogenize the innovation process” (ibid.). Alternatively, they particularly rely on new, publicly created technologies or spillover from firms. According to Shane, public R&D activities do not constrain the exploitation of resulting opportunities by property rights as expected from firms. These kinds of entrepreneurial opportunities are supposed to be rather exploited by new firms (ibid.).

In science, technology and innovation (STI) research and the debate on the knowledge economy, new knowledge plays a decisive role for the emergence of technological opportunities (e.g. Pavitt 1984), as it contributes to diversity and experimentation (Malerba 2010b: 7). In line with the common focus on technological development from above, Groen (2005: 69) is of the opinion that the “development and introduction of new technologies offers opportunities for knowledge-intensive entrepreneurship.” However, it is important to keep in mind that “[d]espite the fact that a large group of the residual inventions originated in governmental or university R&D, a significant number of inventions could still not be attributed to specialised professional R&D” (Freeman/Soete 1997 in Som 2012: 105).

Although many researchers still focus on technological aspects, it is meanwhile obvious that other factors like *market opportunities* likewise play a role in entrepreneurship and innovation processes. In this respect, Radosevic et al. (2011) refer back to Kirzner’s view on entrepreneurship (1980). Market opportunities are explained by uncertainties and information asymmetries that actors sense differently. For example, they can emerge in terms of existing products and resources that have not been valued adequately so far (Hayek 145 in Radosevic et al. 2011: 18). Zoltan Acs (2002) and David Audretsch (1995) also point to these uncertainties and information asymmetries. Coming back to Israel Kirzner, it is important to note that he springs from already existing opportunities in the environment and do not regard underdeveloped markets (Radosevic et al. 2011: 18). Generally, information about prices or profits of new upcoming products does not exist so that entrepreneurs can only estimate this (ibid. 17). Market opportunities can only exist where needs and requirements have been articulated. This process of articulation is again highly related to the existence or absence of institutional opportunities (ibid. 18). Especially in case of emerging industries or industries under transition, market formation is usually underdeveloped (Radosevic 2010: 57 et seq.). The process of Schumpeter’s creative destruction that is often related to such formation and changes lead Radosevic et al. (2011: 18) to assume complementing technological and institutional opportunities that drive market formation in firm entry and exit (cf. Figure 01). The authors emanate from a multidimensional character of an entrepreneurial opportunity. Thereof, the complementary interrelation between market and technological opportunities is not sufficient, i.e. market opportunities alone do not guarantee the realization of technological opportunities. Market incentives and institutional opportunities play another role (Radosevic 2010: 58). Radosevic et al. (2011: 18) conclude for this opportunity component that “the (non)existence and the type of market opportunities may greatly impact on the nature of entrepreneurship that emerges which in its turn may be greatly influenced by the role of the institutional system in conveying information and creating incentives among similar or identical technological opportunities.“

Fig. 01 Systemic entrepreneurship of three types of opportunities



Source: Radosevic (2010: 65).

Compared to market and technological opportunities, *institutional opportunities* have been hardly theorized in entrepreneurship literature until now (Radosevic 2010: 63; Radosevic et al. 2011: 18). The authors (Radosevic 2007; 2010; Radosevic et al. 2011) criticize that Schumpeter and Kirzner and other advocates from the Austrian school “abstracted from the institutional context of the market economy, or briefly touched on this aspect” (Radosevic et al. ibid. 18). According to these views, the market is either considered as given or the formation of a new market automatically follows “entrepreneurial alertness” (Radosevic 2007: 5). In addition, the common view on institutions is more constraining than enabling (Schmid 2004 in Radosevic et al. 2011: 18).

Radosevic (2010) ascribes a central importance for matching technological and market opportunities to institutional opportunities. This third type of opportunity is theoretically traced back to Friedrich List (1909 in Radosevic 2010: 60) who paved the way for the concept of national innovation systems (NIS) with his work “The National System of Political Economy” (Freeman 1987 in Radosevic et al. 2011: 20). Following Freeman, Friedrich List was the first who stressed the meaning of national technological development for the growth of individual businesses (ibid.). Institutional opportunities are related to NIS as institutions that both directly and indirectly have an effect on the innovation process (ibid. 18.). Referring to this, Radosevic broadly defines institutional opportunities as promoting entrepreneurs or innovation (2010: 62). Institutional opportunities occur in the course of institutional structuring between actors (ibid.61/62). Following Alfred Schmid (2004), Radosevic comprehends institutions as „human relationships that structure opportunities via constraints and enablement. A constraint on one person is opportunity for another" (Schmid 2004 in Radosevic 2010: 61). Following these deliberations, market opportunities and entrepreneurial action are embedded in a web of values, norms, beliefs, traditions as well as formal and informal relations. In addition, expectations and conformity of the entrepreneurs' and their business partners' conjectures belong to this web (ibid. 62). Conform expectations are supported in case of a shared set of values, beliefs and norms etc. (ibid.). On the other hand, Delmar and Wennberg (2010: 12 et seq.) have shown that even disagreement between entrepreneurs and partners in an incumbent firm can stimulate an entrepreneurial opportunity. This situation can be seen in the sense of Schmid (2004) that a restriction for decision makers of the incumbent firm is the opportunity for the entrepreneurial employee.

Yet, institutions do not only structure the texture between market opportunities and entrepreneurial action, a further important role with regard to technical change is also attributed to them (Schmid 2004: 199/207; Radosevic 2010: 61). Institutions in terms of e.g. "relative prices, […] industry-specific routines and standard operating procedures, […] [or] irreversibility of technological path, and lock-in" (Schmid 2004: 199) influence relevant preferences of rival interests that seek to control the process of technical change (ibid. 207 in Radosevic 2010: 61). On the other hand, institutions can have a constraining impact on entrepreneurial opportunities (Autio 2009) in Radosevic et al. 2011: 20). This can lead to a situation where technical and market opportunities exist but cannot be exploited because of "pervasive institutional obstacles" like certain interdependencies among actors that do not allow for exploiting opportunities (ibid.). Apart from this, institutional opportunities mediate between the coupling of market and technological opportunities (Radosevic 2010: 62). Thereby, nationally differing institutional opportunities are assumed that "control" for market and technological opportunities (Radosevic et al. 2011: 18). Finally, a whole innovation system can "represent […] an institutional opportunity" (ibid. 20).

Some of the interrelations among the three opportunity components have already become visible in the description of the opportunity types. Basically, the systemic approach considers their interrelations as complementary in the sense that the absence of one leads to matching problems (Radosevic 2010: 66). Such *disarrangements* regarding the alignment of opportunity components are explained by underdevelopment, wrong orientation (e.g. "anti-entrepreneurial institutional system; technology lock in; closed markets") or problems of compatibility due to an isolated developed component of opportunity, for instance (ibid.).

In case of a structural incompatibility of opportunities and insufficient entrepreneurial propensity of the innovation system, entrepreneurs are not able to successfully conduct entrepreneurial activities. Here, a passive perspective on the actors is taken that "perceive, capture and respond to new opportunities" (Radosevic et al. ibid. 9). This owes to the systemic approach that does not understand entrepreneurship as "the result of scarcity of entrepreneurial talent" (Radosevic 2010: 66). The entrepreneur is set up as a "binding agent" (ibid.) whose decision is "part of a system of decisions" (Schmid 2004: 8). Basically, it is assumed that individual behavior is strengthened by institutions and systems. The creation of new institutions by individuals is only considered for the case that a "critical mass is reached" (ibid. 9). Moreover, the systemic concept of KIE addresses interrelations between KIE and structural features of the economic system and their "capacity to generate different entrepreneurial opportunities independently from individuals' capacity to recognize and exploit them" (Radosevic et al. 2011: 15). In this respect, Radosevic et al. assume that individuals operate in a given structure of entrepreneurial opportunities (ibid.). In consequence, underperformance in entrepreneurship is not explained by scarcity but as a result of systemic mismatch (ibid.). Therefore, the matching of opportunity components is a property of the innovation system. This way, entrepreneurial activities are linked with the structural features of an innovation system and its entrepreneurial propensity.

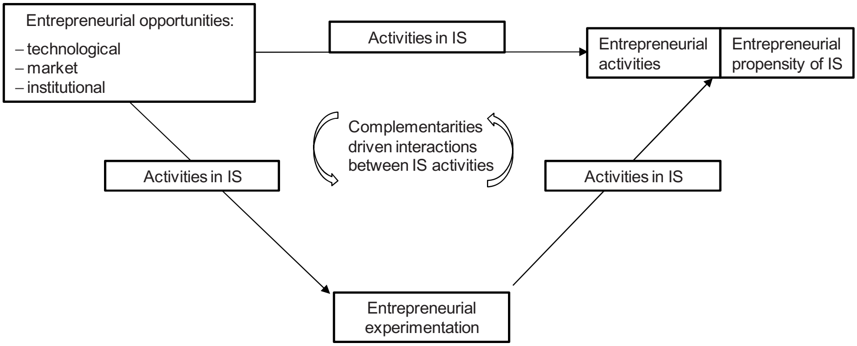
Diagnostic questions concerning systemic entrepreneurial opportunities:

- *Which technological, market and institutional opportunity components exist for KIE (in a low-tech SIS)?*
- *Which disarrangement might exist to match the different opportunity types?*

2.2.2 The entrepreneurial propensity of innovation systems

To understand the 'entrepreneurial propensity of an innovation system' (see Figure 02), the activities and relations that determine innovation processes in the system are taken into consideration (Radosevic et al. 2011: 5). The entrepreneurial propensity expresses the extent to which the innovation system encourages entrepreneurship (ibid. 22); i.e. offer a *systemic entrepreneurial opportunity*. It is based on entrepreneurial opportunities (market, technological and institutional) and entrepreneurial experimentation moderated by activities in the innovation system (ibid. 16).

Fig. 02 Systemic view on entrepreneurship as macro phenomenon



Source: Radosevic et al. (2011: 16).

Entrepreneurial action and propensity of an innovation system “are not derived directly from behaviour of enterprising individuals” (ibid. 15). Moreover, opportunities for entrepreneurship are considered as “initial conditions”, while the activities of the innovation system moderate “the impact of enterprising individuals on entrepreneurship activity” (ibid.). These activities are “equivalent to determinants of the innovation process” (ibid. 11), while they explicitly avoid equaling them with functions used in sociology or corresponding to the consequences of the phenomenon (ibid.). Analysing the interacting *activities of the innovation* helps to understand what constitutes entrepreneurial opportunities and the system’s entrepreneurial propensity (ibid. 5). Accordingly, different extents of entrepreneurial activity and propensity result from the interactions of opportunities and innovation system’s activities (ibid.). This chain of linking interaction mechanisms is supposed to be especially prospering in case of a “mutually compatible sets of opportunities” (ibid.). “If there are not mutually compatible set of structural opportunities enterprising individuals by themselves will not be able to generate entrepreneurship activities as SI [system of innovation] will not have sufficient entrepreneurial propensity” (ibid. 15 et seq.). Generally, it is assumed that “highly complementary activities create highly entrepreneurial system of innovation […] while mismatching activities weaken entrepreneurial propensity” (ibid. 5). Consequently, “inappropriate matching” or “missing activities” can lead to a bad performance of the innovation system where policy recommendations seek to address to (ibid. 13).

Contrarily, an ‘entrepreneurial innovation system’ is able to deal with changing technological opportunities, to improve alerting skills for market opportunities as well as for technical opportunities (Radosevic 2007 in Radosevic et al. 2011: 26). Additionally, it is expected to balance between keeping uncertainty (e.g. by deregulation) and absorbing uncertainty (e.g. support of business model) (ibid. 27). These assets have a long-term character that actually deserves longitudinal historical research for identifying shifting modes. For their research within the AEGIS project, Radosevic et al. followed a medium to short-term approach. Against this background, they termed entrepreneurial an innovation system "that best generates and exploits entrepreneurial opportunities at current technological regime of industry" (ibid.).

Summing up the concept of systemic KIE, Radosevic et al. (ibid. 16) emanate from macro-level mechanisms that generate entrepreneurial activities and entrepreneurial propensity due to structural features of an innovation system. These features are composed of different activities and interactions driven by existing or absent complementarities.

> *Diagnostic questions concerning systemic KIE:*
>
> - *Does the innovation system (IS) offer a systemic entrepreneurial opportunity?*
> - *Which activities of the SIS promote entrepreneurial opportunities and entrepreneurial activity?*

2.3 The concept of institutional entrepreneurship

The view of the institutional entrepreneurship concept on the entrepreneur complements the systemic (macro) perspective from the previously introduced concepts. This is especially useful, if we start from the common assumption that low-tech innovation systems are not entrepreneurially oriented or have a weak entrepreneurial propensity. The systemic approach on entrepreneurial opportunities stresses that in case of structural incompatibility individual actors are not able to successfully set up their innovative venture (cf. Radosevic et al. 2011: 15 et seq.). Following this logic, KIE could not emerge in matured low-tech industries due to a missing structural opportunity. Distinct from this, the concept of institutional entrepreneurship emanates from powerful agents who are able to overcome such structural or institutional barriers. At the same time, their embeddedness in the institutional environment is analysed. For that reason, the concept of institutional entrepreneurship helps to explain and conceptualize the emergence of KIE in low-tech industries.

First of all, institutional entrepreneurs are understood as "agents of change" (Pacheco et al. 2010: 981) consent with Schumpeterian entrepreneurship and Malerba's KIE concept. Shmuel Eisenstadt (1980 in Leca et al. 2008: 3) who used the term first defined 'institutional entrepreneurs' as "catalysts for structural change". Likewise, Malerba (2010b: 3) ascribes to KIE the role of transforming industrial systems or "rejuvenating industrial structure". Based on Eisenstadt (1980), Paul DiMaggio (1988: 14) introduced the institutional entrepreneur to institutional theory as "organized actors with sufficient resources […] [who] see in [newly emerging institutions] an opportunity to realize their interests that they value highly". In the literature, specific capabilities and activities are attributed to them: They are able to "recognize the obsolescence of institutions, design new institutional arrangements" (Pacheco et al. 2010: 979), they "leverage resources to create new institutions or to transform existing ones" (Maguire et al. 2004 in Garud et al. 2007: 957) "that favor his or her interests" (Pacheco et al. 2010: 975). In order to implement institutional change, institutional entrepreneurs are capable of applying different strategies such as mobilizing resources and constituents or framing "issues to their advantage" (Pacheco 2010: 979 following DiMaggio 1988). Thereof, they "create a whole new system of meaning that ties the functioning of disparate sets of institutions together" (Garud et al. 2007: 957). Consequently, these activities are widely connected to result in significant or radical innovations (Walgenbach/Meyer 2008: 140), which make institutional entrepreneurship compatible with the departing innovation understanding of KIE that is taken as a basis in this work. More generally, the concept of institutional entrepreneurship "offers considerable promise for understanding how and why certain novel organizing solutions – new practices or new organizational forms, for example – come into existence and become well established over time." (Garud et al. 2007: 960) These characteristics make institutional entrepreneurship especially valuable for transformation processes of matured low-tech sectoral innovation systems.

The concept of institutional entrepreneurs became widely known when DiMaggio (1988) introduced it to institutional theory to overcome certain theoretical weaknesses. Institutional research mainly studied institutions as constraining actors' action (Fligstein 1997 in Leca et al. 2008: 3), while it could not explain deviating and creating activities and the role of actors with respect to change (Christensen et al. 1997; DiMaggio 1988 in Leca et al. 2008: 3). This also holds true for explaining differences and change in specific "units with distinct institutional structures" (DiMaggio 1988: 7) such as specific sectors or industries. DiMaggio addresses to changes in organizational fields which might also be important for KIE in low-tech sectors; namely he mentions "change in organizational fields that outpaces change in the institutional environment" (ibid. 9), or change "that tends to delegitimate the institutional order of the field" (ibid.12). Hence, this changing activity comes close to the assumed KIE activity in low-tech industries (cf. Chapter 1.4).

Basically, two strands of research on institutional entrepreneurship can be distinguished: on the one hand, an institutional theory perspective; on the other hand, an institutional economics perspective. Pacheco et al. (2010: 981) have recently reviewed and compared both theoretical views. They conclude that "institutional economics focuses mostly on the antecedents and outcomes of institutional entrepreneurship [while] the institutional theory perspective is more concerned with the process and mechanisms that drive such change" (ibid. 974 et seq.). Although both strands have in common "to put human action and agency in the centre of economic and social systems” (ibid. 978), there are differences in the conceptualization of the institutional entrepreneur. Distinct from the restricted institutional economics’ view on the institutional entrepreneur as an economic self-interested actor, advocates of the institutional theory apply “a much broader and diverse characterization of him or her […] conceptualized as institutional innovator” (ibid. 981). Both strands of research have not been linked with each other and still miss a widely theoretical integration with concepts of entrepreneurship research (cf. Battilana et al. 2009; Phillips/Tracey 2007; Shane/Venkataraman 2000; Venkataraman 1997 in Pacheco et al. 2010: 975 et seq.). With respect to the main research question for the emergence of KIE in the institutional environment of a low-tech industry, the perspective on processes and mechanisms is of particular interest. But before these are presented in more detail, the concept’s comprehension of institutions is taken as a basis.

2.3.1 Extending the understanding of institutions

The concepts’ embedding into institutional theory extends the deliberations of the systemic concepts on institutions and for that reason contributes to a better understanding of institutional opportunities. In line with the previous concepts, institutional theory emanates from institutions as “rules, norms and beliefs”. Besides, they are “performance scripts” (Garud et al. 2007: 958) taken for granted. Institutions have the function to provide “stable designs for chronically repeated activity sequences” (Jepperson 1991 in Garud et al. ibid.) and to “specify and justify social arrangements and behaviors” (Garud et al. ibid.). This way, they generally enable action, reduce uncertainty (Deutschmann ibid.) and contribute to stability as a prerequisite for strategic behavior of institutional entrepreneurs and institutional renewal (Walgenbach/Meyer 2008: 144).

In addition, the widely known regulative, normative and cognitive characteristics of institutions (Scott 1995) help to understand knowledge processes and the emergence as well as the absence of entrepreneurial action. The cognitive dimension refers to “categories and frames by which actors know and interpret their world” (Scott 1995 in Garud et al. 2007: 958). These frames “give meaning to inherently equivocal information inputs by directing sense-making processes” (Gioia/Chittipeddi 1991 in Garud et al. 2007: 959). This helps to explain the function of sectoral knowledge bases. Moreover, “these cognitive frames makes it difficult to stray far from them in either thought or deed” (Garud et al. ibid.). This deliberation makes comprehensible why only a minority of people deviates from those frames and succeeds in such knowledge-intensive ventures. As Raghu Garud et al. (2007: 958), with recourse to Ronald Jepperson, further explain, “deviations […] are counteracted by sanctions or are costly in some manner”. If institutional entrepreneurs criticize institutional arrangements, e.g. management practices, they need to point to plausible arguments to avoid sanctions. Usually those arguments are promising that show limiting features in efficiency of previous institutional arrangements and the violation's benefit (Beckert 1999 in Walgenbach/Meyer 2008: 143; see also DiMaggio 1988: 15).

In general, neither constraining nor enabling effects of institutions determine entrepreneurial action (Pacheco et al. 2010: 1004; Walgenbach/Meyer 2008: 144). They do not predetermine concrete action, rather they offer a stock of accepted plots that leaves actors a certain scope of decision making on action (Müller-Jentsch 2003 in Walgenbach/ Meyer 2008: 144). Actors sense institutions as an external or objectively given world that they learn to understand during their socialization (Berger/Luckmann 1967 in Senge 2011: 88 et seq.). But this externalized world and the accumulated knowledge about it is not completely stable. The process of incorporating institutions should not be understood as deterministic but as a creative and ever grappling process with institutional reality (ibid.). Hence, institutional rules should not be considered as universal but only in specific historical contexts and socio subsystems (DiMaggio 1988; Deutschmann 2008: 100). Accordingly, individual behavior is not directly affected by institutions like in case of natural laws. Instead, decisions are mediated through a "sinnhaft strukturierte Selbstreferentialität des Handelns"[14] that allows a mechanical or intelligent following as well as the defiance of institutions (ibid.). In response to DiMaggio's criticism, neo-institutional theorists assume that institutions do not only reproduce behavior or determine action, rather they open up a space for possibilities of typical action patterns (Berger/Luckmann 1967; Müller-Jentsch 2002; Oliver 1991 in Senge 2011: 89). Finally, Konstanze Senge put it straight as institutions that enable action on the one hand, and on the other entail a "Moment der Begrenzung" as an "objektivierte Wirklichkeit"[15] (Senge ibid.).

Institutions exist in various forms and at various levels or subsystems (Deutschmann 2008: 100; Walgenbach/Meyer 2008: 144; Pacheco et al. 2010: 984 et seq./981 et seq.) that are not always compatible. This creates tensions (Leca et al. 2008: 12) that can also be termed an institutional opportunity for institutional entrepreneurs. Regardless of different strands of institutional theory, it is commonly referred to higher and lower levels of institutions or Meta institutions and subordinate institutional arrangements. In their comparing review of institutional theory and institutional economics perspectives, Pacheco et al. (2010: 984) found that the types of institutions studied in the institutional theory perspective rather concentrate on informal institutions like culture, value or norms and mainly institutional practices. Institutional practices are the "first and most approachable level for institutional change" (ibid.), whereas the level of government policy is less studied (ibid.). Compared to this, institutional economics take more often formalized institutions (property rights and government policies) and macro-level institutions such as "government-sponsored policies" (contracts and enforcement mechanism) into account, while informal institutions are less acknowledged (ibid. 984). The "layered institutional model" integrates these

[14] ... meaningfully structured self-referentiality of behaviour (translated by author).

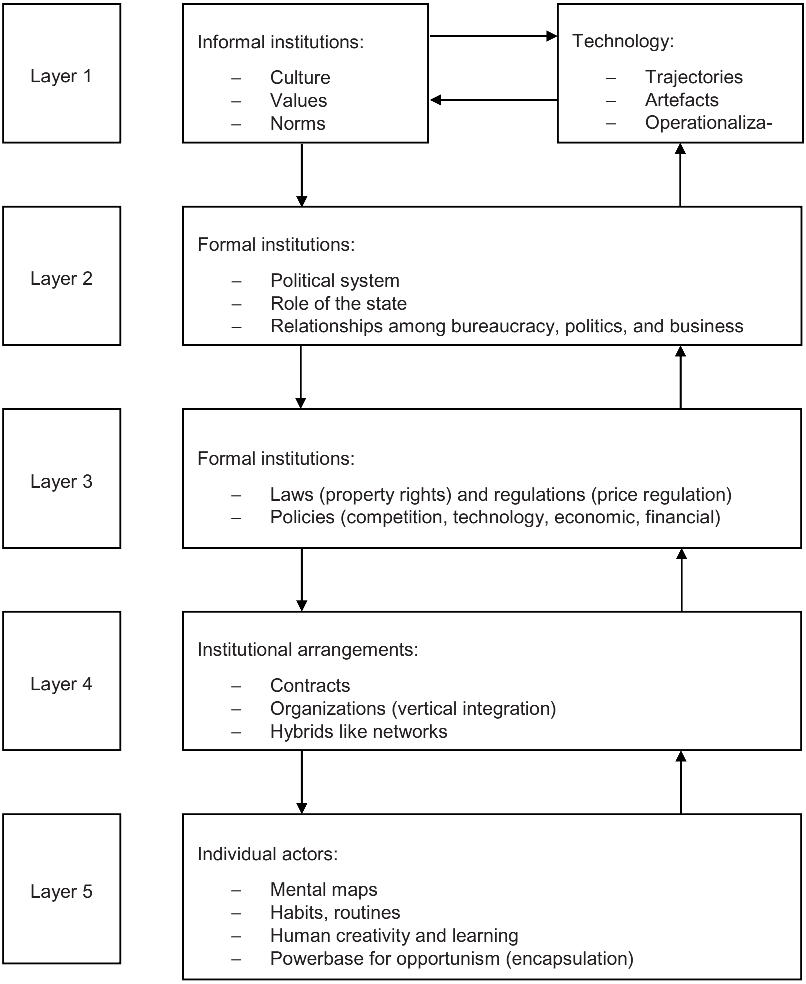
[15] ... moment of limitation [...] objectified reality (translated by author).

various types. As shown in Figure 03, it distinguishes five different layers of institutions of which the first three layers (*informal and formal institutions*) consider the institutional environment followed by *institutional arrangements* at the fourth layer and *individual actors* at the fifth layer. Generally, the institutional environment was described by Richard Scott and Garud as “the elaboration of rules and requirements to which individual organizations must conform if they are to perceive support and legitimacy” (Scott 1995 in Garud et al. 2007: 958). Institutional arrangements (e.g. contracts, organizations or networks) are allocated between layers from the institutional environment and the actor layer (Groenewegen/Van der Steen 2006: 280 et seq.).

They are characterized as taken for granted, reproducing practices that create path dependencies (Arthur 1988; Berger/Luckmann 1967; Langer/Newman 1979 in Garud et al. 2007: 958 et seq.). Interdependencies between the different layers are widely assumed (Pacheco et al. 2010: 984; Groenewegen/Van der Steen 2006: 280). Thereof, “higher layers not only constrain the lower ones but that lower layers within a certain range can influence higher ones” (Groenewegen/Van der Steen ibid.). In conclusion, individual actors can influence institutional arrangements up to institutional environments just as well. Likewise, the institutional environment and institutional arrangements are important aspects to understand the process of institutional entrepreneurship. Based on this, action of willful entrepreneurs of the micro level can be linked with institutional environments and systems on the macro level.

In the next step, this process is brought together by first describing the whole process briefly, then exposing mechanisms of the process, and finally by going into the characteristics of institutional entrepreneurs as well as the conditions of the institutional environment.

Fig. 03 Layered institutional model



Source: Groenewegen/Van der Steen (2006: 281).

2.3.2 The institutional process of entrepreneurship

Neil Fligstein (2001: 111 in Walgenbach/Meyer 2008: 142) raises the basic questions for the process of institutional entrepreneurship: "Why and how do actors who are supposed to only be able to follow scripts recognize these situations and create new institutions?” The process of institutional entrepreneurship is not exclusively ascribed to certain actors or industries. Basically, “all actors might be or become active participants in the process of interpreting institutions” (Zilber 2002 in Leca et al. 2008: 17). In other words, institutional entrepreneurs are conceivable in low-tech industries, too.

In addition, the process of institutional entrepreneurship is closely related to the terms ‘institutional change’, ‘de- or re-institutionalization’ as well as ‘dis- and re-embedding’. Beckert (1999) addresses this issue, constructing a cyclical model that gives a first description of the institutional process. It starts with the violation of institutionalized behavior. This increases uncertainty in interactions, because some of the actors involved likely follow the previous institutional rules (Beckert 1999: 786). The resulting uncertainty can only be reduced by new processes of institutionalization as a necessary precondition for strategic behavior of such entrepreneurs (ibid.). Schumpeter referred to the process as “simultaneous dis-embedding and re-embedding” in newly emerging institutional structures (ibid. 787; Schumpeter 1967: 66). Additionally, Beckert (1999: 787) points towards the uneven character of overcoming frictions during institutional re-embedding as well as continuous dis- and re-embedding during the process. Likewise, Leca et al. (2008: 17) underpin that “institutions are constantly designed and redesigned and changed due to the interactions of the different actors involved in the process.” Institutionalization activities are stabilized “once they have reached a threshold level of institutionalization” (DiMaggio 1988: 6). The institutionalization process proceeds independently of the institutional form (rules, structures or practices) and “diffuse according to the same laws” regardless if it concerns CEOs or social reformers (ibid.).

Before this threshold is reached, institutional entrepreneurs have to deal with existing institutional arrangements, as many authors have pointed to (e.g. DiMaggio 1988; Levy/ Scully 2007 in Leca et al. 2008: 11; also Garud et al. 2007: 959). The challenge hereby is that *institutional arrangements* can imply privileges that are likely to be maintained or even defended by its beneficiaries (Garud et al. ibid.). In general, such beneficiaries or dominant players are expected to be more interested in solidifying the status quo than supporting institutional change (DiMaggio 1988 in Leca et al. 2008: 11). Once central actors are convinced by the benefits of the unconventional innovation and adopt it, it is institutionalized and becomes a new convention (Maguire 2008: 674). This happens, for example, through criticizing the profitability of existing institutional practices (Beckert 1999 in Walgenbach/Meyer 2008: 143; also see DiMaggio 1988: 15). The outcome or success of such efforts depends largely on the relative power of supporters or opponents (DiMaggio 1988: 13).

In a next step of the institutionalization process, institutional entrepreneurs develop new alternative institutional arrangements to implement change sustainably (Leca et al. 2008: 11/17). So-called innovation projects legitimate the implementation of new organizational forms (ibid. 14). According to Leca et al.’s review of institutional entrepreneurship literature, this aspect remains still a less studied field that researchers have recently begun to address (ibid. 17). Furthermore, institutional arrangements are used for collaboration. This way, institutional entrepreneurs try to influence normative and regulative “carriers of institutionalization” (ibid.). Similarly, DiMaggio refers to institutional work that is needed to justify and institutionalize a new organizational form, because “[u]nless they are enacted by an organizational system […] newly institutionalized forms will be highly unstable in their structures, public theories, and programs” (1988: 15). In conclusion, the institutional work outside of the new organizational form, i.e. in the organizational field, becomes crucial for the further institutionalization process (ibid.). In this respect DiMaggio has also distinguished between institutional understandings that open up opportunities to entrepreneurs. For instance, general institutions like “formal rationality and accountability” provide so-called free resources to the entrepreneurs (ibid. 14). Besides these broadly available resources there also exists a more specific institutional understanding that is not easily usable, for example, in highly institutionalized industries (ibid. 14 et seq.). The legitimacy of the industry is based on assumptions about “labor markets, […] product differentiation, demand characteristics” (ibid.) that institutional entrepreneurs have to take into consideration in their institutional work.

Mostly this kind of institutional work deserves support by further actors (DiMaggio 1988: 15), because institutional entrepreneurs cannot solely change institutions (Leca et al. 2008: 11). The supporters of institutional entrepreneurs are therefore distinguished in “existing” and “newly mobilized actors” or “subsidiary actors” (DiMaggio ibid.). Newly legitimated actors are won from successful institutionalization projects. Paradoxically, these new actors help to “delegitimate and deinstitutionalize […] institutional forms to which they owe their own autonomy and legitimacy.” (Ibid. 13) Subsidiary actors additionally provide resources for legitimacy and plausible accountability of the new organizational form (ibid. 15.). At the same time, it is assumed that they also win legitimacy from the project’s success and gain more autonomy beside to core organizations in the considered field (ibid.). DiMaggio (ibid.) calls this “[r]ecruiting or creating an environment […] the central task” of institutional entrepreneurs within institutionalization projects. Hence, these projects are mainly composed by the institutional entrepreneurs and their so-called backers and external constituencies from whom support and legitimacy must be organized (ibid.). Other authors have widely referred to this organizing activity as “mobilizing allies“ (e.g. Boxenbaum/Battilana 2005; Fligstein 1997; Greenwood et al. 2002 in Leca et al. 2008: 11), and especially stressed the *mobilization* of “highly embedded” core agents or “professionals and experts” (Hwang/Powell 2005; Lawrence et al. 2002 in Leca et al. ibid.). In this respect, researchers (DiMaggio 1988; Fligstein 1997; Rao 1998 in Leca et al. ibid. 11/12) emphasize the “discursive dimension” of the institutional entrepreneurship processes, since it is considered as a political bargaining process.

Summing up, the process of institutional entrepreneurship is composed by institutional entrepreneurs’ activity to deinstitutionalize existing institutional arrangements, design new ones and mobilize resources. For establishing new institutional arrangements, new organizational forms are designed through the implementation of an institutional project. Once an institutional project has successfully started, external supporters are gained who help to legitimize and establish the new organizational form and institutional arrangement in the institutional environment. Therefore, institutional entrepreneurs apply discursive strategies and other mechanisms to successfully devise the institutional entrepreneurship process that is presented next.

Diagnostic questions concerning the institutional process of KIE:

- *Did the entrepreneur(s) break or deviate from any routine or institutional arrangement?*
- *Were institutional arrangements deinstitutionalized and newly designed?*
- *How were resources organized or mobilized?*

2.3.3 Institutional mechanisms

Reviewing the mechanisms of institutional entrepreneurship, some address practical techniques how to create innovations deviating from existing institutions (Pacheco et al. 2010: 1003) and others refer more strategically to their institutionalization through institutional projects (Leca et al. 2008: 12 et seq.).

The first introduced *mechanisms of practical techniques* mainly point towards 'effectuation', 'bricolage' and 'exaptation' as relevant mechanisms for "developing the microfoundations of institutional entrepreneurship" (Pacheco et al. 2010: 1003). Effectuation became prominent by Saras Sarasvathy (2001; 2008 in Pacheco et al. ibid.). In situations of uncertainty, a logic of selection is applied that combines only means in reach for new combinations from which then new ends result. The effectual logic is contrasted with causal logic that first specifies ends "subsequently gather means to reach those ends" (ibid.). Against this, the process of effectuation is described "non-linear and participatory" from which researchers expect to learn more about the development of institutional projects (ibid.). Likewise, bricolage refers to similar (re-)combination of "readily available means at hand to create innovations", as Schumpeter once described (cf. Baker/Nelson 2005; Lévi-Strauss 1967; Sarasvathy 1998 in Pacheco et al. ibid.; also Walgenbach/Meyer 2008: 141). Exaptation is closely related to the other two mechanisms springing from evolutionary biology. This mechanism addresses the re-use of existing features or devices – often characterized as inactive and occasional – in a new, useful context, i.e. new markets in the entrepreneurial context. It is connected with a creative ex-ante view and to be distinguished from evolutionary reactive adaptation.

Similar mechanisms can be found in cognitive psychology (Garud et al. 2007: 960). In this context, the term 'bisociation' is used, which means "the intermingling of seemingly unrelated ideas from different knowledge domains" (Koestler 1964 in ibid.). This mechanism can be aligned with the view of distributed knowledge bases (Robertson/Smith 2008). Recombining activities of different intellectual resources are linked to the institutional dimension in terms of addressing legitimacy problems that can emerge from this (Zuckerman 1999 in Garud et al. ibid.). Neo-institutionalists indicate in this regard that an "Innovation lässt sich nur dann erfolgreich institutionalisieren, wenn sie mit Sinn- und Wertstrukturen verknüpft wird"[16] (Walgenbach/Meyer 2008: 142 et seq.). This leads over to the *strategic and discursive dimension* of mechanisms for institutional entrepreneurship.

The discursive dimension is crucial for the process of institutional entrepreneurship (cf. Leca et al. 2008: 12). Few authors claim that institutional entrepreneurs follow a discursive strategy that contains the initiation of discourse and texts to influence "processes of social constructions that underlie institutions" (e.g. Munir/Phillips 2005; Phillips et al. 2004; Suddaby/Greenwood 2005 in Leca et al. 2008: 12). Also without assuming this strategic purpose, further mechanisms to mobilize resources point towards this discursive dimension. The following activities with more or less strategically character are to be mentioned: "collective action through shared goals and group tensions" (Fligstein 1997; Garud et al. 2002; Zucker 1988 in Pacheco et al. 2010: 990), "political tactics" (Fligstein 1997; Lawrence 1999; Maguire et al. 2004 in Pacheco et al. ibid. 989) such as "coalition building and incentivizing behaviors" (ibid. 990), or "framing" (Rao 1998; Zilber 2002; 2007 in ibid.) as well as "professionalization and theorization" (Greenwood et al. 2002 in ibid.; Lounsbury/Crumley 2007). From this list, 'framing', 'professionalization' and 'theorization' are introduced in more detail.

Particularly framing seems to depict an elementary mechanism for institutional entrepreneurship and maybe also for KIE, since it refers to deviating activities that imply framing. The part on institutions addresses Scott's cognitive frames. More generally, frames can be considered as interpretation structures at the micro level. Strategies are perceived and selected, based on such frames. They consist of "the main variables, functions, and contingencies of a particular phenomenon […] [as well as] interpreted relationships between phenomena (and their associated values) and are composed of individuals, mediated at a group level." (Von Tunzelmann/Acha 2005: 430) Frames function as filters that can significantly influence the performance at the organizational level, and even more important, they are arranged by individuals. This way, frames can be allocated as an institutional form somewhere between individual actors and institutional arrangements (ibid.).[17] Differences between high-tech and

[16] … innovation can be only successfully institutionalized when it is linked to structures of meaning and values (translated by author).

[17] Von Tunzelmann and Acha (2005: 419) illustrate the functioning of technology frames in case of managers: "In practice, managers consider particular activities rather than the whole at once. A

low-tech firms are, for example, explained due to differences in technological frames.[18] Accordingly, sectoral and organizational knowledge bases can be broken down to frames at the micro level.

Institutional entrepreneurs deploy framing activities to reach the acceptance of a broader set of actors for their newly preferred institutional arrangement or project. Through "closely integrating new ideas and processes with commonly accepted narratives" (Pacheco et al. 2010: 990), this framing backs the legitimization of new forms and practices. Thus, institutional entrepreneurs especially know how to utilize frames or reframe after having deviated from such frames. Leca et al. (2008: 13) capture this through distinguishing different constellations. Institutional entrepreneurs can benefit from pre-existing frames in specific organizational fields or also from more general societal frames (ibid.). Moreover, they can even draw on multiple frames, if it helps them to alter existing frames, and if it is to their advantage for justifying their institutional project (Creed et al. 2002; Suddaby/Greenwood 2005 in ibid.). Generally, existing frames can depict either "a source of constraints on […] [or] resources for actors' strategies" (Hardy/Phillips 1999 in ibid.). The case in which existing frames are a resource leads to the question if such frames can also be considered as an institutional opportunity, whereas in case of constraining frames, framing activities are addressed towards the "failings of the existing institutionalized practices and norms" and the illustration of the advancing institutional project to win over followers (cf. Boxenbaum/Battilana 2005; Fligstein 1997; Haveman/Rao 1997 in Leca et al. 2008: 12 et seq.). When institutional projects essentially deviate from existing frames and institutional arrangements, authors advise that such projects should not be presented "as too radical" (Maguire/Hardy 2006; Seo/Creed 2002 in ibid. 13). An available frame that is mostly compatible with the project or promises the "highest mobilizing potential at the time" is better to acquire the necessary supporting actors (ibid.).

In general, framing is a crucial activity to organize "legitimacy, finances, and personnel" (Rao et al. 2000 in Leca et al. ibid. 12), which deserves certain skills from the institutional entrepreneur. The selection and mobilization of frames depends on the entrepreneurs' ability to enclose "grievances" and the ability to frame new solutions and a "collective attribution process" (Snow/Benford, 1992 in Leca et al. ibid.). Moreover, the literature points to further conditions as the entrepreneur's own legitimacy in the affected field and the ability to "generate tension around the legitimacy of a particular institutional arrangement" (Creed et al. 2002; Seo/Creed 2002 in ibid. 12 et

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technology frame, therefore, is the interpretative system of managers to understand the firm's technological position and opportunities as well as the expectations of the dynamics of their relevant innovation system(s) (Orlikowski 2000; Orlikowski/Gash 1994)."

[18] "To generalize, variation in technology frames across 'high-tech' firms derives more from a focus on how the technology (broadly stated) should develop, whereas variation in technology frames amongst LMT firms pertains more to what the role for technology (broadly stated) should be." (Von Tunzelmann/Acha 2005: 419)

seq.). Before presenting the entrepreneurs' conditions for the institutional entrepreneurship process, two further strategic mechanisms are presented.

The mechanisms of professionalization and theorization can be linked to framing, providing new solutions or collective attributes (Snow/Benford 1992 in Leca et al. ibid.). Hence, such activities are not only necessary for framing, they also "theorize the institutional project in such a way that it will resonate with the interests and values, and problems of potential allies" (Boxenbaum/Battilana 2005; Fligstein 2001 et al. in Leca et al. ibid.). Theorization launches a theory of new practices that connects the new "means-end relations to outcomes highly valued by field constituencies" (Maguire 2008: 676).

> *Theoretisierung beinhaltet einerseits, einen Sachverhalt als unbefriedigend darzulegen und ein entsprechendes Empfinden bei einer ausgewählten Gruppe an Akteuren zu wecken. Es gilt, ein Problembewusstsein zu erzeugen, wodurch Akteure überhaupt erst auf Neuartiges aufmerksam werden.*[19] *(Schiller-Merkens 2008: 94)*

The new practice needs to be introduced as a preferable and appropriate solution (ibid.). Likewise, the institutional project needs to be set in a more abstract and professional frame. Professionalization can be reached by developing specific measures (Déjean et al. 2004 in Leca et al. 2008: 18), defining a specific professional identity (Hughes, 2003 in ibid.), or attending to (certification) contests (Rao 1994 in ibid.) as well as participating in technical committees for new standards (Garud et al. 2002 in ibid.). Both mechanisms contribute to persuading and legitimizing the new institutional project (Maguire 2008: 676).

Altogether, similar mechanisms across different disciplinary perspectives could be found that cover mechanisms at a more practical level as well as more strategic mechanisms oriented towards resources from the environment. Assuming systemic opportunities are absent in the environment of low-tech industries, it would be interesting, if knowledge-intensive entrepreneurs use some of these mechanisms or similar ones to mobilize resources.

Diagnostic question concerning the mechanisms of institutional entrepreneurship:

- *What kind of strategic or practical mechanisms can be observed?*

[19] Theorizing contains, on the one hand, to declare a situation as dissatisfying and to generate a certain feeling in a selected group of actors. It is necessary to create a problem awareness through which actors become aware of novel concepts in the first place (translated by author).

2.3.4 Institutional entrepreneurs' characteristics

In the literature (Pacheco et al. 2010; Leca et al. 2008), two basic categories of conditions for institutional entrepreneurship are addressed: the institutional entrepreneurs' characteristics and so-called field level enabling conditions (Chapter 2.3.5). Both are interrelated and only separated for analytical reasons.

Starting with the institutional entrepreneur, he or she is defined as the actor responsible "for new or altered institutional arrangements", whereby actor can refer to an individual as well as to a collective actor, such as an organization or social movement (Maguire 2008: 674). Institutional entrepreneurs overcome routines, pay attention to new options, and take over uncommon tasks for realizing new combinations "against the adaptive pressure of [their] social surroundings" (Beckert 199: 786, referring to Schumpeter). Institutional entrepreneurs are to be discriminated from managers, because they "respond creatively" to environmental changes, whereas managers just adapt to it (ibid.). The institutional theory perspective describes them as "institutional innovators" or "agents of institutional change" (Pacheco et al. 2010: 979) who can have several motivations for implementing institutional change. For instance, "functional or economic pressures but also […] political or social forces" (Pacheco et al. ibid.) makes them recognize obsolescent institutions, which illustrates the interconnectedness of environmental and individual conditions.

Moreover, the institutional entrepreneurs' resources, in terms of their background, experiences and skills play a significant role in gaining access to further critical resources along the institutional entrepreneurship process (Pacheco et al. 987; Leca et al. 2008: 14). The presented mechanisms used within the process of institutional entrepreneurship require certain *abilities and skills* from the institutional entrepreneur (cf. Snow/ Benford 1992 in Leca et al. 2008: 12). Many of them overlap with those characteristics known from micro-entrepreneurship research.

The meaning of the institutional entrepreneur's prior knowledge for the beginning of the institutional entrepreneurship process remains still an open issue in this research field (Phillips/Tracey 2007 in Pacheco et al. 2010: 1000 et seq.). Basically, it is assumed that entrepreneurial opportunities can be traced back to the social and distributed character of knowledge (Dew et al. 2004; Hayek 1945; et al. in Pacheco et al. 2010: 1001). Accordingly, a few people with relevant knowledge at command are better in taking note of such opportunities. This knowledge could have been acquired from specific work or educational experiences and makes it "more likely to opportunities in similar applications" (Shane 2000 in Pacheco et al. ibid.). Connected to this, is the initial requirement of certain diagnostic skills to take a reflective stance towards the institutional environment and to question existing rules and practices (Garud/ Karnøe 2003 in Pacheco et al. ibid. 979; Beckert 1999: 786). In addition, creative skills are necessary that enable the entrepreneur to break with these rules and practices, imagine alternative practices as well as initiate mechanisms of de- and re-institutionalization (Garud/Karnøe ibid.; Garud et al. 2007: 962). Hence, they must be able "to contextualize past habits and future projects" Emirbayer/Mische 1998: 963 in Garud et al. ibid.). This relates to framing as well as theorizing and professionalization activity. Contextualizing addresses the process of enabling collective attributes with supporting actors (Snow/Benford 1992 in Leca et al. 2008: 12). In this respect, the articulation and definition of institutional weaknesses or shortcomings are as crucial as the plausible communication of a solution along an alternative "change project" (Garud et al. 2007: 962). These framing abilities are again an elementary precondition for the main task of the institutional entrepreneur: to mobilize the necessary resources for an institutional project and set up a new organizational form. These resources range from legitimacy through human resources to finances (Rao et al. 2000 in Leca et al. 2008: 12).

Considering these elementary framing and mobilizing activities, it becomes clear why Fligstein (1997; 2001 in Leca et al. 2008: 10) and other sociologists like Deutschmann (2008) characterize institutional entrepreneurs as "socially skilled actors". Other authors point to "skilled actors" (Child et al. 2007; Colomy 1998; Greenwood et al. 2002; Suddaby/Greenwood 2005 in Garud et al. 2007: 962). Fligstein refers to basic skills for establishing new or maintaining collective groups of interest that are constitutive for the sustainable implementation of the institutional entrepreneurship process. More specifically, high empathic skills are required from the institutional entrepreneur. This is also useful to analyze the configuration of the field (Fligstein 1999 in Leca et al. 2008: 13) and secure collaborations later on. Empathy helps the entrepreneurs to understand the situation and interests of other actors and to align them with their own ones. Finally, empathetic skills help entrepreneurs identify reasons for collaborations (ibid. 10; Garud et al. 2007: 962).

Altogether, these characteristics back the institutional entrepreneur's ability to develop an institutional project that can be "more or less ambitious" (Colomy 1998; Perkmann/Spicer 2007 in Leca et al. 2008: 10). Last but not least, it is also important to mention that entrepreneurs need to "believe in their abilities to influence their greater institutional environments." (Pacheco et al. 2010: 1001) It is likely that the entrepreneur's *position* in the field also matters for this belief. As the term 'process' implies the process of entrepreneurship does not solely result from the institutional entrepreneur's stable characteristics, Walgenbach and Meyer (2008: 140) assume differently situated capabilities along this entrepreneurial process. These settle on a specific configuration of the field and corresponding position of the entrepreneur, for instance, powerful actors or border crossers between different fields or networks (Boxenbaum/Battilana 2005; et al. in Leca et al. 2008: 9). The social position of the institutional entrepreneur is widely considered a "key factor" (Dorado 2005; Lawrence 1999; Maguire et al. 2004; et al. in Leca et al. ibid. 7-10). It influences the entrepreneur's perception and motivation for institutional change (Greenwood/Suddaby 2006; Leblebici et al. 1991 in Pacheco et al. ibid. 986 et seq.) as well as his or her access to relevant resources for the institutional entrepreneurship process (ibid.). Accordingly, the conditions perceived by the entrepreneur can vary from “objective” conditions (Dorado 2005: 405). This way, Silvia Dorado explains further why some actors incept institutional processes and others don’t (ibid.).

The social position of actors is mostly studied at the organizational level, whereas recently also the individuals’ position in social networks is analyzed, i.e. the entrepreneurs’ direct links to a web of persons (Aldrich 1999; Dorado 2005; Maguire et al. 2004 in Leca et al. ibid. 10). A related resource in this respect is the institutional entrepreneur’s *social capital*[20]. Fligstein (1997 in Leca et al. ibid.) sees a success factor for the likelihood of institutional entrepreneurship in the high level of social capital, since they can use it to link relevant actors for collaboration (Leca et al. ibid.).

The positions of central or powerful actors against actors from the periphery or fringes of the concerned field are contradictorily discussed (Leca et al. 2008: 10). Some authors stress the need of powerful actors to change the field (Greenwood/Suddaby 2006; Sherer/Lee 2002; Zilber 2002 in Leca et al. ibid.; Lawrence 1999 in Pacheco et al. 2010: 986), whereas others emphasize the advantage of entrepreneurs from the periphery to take a reflective, distanced stance from conventional practices in the field. Usually powerful and central actors are not interested in changing the status quo (DiMaggio 1988 in Leca et al. 2008: 11). But if they can be won over as supporters, they can mainly contribute to stabilizing the institutionalization process (Lawrence 1999 in Pacheco et al. 2010: 986). A central position of the institutional entrepreneur in the field helps to “establish alliances with more isolated agents who are unable to act on their own but can support the project” (Leca et al. 2008: 15 et seq. according to Fligstein 1997). Some authors (Maguire et al. 2004; Dorado 2005) conclude from this that institutional entrepreneurs need to gain a position with sufficient power to mobilize and control resources in order to initiate institutional change (Leca et al. 2008: 16). However, a disadvantage of central actors is that their embeddedness and socialization in the institutional field could keep them from taking notice of alternative practices (Pacheco et al. 986). Compared to this, actors of a field’s periphery or so-called fringe players (Leblebici et al. 1991 in Dorado 2005: 405) such as researchers (or research organizations) are expected to be more likely to question existing institutions and institutional practices, because they are less familiar with practices and expectations of the respective industrial field and this way more open towards alternatives (Pacheco 2010: 986; Maguire 2008: 675). Several studies confirm that actors at “the margins of an organizational field […] or the interstices of different organizational fields […] are more likely to act as institutional entrepreneurs.“ (Leca et al. 2008: 9) New entrants or actors from the periphery are more prone to initiate “radically new practice” especially because of their less powerful position that implies probably less sanctions and less potential losses compared to a powerful ac-

[20] According to James Coleman (1988 in Leca et al. ibid. 15), social capital is defined as the “position in a web of social relations that provide information and political support, and considers the concurrent ability to draw on that standing to influence others’ action”.

tor from the center (Leblebici et al. 1991 in Dorado 2005: 405). Additionally, these actors are supposed to “appreciate opportunities where others see only information reinforcing well-established assumptions” (Dorado 2005: 405). Not least, this is explained by different *motivation* for alternatives of peripheral players that might change their position in advantage (Maguire 2008: 674). However, these actors “typically lack the power to do so” (ibid.) and rely on the reception of the central players. In this respect Maguire also observes a kind of threshold (cf. DiMaggio 1988: 6), i.e. once peripheral entrepreneurs have demonstrated the benefits of innovative deviation from conventions and it is taken on by central players, it is in the process of institutionalization as a new convention (Maguire 2008: 674).

Legitimacy[21] is the crucial aspect connected to field level enabling conditions as well as to actor enabling conditions. Usually significant innovation through deviation from norms or practices is not automatically adopted by affected actors (Garud et al. 2007: 960; Walgenbach/Meyer 2008:140). Innovation lacks legitimacy and this also holds true for the entrepreneurs and for the new organization that might be founded in the course of the process. The lack of legitimacy can restrict or impede access to external resources that are necessary for implementation of the innovation or foundation of a new company (Walgenbach/Meyer ibid.). Hence, institutional entrepreneurs need to acquire commitment and legitimacy from their environment as a condition for the institutional change in the end (Garud et al. 2007: 960; Pacheco et al. 2010: 985 et seq.). The presented mechanisms of institutional projects, framing, theorizing or professionalization help to legitimize the innovation and new organizational form (ibid. 986). Besides these efforts, entrepreneurs can benefit from *previously earned legitimacy* that refers to the congruence of the entrepreneur’s action with more general values and expectations of the environment (Durand/McGuire 2005; et al. in Leca et al. ibid. 16). Less studied so far is how so-called formal authority can help institutional entrepreneurs to gain legitimacy or support their framing activities (Fligstein 2001; Phillips et al. 2004 in Leca et al. 2008: 16). This can be an authority of the state or other official positions if not the institutional entrepreneur himself or herself refers to such a formal position (Maguire et al. 2004 in Leca et al. ibid.).

Above all, the elementary initial condition of institutional entrepreneurship is the missing legitimacy of institution breaking projects. Additionally, actor-dependent conditions are characteristics, resources and positions that institutional entrepreneurs need to have at command for changing institutions (Pacheco et al. 2010: 985; Leca et al. 2008: 15). In this respect, “intangible resources” such as “social capital” and legitimacy or “formal authority” have been identified as necessary, enabling conditions for institutional entrepreneurship (Leca et al. ibid.). These conditional factors have to be considered as mainly interrelated with environmental conditions (ibid. 7), e.g. the position of the institutional entrepreneur in the field is not only determined by

21 Legitimacy is an established concept in institutional theory. Institutional entrepreneurship theorists acknowledge “the instrumental use of legitimacy based on the manipulation of symbols or particular frames to obtain societal support” (Pacheco et al. 2010: 985 et seq.).

his or her individual skills but also by other actors' skills, and by the structure of the field. Next, these field enabling conditions are treated.

Diagnostic questions concerning the institutional entrepreneurs' characteristics:

- *What was the entrepreneurs' motivation?*
- *How can the entrepreneurs' position in the field be described?*
- *With which skills did the entrepreneurs contribute to the entrepreneurial process?*
- *Which intangible resources (e.g. social capital or previously earned legitimacy) were used?*

2.3.5 Environmental conditions

As no actor – including institutional entrepreneurs – operates in a vacuum (Walgenbach/ Meyer 2008), this section addresses under which conditions actors become institutional entrepreneurs (Leca et al. 2008: 6) and the process of institutional entrepreneurship takes place (ibid.). Mainly three specific environmental contexts are distinguished: 'crises and jolts' (Child et al. 2007, Greenwood et al. 2002; Fligstein 1997; 2001; et al. in Leca et al. 2008: 7) as well as 'emerging' and 'mature institutional environments' (Maguire 2008; Greenwood/Suddaby 2006; Dorado 2005).

In general, *crises and jolts* lead to external pressure on the actors and contribute to the emergence of institutional change (Oliver 1992 in Pacheco et al. 2010: 985; also Leca et al. ibid.). Further forms of shocks distinguish between social and technological disruptions, "competitive discontinuities", or "regulatory changes" (Leca et al. 2008: 7) that rise to question existing cognitive frames and practices and stimulate new ideas (Greenwood 2002 in ibid.). Beside this, "multi-faceted problems", such as environmental issues, or "acute problems" might accelerate crises and require inter-organizational collaboration (ibid.). Additionally, problems of scarce resources might be of interest for low-tech industries, as it is assumed that these lead to migration of entrepreneurial actors from other fields (Durand/McGuire 2005 in Leca et al. ibid.). Altogether, such crises bring along "ambiguity and confusion" that challenge existing institutional arrangements (Maguire 2008: 675). Maguire calls resulting inconsistencies "unavoidable by-products of institutionalization" (ibid.) that can emerge within or across fields. These institutional contradictions or also *tensions* of environmental dynamics depict an interesting aspect for extending Radosevic's concept of institutional opportunities.

The effects of such forms of crises differ between emerging and matured institutional environments, because they basically differ in structure and *degree of institutionalization* (Maguire 2008: 674; Walgenbach/Meyer 2008: 64; Dorado 2005: 393). Principally it is assumed that "the less mandatory and more optional an institution, the easier it is to deinstitutionalize" (Clemens/Cook 1999 in Leca et al. ibid. 8). Institutional environments are described as specific configurations of rules and needs with which located organizations in this field must comply in order to receive legitimacy or in case of external support (Scott 1995 in Garud et al. 2007: 959). This basic compliance complicates deviation from such prescribed rules and actions for institutional entrepreneurs (Garud et al. ibid.). Many authors describe the institutional environment by referring to the level of organizational fields above all (Pacheco et al. 2010: 986). 'Organizational fields' can be considered as the direct environment of an organization though they are "part of a larger whole composed of multiple, interpenetrating institutional structures operating at multiple levels and in multiple sectors" (Dorado 2005: 392). Hence, the point of reference is closer to an organization's environment than at the sectoral system level and also includes relations to organizations external to the industry, e.g. customers. This field unit is described "through recurring social interactions across members, which produce mutual understandings and common practices" (Pacheco et al. 2010: 986). In particular "the overlap and conflict among the institutional referents in an organizational field frame the form of agency and the resource mobilization process producing institutional change." (Dorado 2005: 392) More generally, beside the position of an entrepreneurial actor (organization or individual) the structure of an organizational field influences the "extent to which institutions within an organizational field can be proactively transformed" (Pacheco et al. 2010: 986). Especially important variables are maturity and concentration, but also the "organizational field's degree of heterogeneity and institutionalization" (Leca et al. 2008: 7) has an effect on actors' behavior and the process of mobilizing resources (Dorado 2005: 393). Leca et al. (ibid. et seq.) found in their literature review that opportunities for institutional entrepreneurship can emerge especially from diverse or alternating institutional orders. Broken down on a lower institutional level: The higher the *heterogeneity* of institutional arrangements in an organizational field, the higher the likelihood that institutional incompatibilities and tensions in a given system arise, and cause opportunities for institutional entrepreneurship (Blackburn 1994 in Leca et al. 2008: 8). Several authors highlight the "enabling role of institutional contradictions" (Leca et al. 2008: 8) that could also be understood in the sense of institutional opportunities. They are further explained by a certain extent of accumulated experiences with institutional contradictions that lead to a shift in collective consciousness and allows passive actors, who reproduce existing institutional arrangements, to turn into active institutional entrepreneurs (Seo/Creed 2002; et al. in Leca et al. ibid.).

Concretely, Leca et al. (2008) found two frequently referenced types of institutional environments what they termed "a first step towards a typology" of conditions, which is still missing for the emergence of institutional entrepreneurship (ibid. 19). According to this, environmental conditions from a context of emerging fields can be broadly distinguished from the context of mature fields. The following comparison draws on the relevant aspects identified from the literature such as the degree of institutionalization, actors' position, endowments and skills (Maguire 2008: 677). According to Maguire, likewise, the actors' motivation for institutional entrepreneurship differs in case of emerging or mature fields or crisis (ibid. 674.). Furthermore, opportunity structure (ibid. 676) and mechanisms identified for the two types of institutional environment are compared, as this could also help to investigate the institutional environment of KIE in low-tech industries.

Most studies of institutional entrepreneurship address *emerging fields* (Leca et al. 2008: 8). Newly emerging fields can be broadly described by a low degree of institutionalization; i.e. less structured, and, related to this, described by a higher degree of uncertainty (ibid. 8 et seq.), and lacking coordination (Pacheco et al. 2010: 986). This situation is considered more prone to institutional or radical change (Maguire et al. 2004 in ibid.), since institutional entrepreneurs are said not to be caught in Max Weber's "iron cage" of established institutions (Maguire 2008: 674); instead, institutional orders are typically missing or just emerging (Pacheco et al. 2010: 986). Maguire further describes this emerging institutional environment by fluid relationships between actors, the co-existence of various meanings and understandings that are "not widely shared, and multiple possible scripts for action" (2008: 674) exist, which reminds of the era of ferment in ILC theory (e.g. Murmann/Tushman 2001). This constellation of actors additionally implies that "resistance to change is not as concerning as in established fields" (Greenwood/Hinings 1996 in Pacheco et al. 2010: 986; Leca et al. 2008: 18).

Actors and especially institutional entrepreneurs are important for the reduction of uncertainty through establishing relationships, meanings and understandings in accordance with emerging interests in the field (Maguire 2008: 674). The advantage of new participants in an emerging field is that they are not embedded in any cognitive or institutional structures of the field. However, researchers acknowledge that those new participants can have central roles in other fields and bring along knowledge based on cognitive structures and norms from these other fields. In this regard, they are "important sources of ideas for change" (Maguire 2008: 675). Based on empirical studies, neo-institutional theorists widely spring from a low number of new organizational start-ups in the environment of newly emerging industries, while their mortality rate is high (Hannan/Carroll 1992; Delacroix/Rao 1994; et al. in Walgenbach/Meyer 2008: 140). The reason for this is seen in the lack of legitimacy of these new organizations and the low degree of institutionalization in the field (Walgenbach/Meyer ibid.). For similar reasons, authors like Maguire et al. (2004 in Pacheco et al. 2010: 987; Maguire 2008: 677) found that institutional entrepreneurs with a legitimacy providing position are especially important in such an emerging environment, because it helps them to link multiple actors and to access necessary resources from them. In this respect, research also refers to the necessary trustworthiness of the respective institutional entrepreneur (Maguire 2008: 677; Leca et al. 2008: 17).

Which resources and mechanisms are used for the institutional entrepreneurship process, can also depend on the environmental context (Leca et al. 2008: 17/14). In emerging fields, especially multiple stakeholders must be convinced (Maguire 2008: 677). In addition, the mechanisms of discourse and framing have to be first of all targeted at establishing a common identity and at legitimizing the new field to established stakeholders from other fields they rely on (DiMaggio/Powell 1991; Koene 2006 in Leca et al. 2008: 14). Missing boundaries and identities in this institutional environment can be established by drawing on professionalization and theorization mechanisms, concretely on “normative or regulatory carriers” (Leca et al. 2008: 18). These can be specific measures or associations, for instance, which contribute to necessary professionalization of the new field and institutional project (ibid.). Finally, institutional opportunities for institutional entrepreneurship rather result from the low degree of institutionalization in this field and the absence of any constraining institutional orders or arrangements.

Compared to emerging fields, only a few studies about institutional entrepreneurship in *mature institutional fields* can be found (Leca et al. 2008: 8; e.g. Greenwood/Suddaby 2006). This institutional environment is mainly characterized by a higher degree of institutionalization in terms of relatively stable structures and established patterns of practices (Pacheco et al. 2010: 986) as well as a common, dominating institutional logic (Maguire 2008: 675). The “repeated reenactment of institutionalized practice and iterated reproduction of institutions is supposed to reinforce cognitive structures that prevent field members from conceiving of alternative” (ibid.). For that reason, Maguire calls it a key question how institutional entrepreneurs come up with new ideas in such an institutional environment, which is comparable with the emergence of KIE low-tech industries.

In mature fields, different positions of institutional entrepreneurs are considered that are further related to actors’ motivation for change (Maguire 2008: 674). As mentioned earlier, disadvantaged or peripheral actors are regarded as more highly motivated to search for alternative practices and change the status quo than central actors (ibid.). “[W]ell-established positions or reputations […] can be both enabling and constraining” for institutional entrepreneurs (Leca et al. 2008: 17). However, central actors of a field can be encouraged to change just as well due to new arising opportunities in terms of new technologies, problems and jolts such as regulatory change that weaken existing institutional arrangements (ibid. 674 et seq.). Another reason for so-called longtime field participants to become institutional entrepreneurs is seen in the participants’ embeddedness or socialization in a further field (ibid. 675). “In this way, even central actors can become aware of and open to alternatives, if they occupy positions that bridge beyond the field’s boundaries” (ibid.).

Specific mechanisms in mature institutional environments are ‘transposition’ and ‘translation’ (Maguire 2008: 675). Consistent with the described innovation activities of reconfiguring in low-tech innovation studies (e.g. Bender 2005; Robertson/Smith 2008), transposition and translation draw on the import, rearrangement and adaptation of practices from other fields (Maguire 2008: 675). Maguire explicitly ascribes these activities to “less or multiply embedded actors” (ibid.) who are able to translate these practices and logics to the mature field (ibid.). In addition, ideas for change can also emerge from rival logics and meanings within the field, because the stability of a dominating logic in a field is not definite (ibid.). Rather, fields can be understood dynamically as “political arenas” where promoters of “different means-ends scripts” participate (ibid.). Once accumulated events that can occur very slowly have reached a “truce-breaking” threshold, power relations may have changed and motivate promoters of competing logics to question dominant institutional arrangements (ibid.). For the realization and support of new ideas it was detected that institutional entrepreneurs in mature fields have made especially use of existing institutional arrangements (Greenwood et al. 2002 in Leca et al. 2008: 118). In particular, here it is referred to established professional associations (ibid.; et al. in Maguire 2008: 677), because these offer discursive arenas that institutional entrepreneurs need for introducing their ideas of change, acquiring supporters and resources and especially convincing resisting participants (Maguire ibid.). Hence, the discursive framing is a very crucial mechanism in mature fields for aligning existent interests and values of so-called dominant coalition members with the new idea (Greenwood/Sudabby 2006; et al. in Leca et al. 2008: 14). This undertaking becomes even more challenging, if there is more than one coalition to be won over. In this case, institutional entrepreneurs have to address “fragmented groups of diverse dominant field members” (Leca et al. 2008: 14). This scenario requires reconciling all interests of these groups in an encompassing discourse (e.g. Fligstein 1997; Hsu 2006 in Leca et al. ibid.). In conclusion, though developed fields are characterized by a higher degree of institutionalization, opportunities can arise from competing logics and actors that become especially triggered in crises or disruptions (Maguire 2008: 675). Finally, opportunities can also be created by the institutional entrepreneurs (ibid. 677). Institutional entrepreneurs “can initiate institutional change in the absence of clear alternative practices to be championed by bringing field participants together to begin to discuss some problem” (ibid.).

The comparison between emerging and institutional environments shows that the process of institutional entrepreneurship proceeds differently depending on different institutional conditions. However, an agreement could not be found in the discussion about the grade of institutionalization’s effect on opportunities for institutional entrepreneurship (Dorado 2005: 92; Leca et al. 2008: 8). Even in highly institutionalized fields, opportunities can emerge, as shown for mature fields. In other words, the simple assumption, the higher the degree of institutionalization, the lower the opportunity and vice versa, cannot be confirmed. However, the degree seems to have an effect on the entrepreneurs' activity (Tolbert/Zucker 1996 in Leca et al. 2008: 8). Some authors even argue that highly institutionalized fields offer a more certain, predictable environment for strategic action like that of institutional entrepreneurs (Beckert 1999; Oliver 1992 in Leca et al. ibid.). Accordingly, "a certain institutionalization and stability is needed for deviating and re-institutionalization activities of entrepreneurs" (Dorado 2005: 393; cf. also Beckert 1999: 786 et seq.). The process is put in a whole cycle of which initially a "moderate level of institutional development" is necessary for the entrepreneur's imagination and estimation to impose change (Dorado 2005: 393 referring to Beckert 1999). This initiation will lead to de-institutionalization and uncertainty again, which brings along adaptation. And finally, when stability and certainty is reached, strategic entrepreneurial action becomes likely again (ibid.). In contrast, other scientists emanate from the opposite that first "uncertainty in institutional orders", i.e. a low degree of institutionalization and structure, creates opportunities for strategic action and institutional entrepreneurship (DiMaggio 1988; Fligstein 1997; Phillips et al. 2000 in Leca et al. 2008: 8).

Dorado (2005) developed an extended typology of institutional contexts, drawing on the degree of institutionalization, heterogeneity and openness of the field to describe *opportunities*.[22] It is based on the assumption that "[o]rganizational fields differ on their openness to ideas practiced in other fields (Greenwood/Hinings 1996) and therefore on the likelihood that actors are exposed to multiple overlapping and conflicting institutional referents." (Dorado 2005: 392) Basically, different institutionalized, imaginative systems overlap in organizational fields, and *institutional arrangement*s are often not distinct but need to be interpreted (Scott 1994; 2001; et al. in Walgenbach/Meyer 2008: 144). This scope of interpretation enables institutional entrepreneurs to change frames according to their interest, if they can successfully embed it in existing rules of the organizational field (Walgenbach/Meyer ibid.). Meanwhile, several authors agree that these tensions emerging from deepening contradictions between actors promote the likelihood of institutional entrepreneurship action (Dorado 2005: 392; Maguire 2008: 675 et seq.). In other words, "actors gain agency from the tensions between divergent institutional referents (Seo/Creed 2002; Beckert 1999 et al. in Dorado 2005: 392; also Pacheco et al. 2010: 984; Leca et al. 2008: 12).

Dorado (2005) investigated in particular three scenarios of organizational fields' *openness* to entrepreneurial opportunities: 'tightly closed fields', 'open fields' and 'too open fields'. Tightly closed fields are less likely to promote creative action, because they are less open to various institutional referents (Dorado ibid. 392). These can take on the form of extremely institutionalized systems with behavioral patterns or power structures that are "so exteriorized and intersubjective that no actor is likely to question them" (Dorado 2005: 394 according to Berger/Luckmann 1967; Zucker 1977). Additionally, actors may be incapable because they have to expect rejection

[22] Dorado (2005: 391) understands opportunities "as the likelihood that an organizational field will permit actors to identify and introduce a novel institutional combination and facilitate the mobilization of the resources required to make it enduring."

of powerful political or economic elites (DiMaggio 1988; Lukes 1974 in Dorado 2005: 394). In such a scenario, change is rather expected through routine behavior in terms of "imperceptible accumulation of slight variations" following existing patterns (Barley/Tolbert 1997; Giddens 1984 in Dorado ibid.). Dorado ascribes these activities to Beckert's (1999: 786 et seq.) cyclical stage of adaptation that also reminds of the prevailing managerial innovation activities described for the low-tech sector (Bender 2005: 95; Hirsch-Kreinsen et al. 2008: 9 et seq.; Som 2012: 9). Compared to this, the investigated scenario of open fields is much more exposed to such tensions and new institutional arrangements (Giddens 1991; Seo/Creed 2002 in Dorado ibid. 392). The third field scenario concerns too open fields where high uncertainty linked with complexity prevails and predictability is low (Duncan 1972 in Dorado ibid. 392). Here, it is expected that actors try to reduce uncertainty through implementing sensemaking behaviors (Starbuck/Milliken 1988; Weick 1995 in ibid.). But in extreme cases, these conditions can be sensed as too insecure or uncoordinated rather than a promising opportunity. This way, a critical view on emerging fields is included that takes Beckert's (1999) deliberation on the institutional requirements for strategic action into account.

Based on the investigation of these scenarios, Dorado derived three dominant types of fields differing in the extent of likely opportunities for institutional change (Leca et al. 2008: 9): 'Opportunity opaque', 'opportunity transparent' and 'opportunity hazy fields'. Opportunity opaque fields describe extremely institutionalized and/or isolated (tightly closed) fields. Meaning opportunities are not provided in this field or are almost absent (Dorado 2005: 394). This field is not permeable for opportunities from other fields (ibid.). Generally, in such opaque fields "the ability to identify and introduce new combinations and gain access to resources to support them will be almost impossible" for actors (Dorado ibid.). Against this, opportunity transparent (open) fields provide several opportunities due to diverse institutional arrangements while securing a substantial level of institutionalization. Hence, a reasonable extent of uncertainty and ambiguity exist for participants in this field (ibid. 402). Finally, opportunity hazy fields are characterized by a highly unpredictable uncertain (or too open) environment, while many practices co-exist. This low degree of institutionalization indeed offers many opportunities for action, but for the same reason actors can have problems to grip them (Leca et al. 2008: 9).

It is remarkable that Dorado (2005: 399) conceives, nevertheless, processes of change also in opportunity opaque or hazy fields, if the social position of the actor allows for more transparency or different access to "institutional referents different from those dominant in the field" (ibid.). In the end she generally confirms that the degree of institutionalization of a field correlates with the opaqueness of opportunities. At the same time she acknowledges that the impact of this on the actors' capacities for change still deserves more elaboration (ibid. 405). Likewise, the influence of the low-tech institutional environment on KIE cannot be anticipated with this open discussion so far. However, it delivers some starting points and diagnostic questions for the investigation in this work.

Diagnostic questions concerning the environmental conditions:

- *How can the institutional environment be characterized regarding the crises and jolts, degree of institutionalization, institutional heterogeneity, and actor constellation?*
- *How open is the organizational field to tensions and new institutional arrangements?*
- *What kind of constraining conditions can be identified?*
- *Which enabling conditions or opportunities can be found?*

2.4 Conclusions from conceptual framing

The framing of applied concepts should help to better understand how KIE emerges in the institutional environment of low-tech industries and to gain insights in the specific environmental conditions of KIE, its characteristics and process as the subordinate objectives of this work. Starting from the supposition that KIE is shaped by innovation systems (Malerba 2010b: 3 et seq.), the effects of sectoral innovation systems (ibid. 13) and of low-tech SIS on KIE particularly constitute a gap of research. The concepts of sectoral innovation systems (SIS), systemic KIE and institutional entrepreneurship (IE) provide useful complementary dimensions and diagnostic questions for the analysis of this multidimensional phenomenon.

The *concept of sectoral innovation systems* (SIS) is used to describe the institutional environment of a low-tech industry. It identifies the industry's main characteristics of innovation activity and pattern in difference to other industries. These characteristics are figured out from the dimension of the sectoral knowledge base, organizational forms, actors and institutions. The identification of sector-specific innovation practices is important to understand the deviation of KIE from them. Established relations and learning practices of actors are in the center of this systemic approach. Although an SIS is expected to change over time, situations of entrepreneurial change or action are not particularly addressed. It must be even concluded that the interplay of the system's components are slow and cannot be set as optimal per se. On the other hand, such dynamics can provide an opportunity for KIE in an established low-tech sectoral innovation system.

The *concept of systemic KIE* connects the innovation system perspective with entrepreneurial opportunities[23]. It integrates different theoretical perceptions of entrepre-

[23] An opportunity refers to a situation where resources are newly combined for a potential profit (cf. Shane 2003: 10; Grichnik 2006).

neurial opportunities by asking for market opportunities, technological opportunities, and for the first time for institutional opportunities. This way, we can learn more about technological and market as well as institutional situations that favor the emergence of KIE. The systemic concept broadly addresses national innovation system (NIS)'s effects on these opportunity components and KIE (Radosevic et al. 2011: 4). A systemic entrepreneurial opportunity is given when all three opportunity components are aligned. The systemic opportunity and activities of the innovation system, such as entrepreneurial experimentation, express the entrepreneurial propensity of the innovation system. In conclusion, opportunities generally describe situations of action, whereas the institutional environment (entrepreneurial propensity of the innovation system) influences the entrepreneur's perception and judgment of the opportunity.

Distinct to Radosevic et al. (2011), the investigation of this work applies the concept of systemic KIE on a sectoral innovation system (SIS). At the same time, effects of the NIS should not be categorically excluded. The SIS concept explicitly assumes interrelations between the national and sectoral level. National institutions can have impeding effects on the development or innovation in certain industries (Malerba 2005a: 394). Mismatches between these two institutional levels and their actors can have similar effects (ibid.). Likewise, positive effects are thinkable. For this reason, the systemic KIE concept is adjusted to SIS as the main level of analysis while taking possible interrelated effects of NIS into account.

In other words, it is assumed that opportunities for KIE in low-tech industries can be distributed across different innovation systems. Malerba (2005a: 389) mentions, for instance, technological opportunities outside a sectoral innovation system. Similarly, distributed knowledge bases have already been identified as particularly relevant for innovation in low-tech industries (cf. Robertson/Smith 2008: 101 et seq.; Hirsch-Kreinsen et al. 2006). An entrepreneurial opportunity can be understood "as a mechanism for knowledge diffusion and for the exploitation of knowledge" (McMullen et al. 2007: 281). Following Saras Sarasvathy et al. (2005: 144), the "dispersion of knowledge is a root explanation for the presence of uncertainty, which gives rise to opportunities in the first place. Second, dispersion is another root explanation of the nexus of the enterprising individual and the opportunity to discover, create and exploit new markets." The questions remain how well knowledge is combined and diffused in a low-tech innovation system (Bergek et al. 2005: 9) and whether it can offer a systemic opportunity for KIE. Or is it possible that some opportunity components (technical, market or institutional) may come from external sources because of underdeveloped opportunity components or missing entrepreneurial propensity?[24] Put

[24] Only a few studies investigated the nature of opportunities, because "most studies have taken opportunities for granted" (Audretsch and Keilbach 2010: 287; also McMullen et al. 2007: 281). "Although scholars widely acknowledge that theoretical development of the opportunity construct is central to entrepreneurship as a domain of academic inquiry, questions focused on the origins of opportunity remain largely unanswered" (Lawrence et al. 2007: 363).

differently, do entrepreneurs exploit opportunity types from other sectoral or national innovation systems for KIE? These questions should help to receive a more differentiated picture about the situation of entrepreneurial opportunities and the emergence of KIE in this specific institutional low-tech environment. Different to the systemic perspective, questions for distributed opportunity components imply that KIE can also emerge in case of missing opportunity components in the low-tech SIS. Against this, the systemic entrepreneurial understanding denies successful entrepreneurship, if the market, technological and institutional opportunity components are not structurally aligned. Critical is that this alignment does not happen automatically. Above all, systemic concepts are suitable to describe the structure and possible systemic opportunities, but deviating, creative entrepreneurial activity and knowledge-intensive entrepreneurs who are able to sense opportunities outside the system are neglected. In particular, this knowledge-intensive action might be necessary in the institutional environment of low-tech innovation systems.

Applied on the traditional view on low-tech industries that assumes low or no entrepreneurial opportunities in these innovation systems, the systemic KIE concept could not explain the emergence of the KIE phenomenon. Because of this seemingly paradox, the *concept of institutional entrepreneurship* (IE) is additionally chosen. It takes into account arbitrary, powerful entrepreneurs who are able to overcome such structural barriers. It largely contributes to explicating the emergence of KIE in the institutional environment of low-tech industries, because it allows for routine breaking activity of entrepreneurs. It helps to understand the knowledge-intensive deviation in mature institutionalized environments and particularly also of long-term field participants (Maguire 2008: 675). In addition, the perception that dominating logics are not considered as definite (ibid.) is helpful to comprehend how knowledge-intensive activity can compete with dominating logics of economies of scale or process optimization in matured low-tech industries. Likewise, it becomes clearer why KIE builds an exceptional event and why most of the actors in the low-tech industries follow innovation routines. In such institutionalized environments, actors usually have to expect the rejection of powerful political or economic elites that prefer solidifying the status quo (cf. Dorado 2005: 394; Greenwood/Suddaby 2006). The majority of actors estimate the risk of changing innovation and sanctions too high. Instead, change is rather expected through routine behavior and accumulation of slight variation or adaptation that follow existing patterns (Beckert 1999; Dorado 2005: 394) as typically described for the low-tech sector (cf. Chapter 1.1). That entrepreneurship can occur under such entrepreneurship-hostile conditions, is an essential starting point for investigating KIE in the low-tech environment.

The question is how knowledge-intensive entrepreneurs sense and align missing opportunity components from external fields. From the perspective of micro-foundations of the institutional entrepreneurship concept, entrepreneurs are able to create new knowledge, design new cognitive frames at the group level, initiate new institutional arrangements that might have effects up to broader institutional levels like industrial fields (cf. institutional layered model). Hence, KIE is a “largely distributed phenomenon” (Radosevic et al. 2011: 4) that requires knowledge-intensive entrepreneurs who are able to sense knowledge and opportunity components from other fields. For instance, assuming that a low-tech SIS misses technological opportunities, they might sense it from another sectoral knowledge base, instead. Or missing institutional opportunities in terms of entrepreneurship enabling institutions are identified in interdisciplinary entrepreneurship programs from the NIS, instead.

The institutional entrepreneurship concept does not only provide a more appropriate actor concept, the institutionalization process for the successful exploitation of opportunities and mechanisms is also treated. The actors are embedded in an institutional environment, which mainly refers to organizational fields that are closer related to the (collective) actors’ environment than national or sectoral institutional environments. Even though the situative aspect of the ‘entrepreneur-opportunity nexus’ has been not systematically integrated into the IE concept[25] (cf. Leca et al. 2008: 21; Pacheco et al. 2010: 998), entrepreneur and environmental enabling conditions are considered. Taking the three different concepts into account helps to bridge the relation between environment and entrepreneur. While the systemic concepts approach the institutional environment of KIE from the macro and meso level of NIS and SIS, the IE concept starts from the “microfoundations of institutional activity” (Tracey et al. 2011: 76).

In addition, the opportunity dimension of the systemic KIE concept introduces the situative moment, while the IE concept additionally includes agency. Situations can be influenced by surrounding structures of sectoral or national innovations systems or organizational fields, or particularly by individuals. Accordingly, a broader scope from more long-lasting structural or systemic opportunities to more specific and individual opportunities can be distinguished. Structural opportunities exist “independently of individuals’ capacity to recognize and exploit them” (ibid.) and are often described as initial conditions (cf. Radosevic et al. 2011: 15). On the other hand, the IE concept points to the case that institutional entrepreneurs can create opportunities, when clear opportunities are absent (Maguire 2008: 677). The recent discourse on entrepreneurial opportunities or the entrepreneur-opportunity nexus paradigm criticize too individualized as well as explanations of objectively given opportunities. Moreover, a linear process proceeding “from the existence of opportunity through the various stages of discovery, decision to exploit, and so on, up to the performing business” (Spilling 2008: 153et seq.) cannot be assumed. Instead, opportunities are just being created during a recursive process of interaction between entrepreneurs and their environment (cf. Sarason et al. 2006; 2010; Sarasvathy et al. 2005 in Pacheco et al. 2010: 1000; Spilling 2008: 154). This understanding of the nexus between en-

[25] Dorado (2005: 391), for example, uses the term likelihood of organizational fields for new combinations instead of situation.

trepreneur and opportunity seems a good starting point for the investigation of KIE in low-tech industries.

Moreover, the IE concept can extend the construct of institutional opportunities. Instead of institutions that generally enable or promote entrepreneurship, IE theory emanates from tensions and disagreements between institutional logics. It is widely agreed that entrepreneurs obtain entrepreneurial action (agency) from these institutional contradictions (Dorado 2005: 392; Maguire 2008: 675 et seq.; Pacheco et al. 2010: 984; Leca et al. 2008: 12). Hence, it describes another side of institutional opportunity that also enables entrepreneurial action.

In conclusion, based on the systemic and actor-oriented institutional concepts, a wider scope of the institutional environment, institutional layers and opportunities for KIE can be grasped. The open conceptual framing allows for rival as well as complementing explanations of empirical findings. The *main analytical questions* derived from this frame are:

- *How are knowledge and opportunities distributed for KIE in a low-tech SIS?*
- *Do changes in low-tech SIS lead to institutional tensions and offer a structural opportunity for KIE?*
- *Which opportunity components can be found in low-tech SIS and which are organized from other sources/systems?*
- *Do entrepreneurs of KIE use mechanisms of institutional entrepreneurship to set up their knowledge-intensive venture in the institutional environment of matured low-tech industries?*

These analytical questions are applied on cases of KIE in the German textile industry. The concrete methodological approach of this empirical investigation is presented next.

3 Methodological approach

For good reasons the following empirical investigation of KIE in low-tech industries will apply quantitative and qualitative methods. First of all, the state of the art on KIE discloses (cf. Chapter 1.2; 2.2) the phenomenon's general complexity, especially considering the environmental context, that is barely covered comprehensively in entrepreneurial or innovation surveys (cf. Malerba/McKelvey 2010: 34). Secondly, most of these quantitative surveys do not consider low-tech industries (e.g. Metzger/Rammer 2009: 4/13)[26].

Researchers of latest low-tech innovation studies as well as from research on KIE emphasize the important contribution of case studies. Robertson et al. (2009: 441), for instance, critically comment on low-tech innovation research:

> *How, critics ask, can the representativeness of a case study be guaranteed? But equally, how can one be sure that statistical findings that relate large numbers of observations be guaranteed to illuminate the experiences of any one of the events considered? What reason is there to believe that most experiences are accurately reflected by averages?*

McKelvey and Heidemann Lassen (2013a/b) use case studies to learn more about KIE and understand this empirical phenomenon. The authors derived relevant topics and developed a management model on KIE creation from case studies (ibid. 2013b).

The explanatory investigation on the emergence of KIE in low-tech industries applies a multi-level research design approaching KIE from the sectoral level, using secondary analysis of survey data, and from multi-case studies, using the case study method. The different units of analysis as well as the approaches to implementation (Chapter 3.1) and analysis (Chapter 3.2) are presented in more detail in the next section.

3.1 The approach to implementation

The introduced concepts to explain the phenomenon of KIE in low-tech industries reveal basic levels of analysis that are linked to this object of investigation (see Figure 04). Beside the industry and firm level the national level, will be included like in the systemic concept of KIE (cf. Radosevic et al. 2011). The national level might be relevant with respect to interrelations between national and sectoral innovation systems (ibid.; Malerba 2005a: 394), e.g. as an additional source of opportunity for KIE

[26] For instance, the serial studies on the German innovation system publish "Unternehmensdynamik in forschungs- und wissensintensiven Wirtschaftszweigen" (Metzger/Rammer 2009).

I. Schwinge, *The Paradox of Knowledge-Intensive Entrepreneurship in Low-Tech Industries,*
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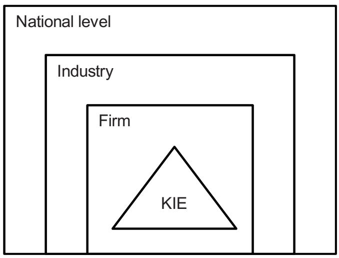
in case of missing opportunity components from the low-tech sectoral innovation system. The research design of the multi-dimensional analysis is structured into two units of analysis. Thereby, the object of investigation is approached through a sectoral analysis and case study analyses (cf. Figure 05).

The first unit of analysis refers to the sectoral level to understand the environmental conditions of KIE and its deviance from the sectoral knowledge base (Chapter 4). The second unit of analysis are KIE cases investigating the object and levels from a micro perspective. Shortcomings or missing quantitative data from the sectoral analysis should be balanced by insights from multiple case studies which also consider environmental conditions (Chapter 5). Therefore, three explorative cases are used that were collected for the AEGIS project.

Fig. 04 Levels of analysis for KIE in low-tech industries

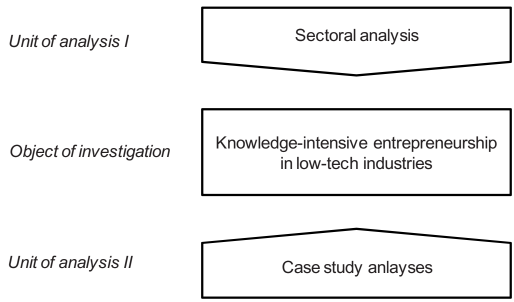


Source: Based on Radosevic et al. (2010: 23).

Because the case study research considers cases that emerged between 2000 and 2006, the sectoral analysis covers the same period and, if possible, earlier years to receive more consistent insights in structural conditions of the low-tech industry. Finally, the results from both units of analysis are merged in respect to consistencies or inconsistencies. Moreover, the meanings of the merged results from the textile industry are discussed with state of the art of KIE and low-tech industries (Chapter 6).

The emergence of KIE in a low-tech industry is exemplarily investigated for the German textile industry. This traditional industry was one of the leading industries during the industrialization. After several technological changes, the matured industry became a typical example for low-tech industries (cf. von Tunzelmann/Acha 2005: 425; Malerba/Breschi 1997) with low investments in R&D, overcapacities and intense international competition with low-wage, newly emerging industrialized countries (NICs) (Robertson et al. 2009: 441) that lead to many firm exits. This concentration process already started in the 1980s. In the 1990s, the textile industry started to respond to this crisis with new technological developments (e.g. Knecht 2003b; Meyer-Storck 2006; Potters 2009). Nevertheless, the average of expenditures on R&D of the textile and clothing industry remained on the level of the low- and medium-low-tech category (Eurostat).

Fig. 05 Research design



Source: Own illustration.

The introductory problem statement (Chapter 1.3) reveals that low-tech industries cannot be adequately described with the category of routinized innovation regimes (cf. Breschi/Malerba 1997), as the majority of firms in low-tech industries are no large companies with R&D departments (Kirner et al. 2009a; Rammer et al. 2010; Som 2012). The same seems to apply for the mainly medium-sized corporate structure of the textile industry (Meyer-Storck 2006). In their comparative analysis of sectoral innovation systems, Breschi and Malerba (1997) indeed apply the categories of Schumpeter Mark I (entrepreneurial regime) and II (routinized regime). The textile industry was investigated among other industries (using data from 1978 to 1991). Because the authors could not allocate the clothing and textile sector to one of the two regimes, they classed it to a third category as traditional sectors of “many innovators […] with no specific knowledge spatial boundaries” (Breschi/Malerba 1997: 143 et seq.). However, this neither helps to determine the conditions of the textile industry for KIE. Since the 1990s, the textile industry in Europe and in Germany has undergone further restructuring, whereas new innovation paths in terms of new functional and technical textiles have developed (Meyer-Stork 2006). This has probably led to changes in the textile innovation system (TIS), but at the same time persistence of established components and actors can be presumed. Consequently, it is not clear how to characterize the SIS of the German textile industry and its influence on KIE processes. According to this, it is worthwhile to conduct a new analysis of the TIS, referring to the period around 2000 and 2006 in consistence with data of KIE cases.

The main function of the *sectoral analysis* is to characterize the institutional environment of KIE in the textile industry. Therefore, the conceptual frame of reference

(Chapter 2) provides the necessary analytical dimensions and diagnostic questions. Following Malerba's dimensions of sectoral innovation systems, the knowledge, actor and institutional dimension of the German TIS are investigated. In addition, to this, the entrepreneurial orientation or propensity of the TIS should be determined according to the systemic concept of KIE. As far as possible, entrepreneurial opportunities should be identified from sectoral data and literature review from this period (2000-2006). Moreover, the investigation of prevalent innovation practices should give insights in entrepreneurial experimentation and entrepreneurial activity in the German textile industry from which first conclusions on the entrepreneurial propensity and systemic KIE can be drawn.

The main sources for the sectoral analysis are statistical data from the Annual detailed enterprise statistics on manufacturing sub-sections[27] by the European statistical office Eurostat, the Mannheim Innovation Panel[28] and the Mannheim Enterprise Panel by the Centre for European Economic Research (ZEW) as well as technical literature on the German textile industry. The secondary analysis of these data and

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[27] The Annual detailed enterprise statistics of Eurostat provide data on general business conditions of the German textile industry (DB Manufacture of textiles and textile products, NACE Rev. 1.1) such as the turnover, the number of firms and employees, the share of R&D expenses on valued added, the share of R&D personnel on the total number of employees employed, etc. In addition this data is also available for further sub-sections of the textile industry (DB17/18 up to 4-digit level of NACE Rev1.1) that are later used in the case studies (http://epp.eurostat.ec.europa.eu/portal/page/portal/european_business/data/database, accessed 27/02/2014).

[28] The Mannheim Innovation Panel (MIP) gathers valuable data for the investigation of enterprises' innovation activity. Since 1993, the ZEW carries out the annual survey in collaboration with the Institute for Applied Social Sciences and the Fraunhofer Institute for Systems and Innovation Research (since 2005). It is commissioned by the German Federal Ministry for Education and Research (BMBF) and contributes to the European Union's Community Information Survey (CIS), carried out by the Statistical Office of the European Communities (Eurostat). However, the MIP is not only used to assess the technological performance of the German economy, it can be likewise used for specific research purposes on sector aggregates. The ZEW also publishes, for instance, annual sectoral innovation reports that inform about the development of key innovation indicators over the past years. The panel data enables to observe firm innovation activity over a long period and helps to identify structures and systemic relations of sectoral innovation systems. The representative sample of the MIP consists of companies with five or more employees in mining, manufacturing, energy, construction and a large number of service sectors. About 6,000 firms respond to the written questionnaire every year. Additionally, about 4,500 firms are interviewed by telephone about key indicators of innovation activity. Values for innovation activity for individual sectors, size classes, and West and East Germany are calculated from the data. Thereof the absolute numbers from the aggregation of firms from the textile, clothing and leather industry ranged from 94 to 145 firms between 2000 and 2006 (ZEW 2011). "The innovation survey alternates on a yearly basis between two forms. The 'long survey' is carried out in odd-numbered years and includes extra questions on circumstances that are relevant to innovation, such as obstacles to innovation, co-operation, intellectual property rights, innovation sources, effects of innovation, public funding of innovation. The 'short survey', in even-numbered years, only asks questions related to the core innovation indicators" (www.zew.de/en/publikationen/innovationserhebungen/repdaten.php3, accessed 27/02/2014) like share of innovators, innovation intensity, expenses on innovation, dis-/continuous R&D, and others.

literature draws especially on the derived analytic dimensions and diagnostic questions in order to characterize the conditions of the German TIS for KIE.[29]

The MIP data that could be acquired from ZEW in December 2011 mainly aggregates the textile, apparel and leather industry. Frequency distribution of data from variables on the following indicators could be assessed:

- Innovation intensity
- Innovators, type of innovators (process/product)
- Expenses on innovation
- R&D activity (continuous and discontinuous)
- Cooperation activity for innovation
- Relevant information sources of innovators
- Innovation constraints
- Protective mechanism
- Public subsidies and assistance

For the time of access (December 2011), many data were not separately available for the apparel and textile industry before 2006 because of a new classification on economic activity. For instance, the proportion of R&D expenditure primarily for product innovations was only separately available from 2006 on for textile and clothing industry and leather industry. In addition, extrapolated values for the variables on personnel, qualifications, demand for employees and financing situation were not available for the purpose of this investigation. Moreover, because of the alternating panel design many data on specific circumstances (innovation constraints, protective mechanism, and subsidies) provide only three measuring points (2000, 2002 and 2004) for the period of investigation.

As the MIP do not provide any data on entrepreneurial activity or new firms, additional data from the Mannheim Enterprise Panel (MUP)[30] were accessed in November 2011. For the evaluation of entrepreneurial activity in the TIS, statistics on the sectoral founding intensity of the textile and apparel industry in Germany could be acquired from the ZEW. The sectoral founding intensity indicates the absolute number of foundations per 10,000 employees of the industry. The aggregated data sets account for the time between 1997 and 2006.

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[29] In a few cases, primary data on entrepreneurial activity from expert interviews with representatives of the German textile association and regional textile association are added. These were actually collected for case study research.

[30] The MUP is a German firm panel carried out by the ZEW in collaboration with the business information service provider Creditreform. It provides data sets on "market entrances and exits [of firms], changes in numbers of economically active firms in specific sectors and regions, the development of firms over time or the dynamics of job creation in firms" (www.zew.de/en/publikationen/gruendungsplattform/mannheimerunternehmenspanel.php, accessed 27/02/2014).

Altogether, the dimension of knowledge and institutions as well as the entrepreneurial activity can only be indirectly derived from these statistical sources. Likewise, the sectoral analysis cannot deliver information about the practice of corporate entrepreneurship. The preliminary concept of KIE in low-tech industries explicitly includes this setting for the investigation of this phenomenon (cf. Chapter 1.4). Within the AEGIS project, a survey was developed that addresses the gap between innovation surveys like the Community Innovation Survey (CIS) and entrepreneurial surveys such as the Global Entrepreneurship Monitor (GEM). However, at the time of investigation the AEGIS Survey was still in work and conceptually excluded cases of corporate entrepreneurship (cf. Malerba/ McKelvey 2010).

In conclusion, for the analysis of an innovation system "it is not possible to come up with an exact figure but the analyst has to make a composite judgment based on both qualitative and quantitative data. Exactly how that is done must be made explicit." (Bergek et al. 2005: 11) For that reason, the approach to analysis will be outlined in the next section (Chapter 3.2). Yet before coming to the analytical proceeding, the implementation of the second unit's analysis is presented which delivers additional qualitative data for a closer empirical mapping.

After mainly quantitative studies in the early state of research on KIE (Malerba 2010a), Malerba (2010b: 24) calls on "deeper analyses of the different dimensions of KIE and their links with innovation systems, […] agent-based models of KIE, innovation and industrial dynamics". In response to this, the main function of the explanatory *case study analysis* is to examine the complex interactions between actors, knowledge-intensive entrepreneurial activity and its low-tech institutional environment during the process of KIE. The analytical dimensions that are taken into consideration are mainly derived from the concept of systemic KIE and its different opportunity components as well as from the institutional entrepreneurship concept. This way, the entrepreneurial orientation of the institutional environment can be assessed, while the institutional conditions distinguish between further institutional layers (cf. Groenewegen/Van der Steen 2006: 281). Starting from the institutional environment of a single case, institutional arrangements as well as formal and informal institutions can be disclosed that existed and were also effective independently from the single case.

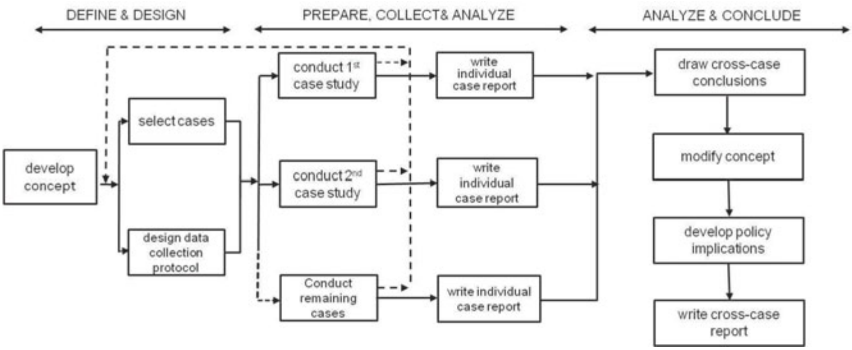
The dimensions from the institutional entrepreneurship concept are suitable as qualitative research and case studies dominate this field of research (cf. Pacheco et al. 2010: 993). Here, likewise, complex processes and multi-level studies including various actors (individuals or organizations) and their embeddedness in multiple fields can be found (cf. Leca et al. 2008: 21). What can be further learned from this field of research is that researchers critically call for more comparative, multi-case research (ibid. 22/24) to overcome limits and idiosyncratic research of common single, in-depth or longitudinal case studies (ibid. 22).

> *In particular, more comparative studies, studies in mature or stable fields, studies of failing or failed institutional entrepreneurs, and studies of individuals acting as institutional entrepreneurs*

are needed. These are all promising research directions that would complement the existing body of research on institutional entrepreneurship. (Ibid. 24)

More generally, a multiple case study design allows not only to identify specific conditions under which a single case emerges, it also helps to gather and build “more general categories of how those conditions may be related” (Miles/Huberman 1994: 173). Accordingly, the case study analysis draws on three cases from the textile industry. However, the three cases build a variant sample, as they are embedded in different sub-sectors of the textile industry and include differing actor constellations. They are differently positioned along the textile supply chain and allow for assessing common conditions but also interrelations of the field specific conditions. Moreover, further possible commonalities in mechanisms, for instance, argue for inter-subjective and structural insights.

Fig. 06 Case study method



Source: Yin (2003: 50).

The implementation of the multi-case analysis slightly differs from the general case study method (see Figure 06), as the main source of case data is based on previously collected explorative case study data from the AEGIS project. For the purpose of this investigation, the author of this work developed a distinct explanatory concept and selected three cases out of five collected case studies from the textile, metal and food industry for the AEGIS project.

The selection criteria applied for the explorative research of the AEGIS project correspond with the specific preliminary concept of KIE (outlined in Chapter 1.4). Accordingly, KIE cases were selected that

- emerged either as a new firm or in established firms (corporate entrepreneurship).
- should be new companies founded between 2000 and 2006 or

- should be existing companies with an innovation between 2000 and 2006.
- should be evidently first movers or assigned to the most innovative companies in the market or product field.
- have a company size of less than 250 employees (SME).
- implemented a product innovation or a new process (technology) which has not been offered to or applied in the (low-tech) industry/product field before.
- embodied knowledge in the innovation not necessarily based on high-tech and R&D activities (but these types of knowledge are not excluded).[31]

The data base of the explorative case studies is extended and analysed with regard to the new conceptual framing.[32] The explanatory data base of the case study analysis includes diverse sources of primary and secondary data:

- Records and transcripts of expert interviews with representatives of industry associations
- Records and transcripts of interviews with participants of KIE cases
- AEGIS standardized company questionnaire (cf. template in Appendix 1)
- AEGIS case study reports
- Firm documents and web pages
- Patents and standards
- Technical literature and studies on product field
- Detailed enterprise statistics on sub-sectors (Eurostat)

Within the AEGIS project, open, guideline based interviews with a representative of the Gesamtverband textil+mode[33] and Forschungskuratorium Textil (June 2009), representatives of the regional association Verband der Nordwestdeutschen Textil- und Bekleidungsindustrie and the initiative Zitex Zukunftsinitiative Textil (May 2009) were carried out in order to receive general information about the textile industry and recommendations for possible cases. Preferably, more than one interview per case was conducted with the managing director of the KIE company and employees and/or partners additionally participating in the KIE process (cf. Table 1). These interviews were also open and guideline based.

The AEGIS standardized company questionnaire collected general information about the firm such as year of foundation, legal form, number of employees and qualification, turnover, products customers and suppliers, innovation and growth rates (cf. Appendix 2). This data was also considered in the AEGIS case study reports on entrepreneurs, innovation, entrepreneurial and innovation process, financing, linkages and cooperation (networks), policy measures. The exploratory reports also included document analysis of firm documents and web pages or reports in magazines. Few

[31] This list is taken from the case study concept of WP1.3 from the AEGIS project. It was developed by the author and distributed among the work package partners but not previously published.

[32] For comparing this approach to implementation with the case study research for the AEGIS project see Hirsch-Kreinsen/Schwinge (2011) and Schwinge/Hirsch-Kreinsen (2010).

[33] Former Gesamtverband der deutschen Textil- und Modeindustrie.

data from detailed enterprise statistics between 2000 and 2006 build the data base of these previous studies. The newly prepared explanatory case studies added further statistics, surveyed additional patents and standards as well as technical literature on the product field to this data base. This owes to the explanatory approach that implies a deeper analysis of the sectoral knowledge base to understand the deviation of the KIE cases and the advanced concept of opportunity types.

Tab. 1 Interview data

Case study	**Interviewee (position)**	**Month/Year**	**Duration**
FuncFiber	Chairman, responsible for R&D	Nov. 2009	1.5 hours
	Chairman, responsible for marketing & sales	Mar. 2010	2.0 hours
	Plant manager (during visit of the plant)	Nov. 2009	2.0 hours
E-Thread	Managing director	Jan. 2011	1.5 hours
	Business unit manager	Jan. 2011	1.5 hours
	2 managing directors of business partner	Jan. 2011	2.0 hours
MultiTex	Managing director	Jul. 2010	1.0 hour

Source: Own illustration.

From the extended data base, three individual case studies are newly prepared and analysed (Chapter 5.1-5.3). The structure of each case study displays the main dimensions from the conceptual frame and follows the derived diagnostic research questions. After a short introduction of the case setting, the environmental conditions of the KIE case are presented following the differentiation of the opportunity components. Accordingly, first the sub-sectoral knowledge base of the KIE organization and technological opportunities are described, then the general market conditions and corresponding market opportunities, and finally the institutional conditions and assessable institutional opportunities. In case opportunities outside the TIS had been exploited, the conditions of these are presented respectively. After an interim conclusion on opportunities from the environment, the case study precedes describing corporate conditions and opportunities for the cases where KIE emerged in established firms. Alternatively, the analysis directly proceeds to describe and characterize the involved entrepreneurs. Finally, the KIE process is described, broadly distinguishing between the exploration and implementation sequences as well as differing actors and mechanisms during these stages based on the process described in the institutional entrepreneurship concept. Therewith the explanatory case studies clearly differ from the previous exploratory case studies. Subsequently, the interim results of the single case studies are merged for cross-case conclusions (Chapter 5.4).

To conclude, the implementation of the case study method in this investigation differs from the common proceeding (cf. Figure 06), as it is based on previously collected explorative case data from which an explanatory concept is developed. Consequently, new case studies are prepared from an extended data base and compared.

3.2 The approach to analysis

The difficulties in analysing a sectoral innovation system and case studies already become visible in the approach to implementation. The way the TIS is evaluated needs to be explicated (Bergek et al. 2005: 11). The same holds true for the case study method. Indeed, many research reports in the industrial sociology applying the case study method describe their approach to implementation and sources of data. The approach to analysis, in contrast, remains mostly vague (cf. Pflüger et al. 2010: 38). For this reason, this section presents the logic of interpretation and analysis used for the investigation.

Altogether, the total empirical investigation addresses the main research question how KIE emerges in the institutional environment of a low-tech industry. In accordance with the outlined objectives of this thesis to gain insights in environmental conditions in low-tech industries, the characteristics and the process of KIE (Chapter 1.5), further research questions are derived from the conceptual framing (Chapter 2.4). Accordingly, the approach to analysis of the exemplary low-tech industry is structured along the following main research questions:

- *How did the German textile innovation system affect KIE in the period of investigation (2000-2006)?*
- *What were the sources of opportunities for KIE in the textile industry?*
- *How did entrepreneurs exploit opportunities?*
- *Which mechanisms were applied during the KIE process?*

Based on literature review of the state of the art (Chapter 1.1-3) and conceptual framing (Chapter 2), it is generally assumed that sectoral innovation systems differently affect KIE (Malerba 2005a; 2010b). For the specific effects of low-tech innovation systems on KIE, first propositions are made:

- *The low-tech sectoral innovation system of the German textile industry is not entrepreneurially oriented and offers either no or only little entrepreneurial opportunities. In other words, it does not support the emergence of KIE.*

- *Entrepreneurial action needs to be particularly taken into account, because low-tech sectoral innovation systems are assumed not supporting the emergence of KIE.*

The logic that links data to the propositions is derived from systemic and actor-oriented concepts, which analytical dimensions collect data from the sectoral (macro) level and the case (micro) level. The resulting data from these two units of analysis should disclose sophisticated insights in the entrepreneurial orientation, opportunity types and mechanisms of KIE expressing specific entrepreneurial actions. Furthermore, the different concepts as well as the broad preliminary concept of approaching KIE in low-tech industries (Chapter 1.4) provide criteria for interpreting the empirical findings. These follow open, rival explanation logic. For instance, the type of knowledge is not restricted to R&D or science-based knowledge but not excluded, too. Likewise, it proceeds with the setting of KIE that can emerge in a new firm but also in established firm. The analysis of different opportunity components and their sources leaves the explanation of KIE opportunities in low-tech industries open. The perception of willful actors based on the institutional entrepreneurship concept is a necessary conceptual extension for the investigation. These open and rival criteria avoid determining anticipations of results from the empirical findings.

The approach to analysis can be further distinguished at the sectoral and case level. Validity of the *sectoral analysis* should be gained through using analytical dimensions from the established concept of sectoral innovation systems (Malerba 2005a; 2006) and further empirical studies (Pitt 2007; Breschi/Malerba 1997; Malerba 2004; 2005b; Radosevic 2010; et al. 2011). Diagnostic questions for the analysis refer to a manual on analysing sectoral innovation systems (Bergek et al. 2005). Criteria for interpreting the different sources of data are frequency distributions from time series that are used to identify dominant practices and established interrelations among actors of the TIS. Preferably, for each dimension several diagnostic questions and variables of the panels should be analysed for a consistent interpretation. The plausibility of the data interpretation is further supported by referring to expert literature and technical studies from the investigated period. Finally, missing variables or data for describing the knowledge base, industry-specific institutions or entrepreneurial activity on this level are compensated by cross-case results from the case study analysis.

The approach of *case study analysis* is especially suitable to explore a phenomenon's complex context relation (Pflüger et al. 2010: 31), as it is given for KIE in low-tech industries.

> *A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. (Yin 2003: 13 et seq. in Pflüger et al. ibid.)*

The validity of the study construct should be ensured by using multiple sources of evidence during data collection and building a chain of evidence (cf. Yin 2003: 34 et seq.). Construct validity is additionally gained through referring to existing concepts and theories for concept development, like institutional entrepreneurship. These in turn provide the base for analytical dimensions and specific diagnostic questions.

Criteria for interpreting a single study's findings are the reference to the context, multi-perspectives, and combination of methods and openness of the research process (cf. Pflüger et al. ibid.). Basically, the reference to the context and relations between relevant contextual factors are analysed. In this investigation, the technical (knowledge), market and institutional conditions of the sub-sector and their opportunities are considered. Moreover, the detailed consideration of different institutional layers enables the assessment of relevant environmental coherences between broad ranging institutions and specific institutional arrangements. The multi-perspectives address the systemic consideration of different actors and their interpretation of action and experiences. Therefore, more than one participant of the KIE process was possibly interviewed per case[34] and multiple cases of different actor constellations are compared. The criterion of combining methods enables to compare between different contexts and perspectives. For instance, statistical data delivers insights in broader sub-sectoral contexts, while the qualitative data allows for detailed information about the organizational field and corporate conditions. Finally, the criterion of openness reconsiders variants and supplements of the developed analytical dimensions and diagnostic questions that can result during the implementation and analysis of the research process. Hence, the interpretation of findings is not exclusively bound to the initially developed conceptual framing. Idiosyncratic insights of the empirical cases beyond the conceptual dimensions and diagnostic questions are included and welcomed. However, these supplements should be plausibly integrable into the research discourse.

Moreover, the approach to case study analyses draws on rival explanations between systemic and institutional actor-oriented perspectives on KIE. The discussion of the empirical findings between these rival concepts contributes to the internal validity of the research design (Yin 2003: 34/36). The following cross-case analysis, with regard to commonalities in opportunity sources, KIE activity and mechanisms independent from the variance of the case sample, approaches a replication logic that is usually used to prove the external validity of multiple case studies (cf. ibid. 34/37).

Both the sectoral and case study analysis have certain dimensions and diagnostic questions in common, approaching the same object of investigation once from a macro and once from a micro perspective (cf. Appendix 2). The environmental conditions and institutions that influence opportunities and entrepreneurial sensing build the main overlap of these two units of analysis. The consistence of the insights from these multiple sources of evidence should finally build a chain of evidence and improve the quality/reliability of the results. At last, the consistent results of the empirical investigation on the German textile industry are discussed for their meaning to other low-tech industries.

[34] In one case (MultiTex) this was not possible. In comparison with the other cases it provides, nevertheless, valuable additional insights.

4 The sectoral innovation system of the German textile industry

The textile industry has an eventful history, starting as a leading industry during the industrial revolution to a “quintessential low-tech industry in the modern era” (von Tunzelmann/Acha 2005: 425). Particularly the relative simple technologies and division of labor in the apparel industry allowed many emerging economies to participate in this industry (cf. ibid. 426). In this respect, the textile industry is one of the most affected industries from changes of market internationalizations (e.g. Konrad 2001: 389). On the other hand, this industry has shown the ability to revolve in new technologies in several times of its industrial life-cycle (cf. von Tunzelmann/Acha ibid.). Examples of the industry’s renewal are the development of artificial fibers at the beginning of the 20th century or synthetic fibers in the middle of the century (ibid.), and recently the launch of smart textiles.

In the 1990s, manufacturers of textile and textile products suffered worldwide overproduction and saturation of consumer demand (Meyer-Storck 2006). This trend also affected the German industrial production in terms of a declining international competitiveness. Meanwhile, market textile commodities close to the consumer are almost marketed as prefabricated imports from emerging low-cost countries on the domestic market (Meyer-Storck 2006). In the period investigated (2000-2006), the situation of the German textile industry remained critical. The number of manufacturers of textiles and textile products still dropped from 11,452 in 2000 to 6,593 in 2006 (43%) in Germany (Eurostat). In the same time period the number of employees reduced from 216,187 to 156,059 (27.8%) (ibid.). The turnover went down by 12.8% to 24.7 billion Euros in 2006 (ibid.). According to the industrial life-cycle theory, the figures describe a shake-out stage typically described for matured, low-tech industries (cf. Peltoniemi 2011; Shane 2003 in Chapter 1.3). Contrary to this general shrinking in traditional domains such as home textiles and clothing, a considerable growth in the field of technical textiles[35] can be assessed (Begemann 2003; Gesamtverband der dt. Textil- u. Modeindustrie 2006; RWI 2010). This development points to a change within the TIS that promise an improvement of the economic situation (cf. RWI 2010: 260). At the beginning of the 21st century “[sind] [v]or allem Entwicklungen textiler Materialien mit zusätzlichen Funktionen oder für gänzlich neue Anwendungsbereiche sowie eine überzeugende Produktgestaltung […] wichtige Faktoren zu Festigung und zum Ausbau der Marktposition von Textilunternehmen.“[36] (Konrad 2001: 389)

35 Many experts from the textile industry likewise use the term ‘high-technology textiles’.

36 Especially developments of textile materials with additional functions or for entirely new fields of applications and product design are decisive factors for consolidation and expansion of the textile firms’ market position (translated by author).

I. Schwinge, *The Paradox of Knowledge-Intensive Entrepreneurship in Low-Tech Industries*,
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The new growing trend cannot be clearly derived from common sectoral statistics on innovation. The sectoral innovation intensity measured in share of expenditures on innovation in value added by the Mannheim Innovation Panel (MIP) indicates some slight dynamics for the TIS. The innovation intensity increased from 1.1% (2000) to 3.1% (2006) in the textile, apparel and leather industry (TAL) (ZEW 2008). The common R&D indicator discloses a weaker increase. The share of R&D expenditure in value added increased slightly from 1.2% (2000) to 1.6% (2006) in manufacture of textiles and textile products (Eurostat). Compared to this, the average of manufacturing industries amounted 8.6% (2000) and increased up to 10% by 2006. The figures for the single textile industry ranged between 1.7% (2000) and 2% in 2006 in the medium-low-tech classification, while the apparel industry remained in the low-tech category with 0.4% share of R&D expenditure in valued added in 2000 that increased to 0.8% in 2006. The figures point to differing innovation activities in the TIS, and they point out that the new technical growth opportunity had not been seized by a broad majority as a general trend at that time. Given the highly segmented supply chain (von Tunzelmann/Acha 2005: 425), this explanation seems plausible.

In the following sections, the German TIS (broadly including the textile and apparel industry[37]) will be determined in more detail for the period between 2000 and 2006. According to Malerba's concept of sectoral innovation systems (cf. Chapter 2.1), first the knowledge dimension of the textile industry will be investigated with recourse to specific knowledge sources, dynamics of the sectoral knowledge base and concrete technological opportunities (Chapter 4.1). The next section deals with the actor dimension, asking for relevant actors, e.g. entrepreneurs, who contribute to innovation with their established competences, practices and interactions with other actors (Chapter 4.2). Finally, the section on the institutional dimension of the TIS (Chapter 4.3) focuses on industry-specific and entrepreneurship enhancing institutions and their influence on structuring interactions and innovation practices. The concluding section (Chapter 4.4) sums up the results of these dimensions. Moreover, it aims at deriving technological, market and institutional opportunities from these analyses to determine the system's entrepreneurial orientation. Finally, it concludes with open questions left for the case study analysis.

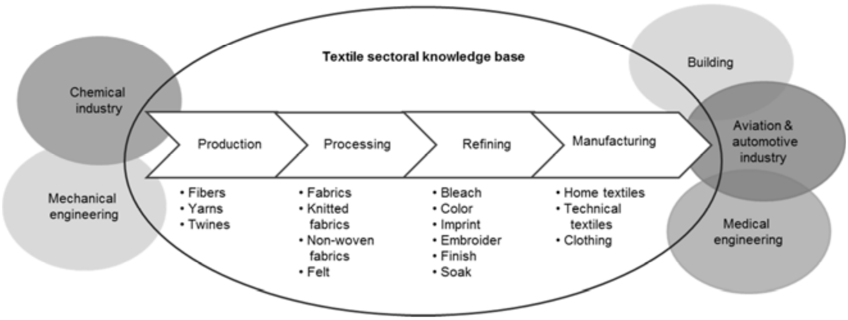
4.1 The knowledge dimension

The analysis of the knowledge dimension reveals a complex, matured knowledge base of the textile industry with several knowledge domains. Nonetheless, dynamics and technical opportunities for new technical applications and markets could be identified. The *knowledge domains* of the textile industry can be roughly divided according to their sub-sectors of home textiles, clothing and technical textiles. Many pro-

[37] Some studies, like the Branchenreport of ZEW (2008; 2011), additionally include the leather industry.

cessing steps across the textile supply chain like fiber processing or textile refinement are based on chemical knowledge. The chemical industry and mechanical engineering for textile machines are important knowledge domains from neighboring sectoral knowledge bases (cf. Figure 07). Many technologies applied in the textile industry, such as chemical process technologies, dye chemistry or measurement and control technologies (cf. Zollinger in Rouette 2006: 11), developed in those supplying industries. Altogether, since industrialization the textile industry has developed various, established technologies in the main domains apparel/clothing, home textiles and technical textiles.

Fig. 07 Textile knowledge base and neighboring sectoral knowledge bases



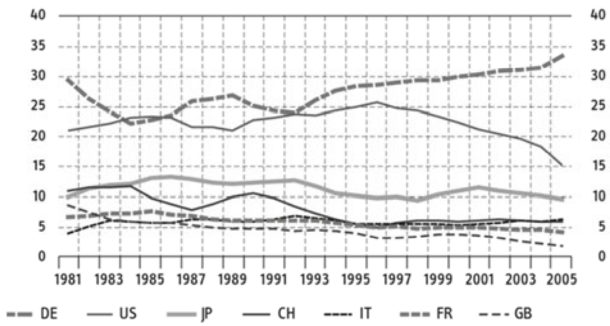
Source: Own illustration based on RWI (2010) and Begemann (2003).

Compared to the domains of home textiles and clothing, the field of technical textiles revealed to be most dynamic in new developments. It offered *innovation opportunities* to new markets but also to the other two fields (Konrad 2001: 389). New technologies extended the fields of application of textile material and enabled the development of new functional textiles (Konrad 2001: 390). 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 sterilization became the leading domains of innovation at this time (Begemann 2003: 262 et seq.; Konrad 2001: 389). All these fields offered product innovations with increasing value to customers (Begemann ibid.). The high cumulativeness of this new knowledge enabled the development of innovative secondary and end-products. Newly developed textile materials, for instance, offered various, compatible and flexible features for diverse applications in several fields of products (Meyer-Storck 2006).

The conditions of this knowledge development and application deviated from established practices. Innovation processes of technical textiles differ from textile products close to the end-user (Meyer-Storck 2006: 42). Innovation activity for these commodities usually aims at visual and haptic changes with low innovation gravity and short development cycles (ibid.). Contrarily, innovation processes of technical textiles are primarily characterized by functionality and deeper development efforts (ibid.). Accordingly, research in this field has to be systematically differentiated from the traditional textile development activity (ibid.). In addition, new textile materials are widely used as a component in combination with other materials or elements in so-called new composite materials. The resulting interactions are complex and their optimization is time-consuming (Meyer-Storck 2006: 50). Finally, users hardly note such innovations in the component segments of end-products. Nevertheless, these innovations are characterized by creative destruction because of their substitution or extension in new fields of application (RWI 2010: 240).

Since the beginning of the 1990s, the change in knowledge creation can be additionally assessed in the rising number of patent applications at the European Patent Office (EPO) (cf. Figure 08). Since 2000, more than 30% of the registered patents came from Germany. However, the patent applications cannot be clearly allocated to companies from the textile industry. Companies from supplying industries such as chemistry or mechanical engineering or research institutes could be applicants of these patents, as well. In this case, the textile firms’ accessibility to this knowledge is not clear yet. Rising patent activities alone do not say anything about the commercial exploitation of this new knowledge. Rather, its diffusion must be assumed restricted.

Fig. 08 Patent applications in the technological field of textiles at EPO

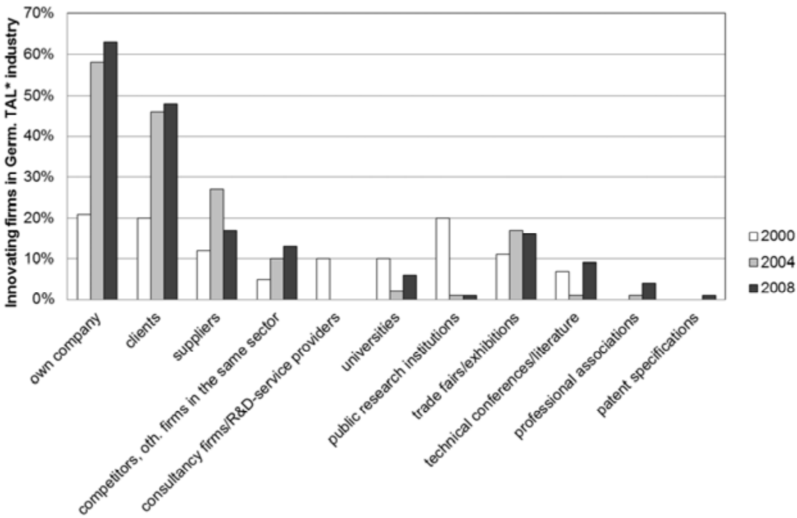


Source: RWI (2010: 262).

Altogether, the development in technical textiles reveals an opportunity for entrepreneurial experimentation in terms of exploring a variety of new technologies and materials in different types of application (cf. Bergek et al. 2005) as deviating KIE activity. But the access, distribution and diffusion within the TIS remain to be answered.

Generally, new knowledge necessary for the exploitation of these opportunities was distributed among other, high-tech sectoral knowledge bases like biotechnology, medical engineering, electronics or micro system engineering (cf. Figure 07). To consider the distribution of the new knowledge relevant for innovation and its diffusion, information sources of innovative textile companies from the Mannheim Innovation Panel (MIP) are used (cf. Figure 09). During the enquiry periods in 2000, 2004 and 2008, the importance of information from the own company and customers mostly increased. The four most important *sources* of information remained in their order in these period: First the own company, followed by customers, while suppliers and fairs were almost ranked equally. These results differ from the common assumption on low-tech firms as supplier-dominated firms (cf. Heidenreich 2009 in Chapter 1.1). Instead of sourcing knowledge from suppliers, innovative textile companies rated the own firm as the most important source. The second important source is again not the group of suppliers but customers. This rating is comprehensible, considering the emergence of new industrial customer markets from which the textile firms needed to source information. Distinct from the common assumption of supplier-dominated low-tech firms (e.g. Heidenreich 2009), suppliers were considerably less often indicated as a relevant source of information (cf. Figure 09).

Fig. 09 Importance of information sources



**TAL: Textile, apparel and leather*
Source: Own processed data based on MIP data (ZEW).

Against the background of new knowledge creation for technical textiles, a rising significance of research institutes and universities could have been expected, but the empirical meaning of these sources remains low from the perspective of companies (cf. Figure 09). Moreover, the innovative firms rated patents as low important source of information. This argues against the diffusion of new, patented knowledge into the commonly shared textile knowledge base. Alternative ways of knowledge creation have already been outlined for low-tech industries and firms (cf. Kirner et al. 2009b). These are, however, more difficult to assess from statistics at the industry level. The actor dimension promises more information of the innovation system's knowledge diffusion.

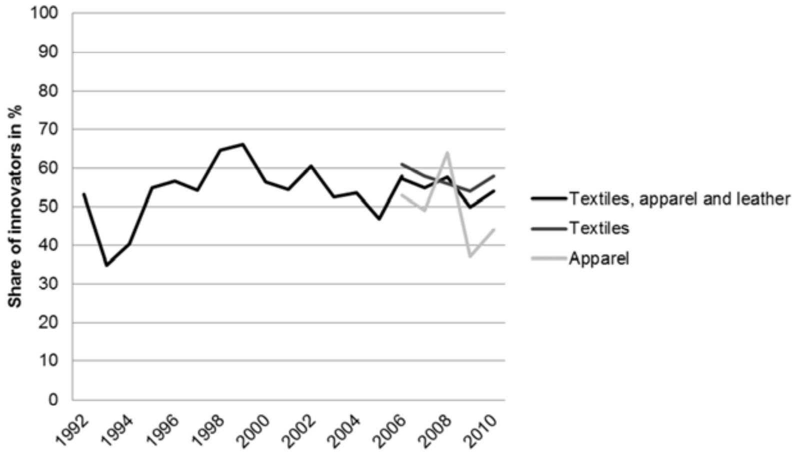
Overall, the analysis of the knowledge dimension discloses various technological opportunities in technical and functional textiles particularly connected with distributed knowledge bases from new customer markets. As mentioned before, this change in the sectoral knowledge base and innovation activity could have offered new actors opportunities "to complement the existing knowledge base" (Pitt 2007: 127), which will be investigated in the next dimension of actors. In any case, the exploitation of new customer knowledge bases became necessary for knowledge creation and new knowledge diffusion.

4.2 The actor dimension

Between 2000 and 2006, the textile industry was situated in a shake-out stage, as the number of textile firms was reduced by 43%. The objective of this section is to identify the remaining *actors* involved in innovation activities, knowledge production and technology development. Besides the characterization of the innovators' competences and established practices, another objective is to analyse established systemic interactions with other actors from the TIS.

Different to the identified new technological opportunities, hints for an increasing number of exploiting innovators or new firms could not be found. According to MIP data, the share of *innovators* among textile and apparel/clothing firms ranged around 50 and 65% between 1996 and 2006 without showing any clear positive trend (cf. Figure 10). Since a peak around the millennium, the trend has been slightly decreasing. In addition, from 2006 on, Figure 10 shows separately measured innovators, distinguishing between textile and apparel industry (MIP). Even though these measures are not available for the previous years, the revealing differences likely existed before and point to innovators from specific fields of the textile industry. This is confirmed by literature on functional textiles. Textile firms performing in new technical textiles, especially the producers of intelligent fibers, are mentioned as the main innovators and winners in the development of technical textiles (Knecht 2003b: 14). In particular, supplying textile firms are challenged or requested to react proactively on the development of their customers (Konrad 2001: 391). Experts recommend these suppliers from the beginning of the textile supply chain to take over the role of a partner through self-initiated developments and the solution of problems (ibid.; also Reinhold 2003). Altogether, these aspects argue for a specific group of innovators within the TIS. Unfortunately, more differentiated measures on the innovators' position or corporate structure could not be assessed from panel and survey data.

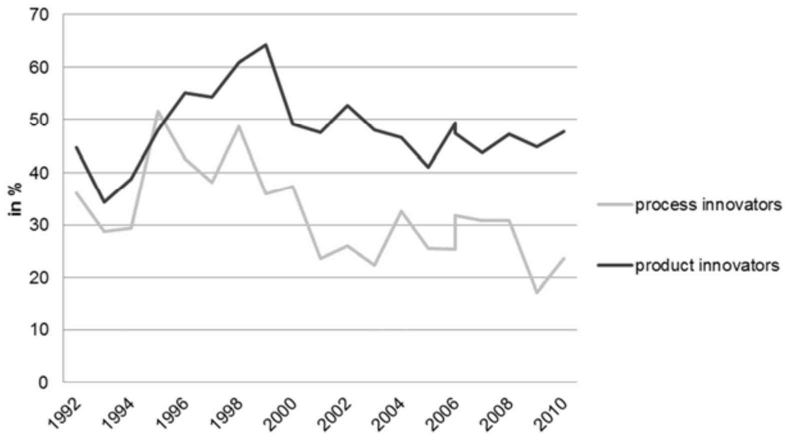
Fig. 10 Innovators in the German textile industry



Source: Own processed data based on MIP (ZEW).

In general, the majority of innovators from the textile apparel and leather (TAL) industry carried out more product innovations than process innovations between 1996 and 2006 (cf. Figure 11). Again, this is a specific characteristic of textile innovators that differs from the common assumption on low-tech firms as mainly process innovators (cf. Heidenreich 2009; Kirner et al. 2009a). Besides, it discloses the innovators' *competences* in product development.

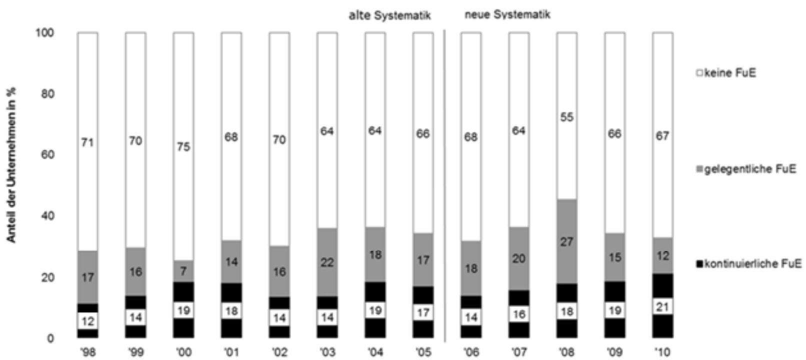
Fig. 11 Process and product innovators (German TAL industry)



Source: Own processed data based on MIP (ZEW).

The innovators' dominant competences are generally hard to qualify in statistics. Several sources prove generally low R&D activities, implying low competences in this respect. The ZEW data shows slightly increasing numbers of textile firms with occasional and continuous R&D compared to a distinct majority of firms without any R&D activities (cf. Figure 12).

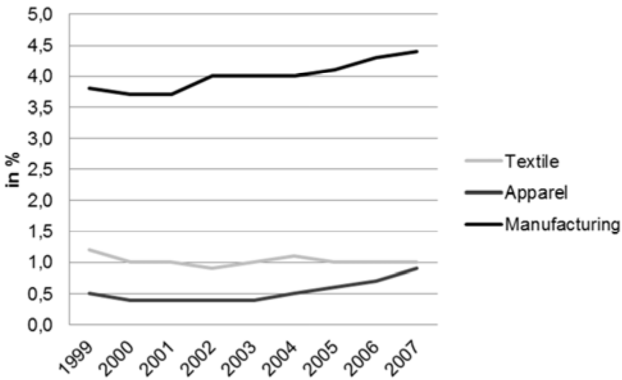
Fig. 12 R&D activities in the German TAL industry (1998-2010)



Source: ZEW Branchenreport (2011: 4).

Likewise, no growing tendency can be identified at the proportion of highly skilled employees with regard to the exploration of the new technological opportunities. The share of R&D employment in the number of persons employed for the textile industry constantly amounted around 1% between 1999 and 2007 (Eurostat, cf. Figure 13). Again, slight differences between the single textile industry with figures around 1% and the apparel industry with lower figures around 0.5% can be observed. Compared to this, the average of manufacturing industry ranged around 4% in this period (ibid.).

Fig. 13 R&D employment in Germany (no. of persons employed)

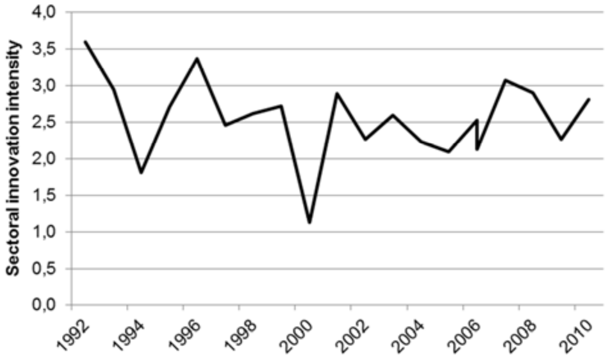


Source: Own processed data based on Eurostat.

Frietsch and Gehrke (2005) offer a more detailed view on the educational attainment for data from 2003. Accordingly, in the occupational category of textile, apparel and leather industry, 21.7% had no qualification, 66.7% had training, 10.4% were master craftsmen and only 1.1% academics in 2003 (ibid. 2005: 11). The distribution among low, medium and high educational attainments in Germany generally performs in favour of higher education, compared to other European countries (cf. ibid. 28). The high proportion of trained workforce and the small proportion of academics in the textile industry correspond with the attainment structure of low-tech industries in Germany (Hirsch-Kreinsen 2005). Moreover, it supports the firms' low competences in formal R&D. Unfortunately more detailed information about innovators' workforce structure could not be assessed from the innovation surveys and panels.

The established *innovation practices* allow for more implications on the innovators' competences. Starting with the sectoral innovation intensity of the MIP, the share of expenditures on innovation in value added is measured. Figure 14 enables a long-term view from 1996 to 2006, showing that the innovation intensity ranged between 3.4% (1996) and 1.1% (2000). Since the bottom low in 2000, the intensity increased again to 3.1% in 2006 but still misses a clear positive trend, as it has not reached the rate of 1996 again. Compared to this, the innovation intensity of the electronic industry amounted 8.3% and the average of the manufacturing industries amounted 4.9% in 2006 (ZEW 2008: 1).

Fig. 14 Sectoral innovation intensity of German TAL Industry

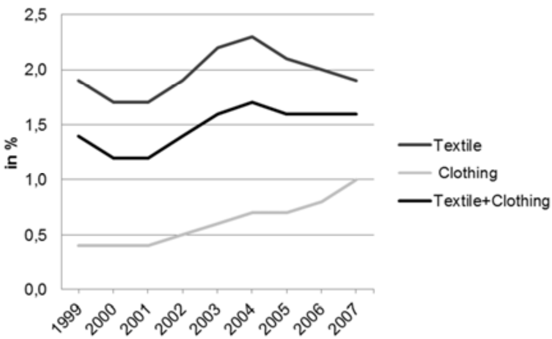


Source: Own processed data based on MIP (ZEW).

Separated measures for textile and apparel accessible from 2006 on again reveal a difference with a higher innovation intensity of the textile industry. This difference can also be assumed for the period before 2006. This difference is supported by figures on R&D expenditures from Eurostat data (cf. Figure 15). The share of R&D expenditure in value added in the single textile industry ranged around 2% between 2000 and 2006 (ibid.). Compared to this, the apparel industry raised its low R&D expenditures of value added from 0.5 to 1% in this period. Following the OECD classification, the textile industry is classified as medium-low-tech, while the apparel industry has to be classified in the low-tech category. These figures argue for higher innovation activity on the side of supplying textile firms than on the side of clothing manufacturers in the TIS. However, mostly innovation surveys and panels do not differentiate consequently between these sub-sectors. This also holds true for the rate of the firms' R&D activity (cf. Figure 12). While the majority of textile firms (more than 60%) constantly did not carry out any research and development activity between 2000 and 2006, the number of firms with occasional R&D and continuous R&D activities increased slightly (ZEW 2011). A rising number of firms carrying out significantly more R&D in the course of the identified opportunities cannot be assessed from this data – be it occasional or continuous.

The textile firms' low own R&D activity suggests that the companies collaborate with other firms or organization with R&D activity in order to source this knowledge instead. One indicator of the MIP (Figure 16) asks for the sources for the development of product innovations that were detected as the major type of innovation of textile innovators before (cf. Figure 11). Most of the firms indicated that development of product innovations was mainly done internally according to the investigation between 2000 and 2008 (MIP). The fewest firms let their products mainly be developed by third parties, whereas the development together with a third party has considerably increased (Figure 16). Figure 16 shows that common product development with other organizations still remained an exception for innovators in the TIS at the beginning of the millennium. On the other hand, it could imply that product innovations are commonly not based on new R&D activity but on the firms' internal design competences.

Fig. 15 R&D expenditures in German textile industry

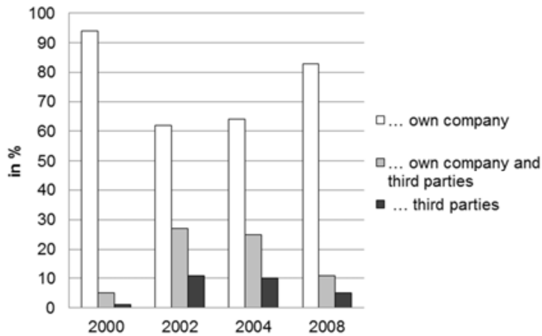


Source: Own processed data based on Eurostat.

Considering the protection practices, most firms prefer the advantage of a temporal headstart, secrecy and trademarks (MIP; ZEW 2012). Registered design increased while patents are less important in this respect (ibid.). In general, the application of different mechanisms has increased from 2000 to 2007 (ibid.). This can be deduced from experiences with violation of intellectual property rights in the course of market internationalization (cf. Gesamtverband der dt. Textil- u. Modeindustrie 2004; 2006). This might also explain the low rate in collaboration owing to the companies' fear of damage of the firm-specific knowledge base.

Altogether, the different sources grasped to describe established innovation practices and capabilities lead to the conclusion that the majority of textile innovators mainly carried out incremental innovations with low innovation gravity, as described by Meyer-Storck (2006: 42). The assessed product innovations are closer to the end-user and can be developed internally in short development cycles (ibid.). Against this, innovation processes of new technical or functional textiles require deeper development efforts and complex interactions with new technical fields (ibid.), which are hard to imagine based on the firms' weak R&D activity and collaboration in product development. In addition, the textile research board indicated that textile companies hardly have any idea of research organizations' created knowledge (Forschungskuratorium Textil 1999: 5). This is confirmed by the firm's low rating of universities and other research institutes as source of information (cf. Figure 09).

Fig. 16 Development of product innovation in German TAL industry mainly by



Source: Own processed data based on MIP (ZEW).

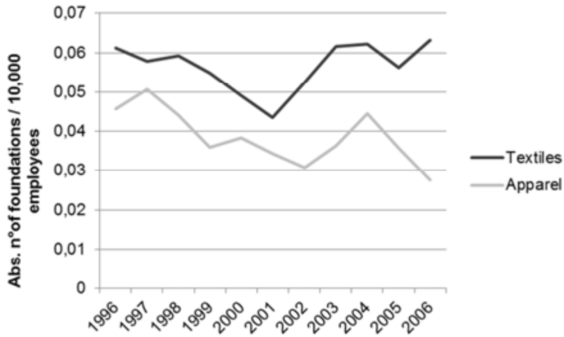
If established textile firms from the innovation panel obviously had problems to sense new technological developments of research organizations, the question remains if any new actors like entrepreneurs can be identified among the innovators in the TIS. The innovation statistics do not allow for identifying the share of *entrepreneurs* among the innovators at the sectoral aggregation level. Between 1997 and 2006, the sectoral founding intensity (absolute foundations per 10,000 employees) by the Mannheim Enterprise Panel (MUP) remained at 0.06 on average for the textile industry and for apparel at 0.04 (cf. Figure 17). Compared to this, the average of main industries in Germany accounted for 46 per 10,000 employees in this time (cf. Figure 18). Besides the industry's very low founding intensity, no increase in spin-offs from research institutes was noticed by the representative of the Forschungskuratorium Textil (textile research board) (expert interview 2010), although entrepreneurship research assumes that in "industries in which government research labs and universities create most of the technology, opportunity exploitation through new firm formations is more prevalent." (Shane 2003: 123).

In place of new start-ups experts from the textile associations[38] point to the form of corporate entrepreneurship. The experts observed for several cycles of the textile

[38] Gesamtverband textil+mode [former Gesamtverband der dt. Textil- u. Modeindustrie] and Forschungskuratorium Textil (2010), Verband der Nordwestdeutschen Textil- und Bekleidungsindustrie and Zitex (2009).

industry's renewal that traditional firms survived by learning to diversify their business or setting up new businesses following emerging market trends. After the new business unit prospered, it is outsourced or substitutes the former main business after a while. However, this form of corporate entrepreneurship is hard to measure in surveys.

Fig. 17 Textile sector-specific founding intensities

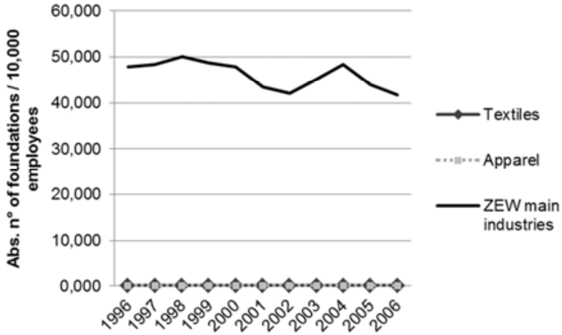


Source: Own processed data based on MUP (ZEW).

Beside the textile firms as the main actors of the TIS (cf. Malerba 2005a: 390), further actors are described in the following before going into prevailing interactions between these actors. While innovators indicated suppliers from neighboring industries such as chemistry or mechanical engineering as not so important sources (cf. Figure 09), new actors from new customer markets can be particularly identified in the literature (Begemann 2003; Meyer-Storck 2006, Knecht 2003a/b). The previous section already described the textile industry's opening to other sectors (cf. Figure 07). The traditional customers from home textiles and the clothing industry customers from the automotive and aerospace industry as well as machinery and plant engineering can be enlisted for the new textile materials. Hence, new purchasing actors emerged in the TIS. However, the articulation of this new demand at business and consumer markets is still assumed weak at the beginning of the millennium due to the fact that the innovative textile components have rather improving or substituting functions in existing end-products (RWI 2010; Knecht 2003b). The role of the new customers as drivers of innovation is hard to estimate from the literature and databases. According to Walter Begemann (2003: 268), 1993-2008 chairman of the Gesamtverband textil+mode, growing rates were registered for markets of technical textiles in the past years. These should also be reached in the established markets of clothing and home textiles. Thus, differences in the meaning of customers or market opportunities can be derived from this.

The same way the textile firms have undergone a concentration process, the federal and technical industry associations of the textile industry were affected. This actor seemed to be less important for the innovation activity of the textile firms. Innovators from the MIP rated them as less important sources of information (cf. Figure 09), although their formally main function is the distribution of the latest results and information of the textile research board.

Fig. 18 Sectoral founding intensities



Source: Own processed data based on MUP (ZEW).

The textile research board has been an established actor for more than 50 years in the TIS. Its central task is to promote the development of 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). A committee consisting of experts from research institutes and textile firms is agreeing on the research agenda. The common 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. According to the AIF, the textile sector received between 2000 and 2006 on average 15 Million Euros per year as one of the biggest proportions of the funds (unpublished data provided by AIF). Promoted projects are those with several actors from science and industry, especially SME, but they basically encompass only the pre-competitive stage. Hence, these network research activities do not necessarily cover entrepreneurial experimentation. In addition, no entrepreneurship-specific innovation programs exist according to the representative of the textile research board (2010).

Different to the majority of innovators (MIP), the research board and central industry association expected from research institutes an important contribution to the development of innovation (Begemann 2003: 268). The research organizations offer several prospective R&D results (Forschungskuratorium Textil 1999: 5) to small and medium-sized textile companies, because those have mainly no own capacities for such R&D activity (Begemann ibid.; Meyer-Storck 2006). Altogether, the scientific research infrastructure in Germany did not undergo such a huge consolidation process as the other actors and seems to be in a good position compared to other countries (interview with textile research board in 2010).

Regardless of the important role of research institutes, the interactions with firms remained weak. In 1999, the textile research board launched a guideline to improve the transparency on the textile research institutes' offers and access by textile firms and to facilitate communication between these actors (Forschungskuratorium Textil 1999: 5). Still, in 2006 the chairman of the German textile research board proclaimed weaknesses in the transfer of research results (Meyer-Storck 2006). Accordingly, medium-sized companies especially face difficulties in finding the right middle course between joint pre-competitive development and a permanent distinction of an own market niche (ibid. 50) which comes close to a form of KIE.

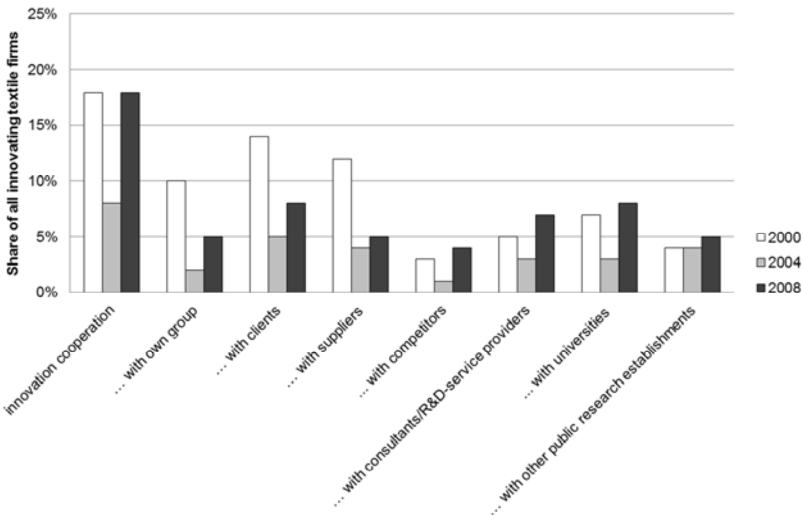
The investigation of *prevailing interactions* in the TIS discloses weaknesses in further interactions of actors. Basically, textile experts stress the necessity of interactions for the complex development and integration of new textile materials and components. Konrad (2001: 392), for instance, emphasizes the willingness to dialogue and exchange as a basic prerequisite for textile firms. Another prerequisite is to hold knowledge about the technologies and interests of potential partners for prospective cooperation (ibid.). Likewise, Reinhold (2003: 215) underlines the new necessary communication of actors along the whole textile supply chain from production to distribution. "Hersteller, Vorlieferanten und Händler müssen sich also gegenseitig über den Mehrwert informieren. Und die Entwickler müssen sich wiederum am Markt informieren, welche Funktion gewünscht wird, welcher Mehrwert ein Verkaufsargument am POS [Point of Sales] ist."[39] (Ibid. 220 et seq.) Especially in traditional fields of clothing, new technical functions are often complex and unfamiliar to salespersons. Therefore, Reinhold stresses the necessity of specific marketing for such innovations. But "nicht immer sieht der Hersteller in der Vorstufe seine Produkte am POS gut vermarktet."[40] (Ibid. 218)

[39] Hence, producers, pre-suppliers and traders have to inform each other about the added value. And the developers, in turn, have to inform themselves at the market about which functions are requested, which value added is a sales argument at the POS [point of sales] (translated by author).

[40] The manufacturer from the prestage does not always see his or her products well merchandised at the POS (translated by author).

The challenges that the new technological opportunities bring along stress the relevance of cooperation along the whole value chain (cf. Begemann 2003; Konrad 2001; Knecht 2003b; Reinhold 2003). Nonetheless, several empirical sources support the generally low cooperation performance in the textile sector on the European level (Heidenreich 2009; Hollanders/Arundel 2005) as well as on the national level (MIP). Figure 19 describes the German firms' behaviour in cooperation of innovations with different actors. It is notable that cooperating behaviour differs from the innovators' rating of important sources of information (cf. Figure 09). The high and increased rating of customers and suppliers during 2000, 2004 and 2008 does not correspond with the overall low and decreasing cooperating behaviour in those periods. Indeed, the responding firms again indicated slightly more often cooperation with customers than with suppliers (2000), but in 2004 and 2008 the decreased rate of cooperation was almost equal for customers and suppliers. The collaboration of innovators with universities and research institutes was also lower rated, but performing better than in the rating of important innovation sources. In addition, a stronger growth in collaboration with research organizations can be observed over the time that does not correspond with the development in the rated importance of universities and publicly funded research organizations (cf. Figure 19).

Fig. 19 Innovation related cooperation in German TAL industry



Source: Own processed data based on MIP (ZEW).

An explanation for the difference between relevant information sources and cooperation behaviour for innovation might be a negative effect of previous cooperation. However, this cannot be proven at this point.

Coming to the last important interaction in innovation systems, financing is considered. The MIP data for publicly funded innovators fluctuated between 8 and 25% during 2000 and 2008 (ZEW 2012). It reveals an increasing use of public funds by innovators, whereas the figures say nothing about the amount or importance of this financing. Following the chairman of the Gesamtverband textil+mode, Walter Begemann (1993-2008), the fluctuation can be explained by funding shortfalls in several public programs at that time (Begemann 2004: 22). In fact, the textile industry received the main share of AIF funding between 2000 and 2006, but the state budget of AIF was frozen in 2004, which did not happen for the first time (ibid.). Likewise, the Federal Ministry of Economics and Labour closed the innovation program for SME (ProInno) for applications in 2003. At the same time, the Federal Ministry of Education and Research decreased the funding of technical projects (ibid.). "Insgesamt geht Industrie wie Forschungseinrichtungen damit die Planungssicherheit verloren. Da die mit dem Forschungskuratorium kooperierenden Institute überwiegend als eingetragenen Vereine organisiert sind, können in den Haushalten keine Rückstellungen für ausbleibende Fördermittelzahlungen erfolgen […], sodass als Konsequenz zum Teil das Forschungspersonal abgebaut werden muss."[41] (Ibid.) The chairman additionally criticizes that 6th framework program of the European Union is not appropriate for the many SME of the textile industry.

Furthermore, a project report on "opportunities and challenges for financing innovation in the European textile and clothing industry" (NetFinTex 2007) discloses some more information on interactions. It investigated firms and financing experts from Germany among other European countries. The study assesses a considerable gap between the textile entrepreneurial community and investors. Reasons for this are seen in an underestimation of the growing potential in textiles by both groups. Additionally, a negative image of the textile industry is identified concerning scarce familiarity with financial instruments on 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 is assessed (ibid.). The report concludes with characterizing the textile industry by a fragmented supply chain and capital market (ibid. 38).

Summing up the actors and interactions of the TIS: First, a focus on innovators from the beginning of the textile supply chain can be assessed. Second, the innovators'

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41 All in all, the industry and research institutes lose planning security for this reason. Because the institutes cooperating with the textile research board are mainly organized as registered associations, they cannot build reserve assets for missing subsidy payments [...] so that in consequence partly research personal has to be abolished (translated by author).

competences are harder to qualify. Different statistical sources cannot identify increasing research activity at the firms in order to exploit the complex technological opportunities. Instead, most innovations are product innovations and developed inside the firm without R&D. Textile research institutes are an important creator of new knowledge for distinct textile material and applications. Following Pitt (2007: 127), interactions with these knowledge creators become especially important for textile firms but require their ability to effectively interact with these actors. The analysis of the innovators' important information sources and collaboration activity reveals, however, considerable gaps and weaknesses in these interactions. In the next section, institutions of the textile innovations system are investigated that structure those interactions.

4.3 The institutional dimension

The shrinking process of the German textile industry during the last decades led to many firm exits and relocations to other countries. This in turn caused uncertainty in many business and cooperation relations among the resting firms and non-commercial actors. Moreover, the industry dealt with a negative "old-fashioned image" (EPPA/CEPS 2002: 24; also Robertson et al. 2009: 441) that is also underlined by the NetFinTex report (2007) and the chairman of the textile research board (expert interview in 2010). That most of the new textile developments were supplier products, thus components which are not visible at the user market, made it additionally more difficult to change the image of bad prospects outside the industry.

The negative image did not only affect customers and potential development partners, it also influenced the recruitment of young professionals. Given the new technologies and applications in new domains, it actually had to be expected that the educational system adapt to these developments. In its place, a study of the pan-European consultancy EPPA and the Centre of European Policy Studies (EPPA/CEPS 2002: 26) assesses a decline in the number of both students and higher textile educational institutions. The thinned out labor market (cf. Eurostat) additionally reinforced these negative prospects and unappealing image to junior employees. Likewise, the EPPA/CEPS study (ibid. 6) identifies a serious recruitment situation. In particular, recently trained and highly skilled professionals, also from other fields, were necessary for established firms to understand emerging technologies and the technologies of potential partners from new customer markets (cf. Konrad 2001: 392). But these were hard to attract in such a situation.

Actors like textile firms, research organizations or industry associations not only had to overcome this restricting image in order to convince young professionals, investors (NetFinTex 2007) and new customers, particularly the textile firms themselves had to overcome their established belief in cost reduction and process optimization that had consolidated itself from their survival strategies during the last, shrinking years. It is hard to prove but plausible that those beliefs and images had a restricting effect on the direction of knowledge creation, entrepreneurial experimentation and innovation development in the TIS at that time.

Moreover, the textile firms' attitudes towards cooperation are described as "possible add-ons that can be used in times of exceptional need" (EPPA/CEPS 2002: 19) but were no institutionalized practice at that time. Accordingly, "a change in existing mentality" (ibid.) of the firms is requested in the EPPA/CEPS study otherwise a serious "Standortnachteil" [location disadvantage] (ibid.) is assumed for the German textile industry. Another *industry-specific institution* responsible for missing cooperative arrangements is probably the vertical disintegration along various stages of production and organizations (cf. von Tunzelmann/Acha 2005: 426). A technical handbook (Rouette 2006: 23) describes the typical structure of the textile value chain as follows:

> *Von wenigen Ausnahmen (z.B. Textilveredlung) abgesehen, verläuft der Warenfluss im textilen Produktionsprozess in eine Richtung, d.h., jede Stufe beliefert i.d.R. nur nachgelagerte Stufen und erhält i.d.R. nur Waren von vorgelagerten Märkten. Diese fast ausschließlich einseitige Wirkungsrichtung der textilwirtschaftlichen Lieferbeziehungen liegt dem häufig verwendeten Begriff ‚Textil-Pipeline' zugrunde.*[42]

The industry's vertical division of labor structures the knowledge flow and interactions among actors. Consequently, the firms' performance and knowledge is limited to the demand from the next purchaser or customer downstream the supply chain (cf. ibid. 21). Exiting suppliers and customers as well as the cutting of prices that was passed along the supply chain from retail up to the pre-suppliers hampered the diffusion of new knowledge and cooperative development along the supply chain. This industry-specific structure became even more problematic, as the driving innovators for new functional and technical textiles (fiber and textile producers) came from the prestage of the textile value chain. Over the past decades, specialized firm-specific knowledge production and adverse relations between established actors had evolved that were counteracting the requirements of the emerging technical innovations. As mentioned before, those required especially the exchange between processors for the applicability of new textiles in final products along the several steps of processing (Meyer-Storck 2006: 49).

Time and costs especially required for testing possible interactions with other components or materials and their optimization considerably extended the firms' usual investments on innovation (ibid. et seq.). According to the chairman of the textile research board, at that time the mainly medium-sized structured textile firms in Germa-

[42] Apart from a few exceptions (e.g. textile refinement), the flow of goods proceeds in one direction in the textile manufacturing process, i.e. each stage as a rule usually supplies only stages downstream and receives only goods from upstream markets. This almost exclusively one-way effective direction of the supply chain is based on the widely used term of the 'textile pipeline' (translated by author).

ny were overcharged by these investments of development and their higher risks (ibid.). The more important inter-organizational interactions had become.

Experts consider publicly funded research a solution. Likewise, the EPPA/CEPS study (2002: 27), for instance, indicates it as “a catalyst for company specific research” (cf. also Meyer-Storck 2006: 52). At the same time, the study evaluates that the majority of these SME were not open and aware enough for this new knowledge (EPPA/CEPS ibid.), as it is confirmed by MIP data. But also on the side of the textile research institutes, the EPPA/CEPS study (ibid.) recommends to strengthen cooperation with research institutes from other emerging market fields such as construction etc.. As outlined by Meyer-Storck (2006: 42), the emerging technical textiles deserve research that systematically differs from traditional development activity. Hence, also the research institutes had to adapt to the technical changes and challenges of new technical textiles.

Coming back to the textile firms, sourcing advices from scientific organizations and cooperation with them was not the only challenge for them. The emerging functional and technical textiles were complex in their need of explanation, while their value was usually not visible to users (Knecht 2003b: 14). Therefore, the establishment of their acceptance at users and consumers was difficult and required a real added benefit (ibid. 15). This in turn required further new forms of cooperation that also involved the retail and partners from new sales markets like the health care sector, for instance (ibid.; also Begemann 2003: 267 et seq.).

Altogether, different sources prove an institutionalized fragmentation (EPPA/CEPS 2002: 27; NetFinTex 2007: 38; MIP 2000, 2004, 2008) that restrictively structured the interactions of actors in the TIS around 2000. The textile industry-specific institutions had likely not reacted towards emerging technical changes. At the same time, a few initiatives can be identified supporting innovation. As assessed for the actor dimension on innovators, few actors of the textile industry early sensed the new opportunities. The general conditions of the industry like market liberalization, price competition and catching up of emerging markets had led to increasing technology orientation in the German textile industry in order to gain a unique selling position.

In addition, new technology-intensive customer markets, like the automotive or aerospace industry, contributed to a market pull (RWI 2010) that influenced the direction of knowledge development and innovation activities. In this respect, Konrad (2001: 391 et seq.), for instance, referred to the increasing importance of inter-sectoral innovation cooperation across technologies for the textile firms’ innovation capacity. Additionally, the increased importance of customers (cf. MIP) supports the argument of market pull, but concrete measures from the beginning of the millennium could not be found in the literature.

Likewise, the textile research board’s influence on the direction of new knowledge creation and development is hard to evaluate. The evaluation by the RWI (2010) refers to a later period. Following sociological technology studies, joint industrial research, as promoted by the board, is considered an institution to control the destructive power of entrepreneurial innovation (Rammert 2000: 167). Accordingly, it has to be assumed that this institution was initially not oriented towards technical changes with a character of creative destruction (RWI 2010) and the promotion of entrepreneurial experimentation. It is questionable if the institutionalized joint industrial research could have changed so fast against persisting interests of board members from industry and science.

Beside this institution, a few occasional, new institutional initiatives could be assessed from literature review that already started in the end of the 1990s. One of them particularly promotes collaboration between the textile and apparel industry (Baldin-Erbe 2001). The “Dialog Textil-Bekleidung” exists since 1982 (cf. dialog-dbt.de) and annually invites companies from both sub-industries as well as machine manufacturers to exchange experiences and give concrete recommendations on processing of new materials (ibid. 79). The technological changes affected the initiative in so far that no standardized operating numbers and tests existed for the processing of the new technical materials. In response to this change, Baldin-Erbe (ibid. 85) reports on the establishment of a database: “Bis es hier einen einheitlichen Lösungsansatz für die Industrie gibt, ist der erste Schritt, Vergangenheitsdaten festzuhalten […]. Hierbei ist es wichtig, die Erfahrungswerte in Hinblick auf Vernähbarkeit, wie Maschineneinstellungen, Nadel- und Nähfadentyp usw. […] festzuhalten.“[43] This form of institutional work illustrates on the one hand an era of ferment of new textile materials that still missed dominant processing and standardized parameters and had not been commonly shared at the textile and clothing knowledge base. On the other hand, the initiative seeks to jointly reduce these uncertainties and diffuse new knowledge and experiences among the actors.

In 1996, another initiative on the prospects of the textile industry was established in North Rhine-Westphalia. The federal state funded initiative zitex is also oriented towards improved communication and cooperation along the textile chain, an increasing transfer of technology from R&D, the improvement of companies’ innovation capacity. Moreover, it supports internationalization and export activities, learning and training of firms and employees, and a strengthened exchange of experiences of all partners from the industry (Forschungskuratorium Textil 1999: 7). In 1997, the initiative BAIKA on collaborative innovation in the automotive supplying industry was launched in Bavaria. It offers textile companies the opportunity to participate in different task forces with their interests in technology and cooperation in different task forces (Konrad 2001: 394). In particular, firms of the textile industry should be actively involved in networks from other industries like medical engineering and further platforms of emerging cross-disciplinary technologies and new materials (ibid.). In the

[43] Until a coherent problem solving approach exists for the industry, the first step is to record data from the past […] [like] empirical values with regard to the sewability, like machine settings, type of needle and sewing thread etc. […] (translated by author).

following years, fairs like the Internationale Automobilbau Ausstellung (IAA) in 1999 or the Automobilbau in 2000 started to promote the involvement of scientific institutes and nationwide forums for cooperation (ibid.). However, these new initiatives did not come specifically from actors of the TIS, and they exclusively addressed suppliers of technical textiles and fabrics.

Against this background, the chairman of the textile research board draws the attention to the traditional domains of home textiles and clothing (Begemann 2003: 268). The rates of growth need to be expanded to these fields as well (ibid.). First prototypes of so-called smart clothes or smart textiles with new technical functions were presented, for instance, at the Avantex in 2000 and 2002 (Knecht 2003b: 14). However, Knecht alerts that those fairs can only be a start. The textile companies themselves are requested to become active also in initiating discourses with new actors (ibid. 15). Nevertheless she calls on more platforms of communication to promote such discourses (ibid.).

In sum, the development of so-called high technology textiles presupposes cooperation along the whole textile supply chain up to the involvement of consumers as well as the interdisciplinary collaboration with companies and research institutes from other industries (Begemann 2003: 267 et seq.). Some experts disclose first responding developments in this direction apart from the institutionalized fragmentation among actors of the TIS. Meanwhile, more innovations arose from textile surfaces and not only from fibers anymore (Reinhold 2003: 217). Reinhold additionally assesses that innovative materials were increasingly developed in collaboration at the textile prestage (ibid.).

To evaluate a specific institutionalized form of knowledge development within the TIS remains difficult from literature review and statistics. Sources for knowledge development can be basically R&D, learning from new applications, imitation or entrepreneurial experimentation (cf. Bergek et al. 2005: 15). The presented new institutional initiatives especially refer to joint R&D or the transfer of scientific R&D into a firms' application. Further initiatives, like the Dialog Textil-Bekleidung, address organizational learning from, and imitation of, other firms. Additionally, the described practice of corporate entrepreneurship by experts from the North Rhine-Westphalian textile association and zitex initiative (expert interview in 2009) underline the textile firms' imitating behavior. Accordingly, many textile companies typically await trends and pioneering activity before they adapt their product range to them, establish new business units that spin off or substitute the main business after a while.

This practice of corporate entrepreneurship might also be a reason why traditional *entrepreneurship enhancing institutions* promoting start-ups cannot be assessed within the TIS. Indeed, some institutions like the textile research board mobilize resources for the firms' innovation activity, but foremost they fund research activity of institutes on a pre-competitive stage or the exchange among established firms later on. Beside hesitating and risk-averse incumbents, the absolutely small number of start-ups (cf. MUP) argues for no specific institutions that could encourage researchers for spin-offs from research institutes. Conversely, the well-placed infrastructure of textile research institutes and promotion of joint industrial research and corporate entrepreneurship practice likely had the opposite effect on researchers: either they stayed in science or they transferred to existing firms. The proportion of employees in R&D in total numbers of employees does not confirm a positive tendency towards the second option (cf. Eurostat, Figure 13).

Entrepreneurial experimentation as a form of knowledge development remains difficult to evaluate for the TIS. For now, corporate entrepreneurship can be assessed as a specific form of entrepreneurial practice, but it was described in context of imitation that does not comply with deviating KIE activity. A more precise determination of corporate entrepreneurship practices is hard to evaluate on the basis of broad quantitative surveys.

In conclusion; the presented industry-specific institutions do not seem to be oriented towards technical changes and new requirements for the investigated time. New institutional initiatives indeed focus on strengthening interactions and collaboration with new actors, but most of them are limited to technical fields or specific regions. In particular, enabling institutions could not be assessed to overcome the overall fragmentation among the textile supply chain and weaknesses of established firms. It can be assumed from the initiatives on cooperation that these are mostly taken on by firms that already have this collaborative capability. Likewise, indications for industry-specific institutions that promote the firms' capabilities of entrepreneurial experimentation cannot be found.

4.4 Results from the analysis of the German TIS

The results from the different dimensions of the TIS help to determine the conditions for KIE and its deviation from established innovation practices in the period between 2000 and 2006. Moreover, the entrepreneurial propensity of the TIS is evaluated with respect to entrepreneurial opportunities and entrepreneurial activity among the activities of the innovation system (cf. Radosevic et al. 2011: 16/22).

Summing up, the results from the knowledge dimension: The TIS has proven in its evolution that its knowledge base evolved through new technologies mostly from the chemical and engineering industries (cf. von Tunzelmann/Acha 2005: 425; Rouette 2006; Konrad 2001). Since the 1990s, distinct knowledge creation for new technical textiles can be identified (Meyer-Storck 2006: 42). The new dynamics in the textile knowledge base are shown, for instance, by increasing patent applications (cf. RWI 2010). The resulting innovations from this new knowledge are characterized by creative destruction (ibid.) that points to opportunities for deviating KIE activity from the established knowledge creation practices with lower innovation gravity.

The analysis of the actor dimension indicates that actors developing the new distinct knowledge are mainly institutes of industrial research (Meyer-Storck 2006, Begemann 2003), whereas the majority of textile innovating firms had not changed their knowledge and innovation development activity (MIP). They mainly carried out internal product innovations through broadening product variations that imply competences in routinized, incremental innovation practices without R&D (cf. MIP, ZEW 2008; 2012, Eurostat). In addition, most of the textile firms missed the interest and ability to inform about new developments and results from research organizations (EPPA/CEPS 2002), which can be partly traced back to a weak proportion of R&D personnel and R&D capacities at the mainly small and medium-sized textile companies (cf. Eurostat; Meyer-Storck 2006). This reason also contributes to the weak established collaboration practices of firms. Altogether, the innovators of the prevailing TIS made only limited use of external sources during innovation activity. On the other hand, it has to be acknowledged that most of the newly created knowledge and technologies of R&D organizations referred to textile pre-materials. For that reason, it was mainly useful and if ever comprehensible for textile manufacturers from the prestage. Furthermore, the institutionalized joint industrial research exclusively focused on basic research in the pre-competitive stage (cf. Meyer-Storck 2006). This made the transfer and distribution of the distinct knowledge additionally harder to actors along the resting disintegrated textile supply chain. Indications for new entrepreneurial actors who are able to transfer this new knowledge into innovation and complement the textile knowledge base (cf. Pitt 2007: 127) cannot be assessed from the data (e.g. MUP; Eurostat) and expert interviews. Overall, fragmented instead of cooperative interactions prevailed between actors from science and industry in the first years of the millennium.

The results from the investigation of the institutional dimension explain the weak interactions and cooperation activity in the TIS. The internationalized, highly disintegrated textile supply chain had a restricting effect on knowledge flow and exchange, while competitive interactions prevailed among business partners. This general institutional structure of the industry likely had a considerable impact on interactions within the innovation system, hampering emerging innovation action. Moreover, the bad image from crisis and shrinking made it more difficult to win over new actors from new customer industries and necessary young professionals outside the TIS (cf. EPPA/CEPS 2002; NetFinTex 2007; chairman of textile research board 2010). Some new institutional initiatives promoting necessary, new cooperative arrangements can be identified. But they focused either on established firms, specific technical fields, or on specific regions. Indications for institutions that stimulate entrepreneurial experimentation at established firms or cooperation between suppliers from the prestage and processors from traditional textile domains could not be found in the analysis. The same holds true for industry-specific institutions to attract new entrepreneurial actors. In its place, an institutional practice of corporate entrepreneurship had evolved from previous technical changes. Thus, the TIS differs from classical entrepreneurial regimes, where innovation is mainly organized by new entrants. This could be a sectoral peculiarity for the period investigated. Finally, the analysis of the institutional dimension remains rudimentary on this level of investigation. In particular, the innovation surveys do not provide sufficient information about the systems' activities with respect to entrepreneurial activity and entrepreneurial experimentation. Likewise, expert interviews deliver solely first assumptions in the direction of specific corporate entrepreneurship practices.

If the industry's situation and prevailing activity of the TIS stimulated or hampered KIE in the period between 2000 and 2006 is not clear. The impression arises that the TIS focused on production of scientific, pre-competitive knowledge while lacking activity and institutions for its diffusion and commercial exploitation. The emerging technical opportunities were first of all limited to innovators from the beginning of the textile supply chain, although their broad appropriability also promised opportunities for innovation to processors downstream the traditional textiles supply chain. The new functional textiles opened up further market opportunities outside the traditional innovation system in emerging markets of composite materials. Again, these opportunities first of all referred to material producers. However, these emerging markets with uncertain articulation of demand had not been institutionalized at that time. In consequence, the industry's *paradox situation* of specific opportunities and uncertainties could indeed have a stimulating effect for a minority of knowledge-intensive entrepreneurs, while the prevailing innovation system had not oriented its institutions and activity towards the new problems and opportunities yet. In this case, a minority cannot be sufficiently evaluated through statistical average values from frequency distribution of innovation surveys on the sectoral level. Altogether, the sources investigated do not point to an entrepreneurial orientation of the TIS in terms of legitimizing entrepreneurship or mobilizing resources for entrepreneurship at that time. Likewise, a systemic institutional opportunity in the sense of Radosevic et al. (2011) that matches technological with market opportunities is not clearly assessable. Sebastian Meyer-Storck (2006: 52), 2002-2008 chairman of the textile research board, illustrates the institutional disarrangement of the system arguing for further incentives through public funding: "Gerade in einem Branchenumfeld, das durch mittelständische Traditionen, eine ausgeprägte Arbeitsteilung in der Wertschöpfungskette und einen geringen Anteil vertikal operierender Unternehmen gezeichnet ist, hängt der Innovationserfolg aber auch von der Möglichkeit ab, Anlaufhürden durch öffentliche Förderung zu senken."[44]

An entrepreneurial innovation system is said to orientate towards changing technological opportunities, the improvement of alerting skills for technical as well as market

[44] Especially an industrial environment that is denoted by middle-class traditions, a distinct division of labor in the value chain and a low proportion of vertically operating enterprises, the success of innovation depends on the opportunity to reduce start-up obstacles through public promotion" (translated by author).

opportunities (Radosevic 2007 in Radosevic et al. 2011: 26). Moreover, it should balance between maintaining and absorbing uncertainty (ibid. 27). Indeed, the TIS promoted uncertainty through industrial joint pre-competitive research that in turn creates new technological opportunities. But on the other hand, no indications for rebalancing these uncertainties can be found in the analysis, for instance, in improving the incumbents regressed entrepreneurial alertness for those technological and market opportunities.

In conclusion, these first results refer to a changing situation of the TIS. Consequently, the established knowledge base, actors and institutions had to be reoriented to this development and especially to entrepreneurial activity in order to exploit the new knowledge. In this transition, a structural incompatibility between underdeveloped entrepreneurial and wrongly oriented institutions from the prevailing routinized innovation system with newly emerging institutions and new potential actors needs to be assumed. In such an assumed situation of missing established entrepreneurial orientation, the emergence of KIE can be determined in so far that the actors of the innovation system do not proactively respond to this change in terms of sensing and seizing problems and opportunities (cf. Pitt/Nelle 2008: 4). This assumption is, for instance, supported by the NetFinTex report (2007: 37) that assesses an underestimation of the growing potential of new technical textiles by the textile entrepreneurial community. This likely also had consequences for acquiring new investors outside the prevailing innovation system, e.g. venture capital firms (cf. ibid.). All in all, the analysis of the German textile industry's innovation system reveals a sophisticated conclusion for the conditions of KIE. Indications from the different analytical dimension condense the assumption that the TIS had not changed from a matured routinized innovation regime to an entrepreneurial innovation system between 2000 and 2006. Otherwise, the resulting contradictions, e.g. from distinct technical opportunities limited to a specific group of innovators, could have particularly stimulated a minority to carry out KIE. The specific conditions and influences during these extraordinary entrepreneurial ventures cannot be derived from the underlying sectoral data. Further data on entrepreneurial activity need to be gathered to evaluate the entrepreneurial propensity of the TIS and to gain more information about the systemic opportunities or disarrangements for matching the technological and market components. The identified institutional practice of corporate entrepreneurship seems to be a first starting point in the following case study analysis.

5 Knowledge-intensive entrepreneurship in the German textile industry

The main objective of the case study analysis is to comprehend how KIE deviated from existing innovation practices and how the TIS affected the emergence of the studied KIE cases. For this reason, it will be of interest which opportunity components (technological, market, institutional) were seized and exploited in these cases and which of them came from the TIS or any other innovation system (sectoral or national).

The selection of cases followed the selection criteria introduced in the methodological chapter (Chapter 3.2). Accordingly, all three cases carried out KIE between 2000 and 2006, launching a distinct innovation either through a spin-off or new business unit (cf. Table 2). The cases were identified through an expert interview with a representative of the Gesamtverband textil+mode and Forschungskuratorium Textil (textile research board), as well as through online search for awarded textile pioneers. The selected cases of KIE emerged at different positions within the textile supply chain in fiber and thread production as well as textile refining and manufacturing (cf. Figure 07). Accordingly, different innovations were carried out that can be embedded into the listed domains of innovation from the TIS analysis, namely functional fibers and electronics.[45] Altogether, the sample of cases describes a variance in knowledge domains, actors and organizational forms of KIE. It covers a broad empirical scope how KIE can emerge in the TIS. Although the sampling was open for start-ups, no case of an independent start-up could be identified during the selection process. Regardless of their different organization through a new business unit, academic or industrial spin-off, all three cases of KIE emerged dependent on an established organization meeting the outlined definition of corporate entrepreneurship (cf. Sharma/Chrisman 1999:18).

The structure of the case studies follows the outlined analytical dimensions from the conceptual frame of reference (Chapter 2) and approach to analysis (Chapter 3.2). First of all, the case setting is described, then the environmental conditions are described in terms of the field specific knowledge base, market and institutional environment in which the case was embedded before the KIE process started. From these descriptions, technological, market and institutional opportunities should be derived. Additional to these mostly known dimensions from the sectoral analysis, also existing opportunities that were sensed and exploited outside the TIS are portrayed in this section. Moreover, the specific corporate environment that determined the KIE process is disclosed before the entrepreneurs are characterized. After this overall determination of previous environmental and entrepreneurial conditions, the KIE process will be reconstructed with recourse to elements and mechanisms of institutional

45 In the third case a new field outside the TIS was exploited based on textile finishing.

I. Schwinge, *The Paradox of Knowledge-Intensive Entrepreneurship in Low-Tech Industries*,
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entrepreneurship but also to supplementing peculiarities. At the end of each case study, a conclusion is drawn on the main characteristics of each KIE case. The case study analysis will be completed by a cross-case analysis on common results of the different cases that proves structural influence and inter-subjective characteristics of KIE in the German textile industry.

Tab. 2 Sample of KIE case studies

Cases ***Characteristics***	**FuncFiber**	**E-Thread**	**MultiTex**
Identification	society recommendation	award in cooperation	award in innovation
Organization of KIE	institute's spin-off	new business unit	spin-off
Foundation/Spin-off	2005	1953/2005	1956/2004
Employees (in 2009)	28	83	60
Innovation	functional fibers	elastic, conductive thread	advertised conveyor belt

Source: Own illustration.

5.1 The case of FuncFiber

This case was recommended within an expert interview with a representative of the German Textiles and Fashion Industry Association (Gesamtverband textil+mode) and the Textile Research Board (Forschungskuratorium Textil).[46] After the director of a private research institute (fictively named PrivIn) could not find any potential buyer for a newly developed process technology, he organized the exploitation of this technology in a spin-off, fictively named FuncFiber. The new company was founded out of PrivIn (a registered association) in 2005 with the legal form of a stock company. The board of FuncFiber consisted of the director of PrivIn, Mr. R, and Mr. L, an expert in founding and marketing activities. For the establishment of FuncFiber, a 100% subsidiary (Ltd.) of the institute PrivIn, a company for materials testing (MaTest), held an initial interest of 49%. The rest of shares owed to investors organized by Mr. L and himself.

[46] For this case study, interviews have been carried out with the two chairmen, one of them being responsible for R&D and processing (1.5 hours in November 2009), the other one being responsible for marketing, sales and product launching (2 hours in March 2010) and a visit of the plant with the plant manager (2 hours in March 2010) with post scripts. Additional information has been collected through telephone calls with the interviewees.

KIE showed up in this case in terms of introducing new, functional cellulosic fibers applied in different new consumer products on the market. The production of the innovative fibers was based on a technology that had been developed and patented by the institute PrivIn. The innovation was deviating from the knowledge base of cellulosic fiber production and usual application in this product field. Thus, the exploitation and commercialization of this new technology and material built the knowledge-intensive entrepreneurial activity.

FuncFiber is operating in preparation and spinning of fibers. Like PrivIn it is located in a former industrial district for man-made fibers. In 2010 FuncFiber employed 28 people. It was the only manufacturer of such functional cellulosic fibers in the market. Regarding the position within the supply chain, FuncFiber was positioned at the very beginning of the textile supply chain, supplying yarn producers or producers of non-woven textiles (fleece). The key purchasing market was wood pulp from Finland. The developed consumer products (an anti-bacterial cleaning towel and washing ball for laundry) were produced by production partners like yarn, weaving or spinning mills and also a polymer processor. FuncFiber sold them to trade partners and retailers. Customers buying the new fibers were mostly manufacturers of apparel and home textiles. Key sales markets were apparel and home textiles in Europe. Besides this, there were growing sales to markets in the USA, Canada and Japan.

5.1.1 Sectoral knowledge base and technological opportunities

For the case of FuncFiber, the man-made fiber industry represents the affected sub-sectoral knowledge base. Compared to the traditional textile spinning industry, the man-made fiber industry is rather young. Basic innovations like spinning technologies for viscose (cellulose) fibers had been developed at the end of the 19th century, but the industrial production of man-made fibers did not replace the dominating natural fibers (like cotton or wool) before the 1970s (Löbbe 2008: 13). Fibers for textile fabrics and their technologies became the driving force of innovation for the whole textile industry in the 20th century, because they offered various new technological opportunities (Mieck 2001: 70). They did not completely substitute the natural fibers. Many textile material fabrics still have a certain share of natural fibers (ibid.). Around the millennium, the fiber industry contributed again to innovations in the development of new technical textiles (Knecht 2003b: 14).

The knowledge base of the man-made fiber industry is characterized by knowledge from the chemical industry[47] as well as knowledge about various materials, products and diverse technologies (Löbbe ibid.). The main *knowledge domains* of chemistry of fiber-type specific treatment and the mechanical spinning process are established for many decades. The three main spinning processes of wet spinning, dry spinning or melt spinning are incorporated technologies in the sub-sectoral knowledge base (cf.

[47] Classed as medium-high-technology (OECD 2011).

Koslowski 1997). Within the technological domain of man-made fibers, two fiber categories are roughly distinguished in synthetic and cellulose fibers (IVC 2007: 4). Considering the major man-made fiber manufacturers in Germany, Austria and Switzerland, the companies can be clearly assigned to one of these fiber categories with regard to their listed trademarks (ibid. 18 et seq.). Most of the firms operating in this industrial field are specialized in one of these fiber categories where they sometimes register several trademarks of sub-types of synthetic polyester fibers, for instance (cf. ibid.). In contrast to the majority of firms in the low-tech sector, laboratories or R&D departments for product tests and design are common for these firms. Traditionally the average of fiber producers spends more on R&D and employs a higher share of R&D staff than the average of the low-tech sector (cf. Table 3).

At the beginning of the 21st century a broad, new technological field of functional fibers developed beside textile mass fibers (Mieck 2001: 72). Technologies for functions such as flame-retardant, electrically conductive or antibacterial were applied and incorporated into to the sub-sectoral knowledge base (ibid. 72/77). However, data of the widespread R&D indicators of Eurostat disclose no conspicuous shifts or dynamics between 2000 and 2006 (cf. Table 3) for the general description of knowledge creation in the man-made fiber industry. Although the whole sub-sector faced serious competition, no evidence for rising efforts in R&D activities of the fiber manufacturers can be assessed. Given the intensive international competition and shrinking of the domestic industry, the share of R&D expenditure in value added did not significantly increase between 2000 and 2006. Indeed, the expenditures slightly decreased from 4.9 to 4.1% (cf. Table 3). Likewise, the shares of R&D employment in the man-made fibers industry show no trend of increasing industrial research efforts. In fact, between 2000 and 2006 the share of R&D employment of the total employment rate slightly shrank by 0.5 to 2.1% in 2006. The total expenditures on intramural R&D dropped from 61.3 (2000) to 35.9 million Euro (2006). Increasing knowledge creation at firms cannot be derived from these statistics in the period before the KIE process started.

Tab. 3 Fiber industry's knowledge base measured in R&D indicators

Manufacture of man-made fibres in Germany	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Share of R&D expenditure in value added (in %)	4.9	3.9	4.3	4.0	3.7	3.9	4.1
Share of R&D employment in no. of persons employed (in %)	2.6	2.5	2.9	2.7	2.7	2.5	2.1
Total intramural R&D expenditure (in thousands of Euros)	61,3	41,9	42,2	43,3	39,1	38,5	35,9

Source: Eurostat (NACE code DG 247, Rev.1.1).

In its place, a study about the sustainability of the man-made fiber industry in Germany (Löbbe 2008: 22/93) assesses a rise of public research projects by numerous research institutes of textiles and man-made fibers research. Following the study, the industry used this research for compensating the declining intramural research activities, but at the same time firms rated the use of this knowledge low (ibid.).

To understand the technological opportunity for the emergence of the new fiber technology, the 'comeback' of cellulose fibers is briefly outlined. The conventional types of man-made cellulosic fibers are characterized by chemical treatment and intensive use of energy. In the course of the energy and oil crisis in the 1970s and 1980s there had been new research on energy-intensive oil-based materials for man-made fibers. As the raw materials for synthetic fibers originate from crude oil and also the production of man-made cellulosic fibers is energy-intensive, the improvement of material or energy efficiency alone could not absorb the increasing costs (Löbbe 2008: 65 et seq.). Then in the 1990s, a new type of cellulosic fiber offered superior performance compared to former man-made cellulose fibers (Highbeam Business 2010). It could be manufactured with fewer hazardous waste emissions (Koslowski 1997: 95 et seq.). Departing from the conventional man-made cellulose fibers, a new process technology dissolves the basic cellulose material without chemical treatment. Additionally, the solvent is almost completely reclaimed during the spinning process (ibid.). As a result, the new type of cellulose fiber is to be distinguished from conventional man-made fibers and also from ordinary natural fibers of wool or cotton, because these cellulose fibers are processed in a more environmentally friendly chemical treatment (cf. Koslowski 1997: 95; Rauch, IVC 2007 in Löbbe 2008: 88et seq.). The new, not oil based fiber promised to offer new opportunities for the struggling fiber industry (Highbeam Business 2010). It was even assumed that such new materials could revolutionize the technological base of the industry (Löbbe 2008: 45). At the end of the 1990s, the company which invented this new cellulose fiber was bought up by the only competitor in this field. From then on the buying firm became monopolist, holding the patent of this new cellulosic fiber type. In conclusion, the accessibility to this new technological knowledge was limited to the monopolist's willingness to licensing. At that time there were only three facilities worldwide where the technology for this new type of fiber was applied (press release by monopolist 2005). Accordingly, the diffusion of this new, innovative knowledge had not penetrated the fiber industry's knowledge base.

Parallel to the industrial research, the private research institute (PrivIn) had also begun to research on alternative cellulose deforming in the1980s. At this time, PrivIn still belonged to former East Germany. Finally, it patented a similar process technology in the 1990s as well. The technology is an independent variation of the new resolving technology for the production of specific cellulosic fibers. This technological variation is particularly characterized by its environmental sustainability and a closed cycle of technology. The *technological opportunity* for the emergence of FuncFiber was based on this development, because the essential invention of this case happened accidentally during contract research of the institute in this field. A researcher discovered by coincidence the exceptional features of cellulose fiber structure for incorporating additives. Based on this discovery, the institute developed a so-called platform technology that consistently integrates additives of different substances into the cellulosic fibers to a hitherto impossible amount. This led to new functional fibers with a high strength, and a high functional and long lasting efficiency. Produced in thin filaments, only a driblet of these fibers is necessary to be interwoven in technical textiles while not losing their stability. The commonly applied technology of micro capsules for integrating additives in fibers (cf. Mieck 2001: 75 et seq.) is not able to reach this strength and low weight of fiber due to constructional and material conditions. Additionally, these fibers are more temperature resistant than ordinary synthetic fibers because of the new technology and cellulose as the basic material of the fibers. These new fibers lay the basis for new materials with diverse technical functions and opened up several new markets for application in the industry, e.g. for new materials in the already mentioned innovation fields of building, aviation and automotive industry, mechanical engineering, medical engineering and environmental process engineering (cf. Figure 07). PrivIn patented the new platform technology in 2003/2004. The patent prevented the diffusion of the new knowledge into the subsectoral knowledge base. But unlike the monopolist, PrivIn offered the patent to the industry so that firms basically had the opportunity to exploit this new technology.

Summing up the knowledge base of the man-made fiber industry, knowledge is mainly created by research and development on chemical treatment and machinery engineering in large leading companies or by research institutes along already established knowledge domains of synthetic and cellulose fibers. The crisis in rising energy costs led to first improvements and efforts in energy saving considering established fiber types. A new cellulose fiber type was finally developed that can be neither counted to natural fibers nor to man-made fibers because of its high remaining amount of cellulose and environmentally friendly treatment. The *accessibility* of knowledge and knowledge diffusion was mainly restricted to the firm level in terms of patents or registered trademarks. Under the specific circumstance of the East German research institute PrivIn, the technological knowledge base for the invention could evolve. The described technological opportunity was a superior technology for integrating functional additives into cellulosic fiber that had not been commonly shared in the industrial knowledge base of man-made fibers yet. The technological opportunity was objectively given to interested parties, because first of all PrivIn offered the patent for sale.

5.1.2 Market conditions and market opportunities

The *market conditions* of the new cellulose fiber types are embedded in the man-made fiber market and more specifically in the market of man-made cellulosic fibers. According to the industrial life-cycle theory, the man-made fiber industry in Germany reached its peak of output in the middle of the 1990s (Löbbe 2008: 14). Beforehand, man-made fibers prospered and superseded natural fibers like cotton worldwide. They reached a share of more than 90% in apparel, home textiles or technical textiles. Earlier crises in the 1970s had illustrated the limits of the man-made fiber market's expansion in standard products (ibid. 78). Since the boost of emerging economies in the 1980s the export oriented man-made fiber industry in Germany faced the problem of overcapacities. At the same time, the pressure to import fibers grew on the remaining domestic textile customer market. However, the main share of imports and export activities between 1996 and 2006 took place within the European Union and Europe (IVC 2007: 5-7). While the German exports of man-made fibers slightly went down to 6% from 1996 to 2006, the import of man-made fibers surged by 58% in this time. Thereof, the import of synthetic fibers was increased by 73%, while the import of cellulosic fibers increased only by 33% between 1996 and 2006 (ibid.).

The boom years for the German man-made industry had already passed; instead, it is described with increasing growth retardation (Löbbe 2008: 106). Along with the expansion of manufacturing markets in Asia, like China, Indonesia or India, the capacities of mass fiber products grew very fast (ibid. 55 et seq.). This development intensified the competition on prices. The producer prices deteriorated continuously between 1995 and 2000 in the German man-made fiber industry (ibid. 29). From then on to 2007 they slightly increased (ibid.). The growing export orientation of emerging industries and the rising quality of the import articles led to a serious crisis in the income of the German man-made fiber producers. The demand for fibers shifted together with the production of textiles to locations in emerging industrial regions. Between 2000 and 2006, the sales of the German man-made fiber industry went down by 11% (Eurostat) and the output by 5% (IVC 2007: 4).

The new Asian manufacturing markets did not only take over standard commodities of synthetic and cellulose fibers but were also catching up for qualitative market segments, which lowered the innovative advantages of traditional Western manufacturers. Though decreasing unit labor and equity costs, improvements in process efficiency and quality were no longer sufficient for competing with the Asian markets (Löbbe 2008: 29). In addition, the clearly increased costs for materials, primary products and energy reduced the profits of the German producers (ibid.). Again these additional costs were unlikely to be absorbed just through improvements in material efficiency or energy efficiency (ibid.). Only particular high performing or distinct fibers were expected to carry out higher prices, but even here to a limited extent (ibid. 37). Therefore, distinct deviating product innovations as defined for KIE promised an adequate return on investment. Against this background, innovative functional fibers offered the opportunity of new niche markets. In response to this, sales shifted from clothing and home textiles markets to technical textiles that still offered growth in market shares (Löbbe 2008: 13). Statistics on the fibers' fields of application (IVC 2007: 10) indicate that the field of technical applications took over clothing and apparel, amounting over 55% in 2006 (compared to 40% in 1996). The development of specific functional fibers and yarns for outdoor clothing and the exploitation of new fields of application in technical fields, such as automotive or in hygiene, as well as the improvement in the fibers' properties kept sales and employment for a while (Löbbe 2008: 19).

German producers of man-made fibers faced demanding competition at the national and international markets (ibid. 20 et seq.). They had to accept enormous declines in nearly all types of fibers at the world market in the last years – except for cellulosic fibers (ibid. 26). The traditional market of cellulosic fiber represents only a small share of the worldwide man-made fiber production (IVC 2007: 2). Worldwide, the cellulose fiber industry reached its peak in the 1980s and then went through a tremendous decline (Asian Textile Business 2006). In the mid-1990s, the surviving cellulosic fibers producers hoped that a new fiber type based on the new technology might rescue the struggling industry (see Chapter 5.1.1). Two of the largest competitors were competing for domination of this new market segment which was then controlled by the monopolist. In comparison with other countries, the German industry of cellulosic fiber ranged at the lower end of large producers. In 1996, the German cellulosic fibers industry held 7% of the worldwide output of cellulose, which came to 6% in 2006 (based on CIRFS data).[48] In Germany, cellulose fibers had already been manufactured before World War II and had its peak during the war (ibid.). After the establishment of man-made fiber technologies, the production of cellulose fiber remained on a low level, but quite constant in Germany (IVC 2007: 2). Between 1996 and 2006, the share at the total fiber production in Germany went down from 12 to 8%, although the output grew by 20% (1996: 202,000t, 2006: 200,000t, IVC ibid. 4). But at the same time, the German synthetic fiber production even grew by 77% (ibid. 2/4).[49]

In this case, PrivIn sensed the *market opportunity* of the new functional cellulose fibers through contract research with industrial partners. 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 (Forschungskuratorium 1999; Mieck 2001), but based on different technologies. Some first successful product innovations and a rising interest for prototypes at fairs indirectly showed the potential market interest for these functional fibers. The market niche of functional cellulose fibers with their superior and efficient features had not been exploited before. This was a market opportunity for fiber producers, as the technological deviation promised profits from new market niches.

48 Canada and the USA together produced, for instance, 9% of the world output in 2006. Since 2001 China is by far the biggest producer with a market share of 24% that came up to 38% in 2006 (CIRFS based on Fiber Organon statistics). Beside this, India and Indonesia belong to the big producers with 9 and 8% in 2006 (respectively CIRFS ibid.).

49 A more differentiated look at single types of synthetic fibers like polyamid or polyacryl shows that these went down, while the production of cellulosic fibers overtook them (IVC 2007: 4; Löbbe 2008: 25).

Although the analysis of the technological and market conditions revealed technological and market opportunities, the institute PrivIn could not find any interested party on the market. In the following, the conditions of the institutional environment are further examined to explain this disinterest. Moreover, the existence or absence of an institutional opportunity in this case should be investigated.

5.1.3 Institutional environment and institutional opportunities

Following Radosevic (2010) et al. (2011), institutional opportunities play an important role for matching technological and market opportunities. For that reason, the institutional environment is specified through going into the different introduced layers of institutions (cf. Groenewegen/Van der Steen 2006: 280; Figure 03) considering informal and formal institutions, institutional arrangements and individual actors.

Starting with the consideration of *informal institutions* (layer 1) such as culture, beliefs or perception, several inconsistent points can be found in the analyzed case data. Already since the middle of the 1990s, the belief of the man-made fiber producers had been strengthened that the economic problems could not solely be solved through changes in the production range (Löbbe 2008: 78). More radical strategic and organizational decisions were necessary (ibid.). But the deliberations about the dynamics of the sectoral knowledge base and indicators about investments in R&D and R&D staff above (Eurostat, cf. Table 3; Löbbe ibid.) do not show any efforts of companies in this direction. Another ambiguous point on the perception of innovation activity is that, although public research projects increased and should compensate the companies' weak intramural research activities, the industry rated the use of this newly created knowledge very low (Löbbe 2008: 93). This critical attitude is supported by the director of PrivIn and chairman of FuncFiber (Mr. R):

> *Nee, was erwartet man von einer Forschungseinrichtung, dass die jetzt noch produzieren und dann noch alles einhalten? Das glaubt uns niemand als Forschung […] brauche ich gar nicht anzufangen […] können Sie vergessen. Da haben die viel zu viele negative Erfahrungen gemacht mit dem, wie eine Hochschule oder eine Forschungseinrichtung arbeitet. […] Die wollen lieber mit einem wirtschaftlich tätigen Unternehmen, das nicht von irgendwelchen Fördermitteln abhängig ist oder sich irgendwelche tollen Forschungskonzepte überlegt, zu tun haben.*[50]

The negative experiences point to an advanced era of ferment, as several new functional technologies developed by research institutes implied no entrepreneurial experimentation. In its place, the scientific developments created uncertainty among companies due to first failures in the industrial application or missing acceptance of consumers. Mr. R reported, on the other hand, that requesting companies expected

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50 What do you expect from a research institution? That you even produce and comply with everything? […] No one trusts in us as research in this respect. […] No, I don't need to start with this at all. […] Forget about this, because there are too many who had negative experiences with the way a university or a research institute is operating. You can forget this. […] They prefer being up with an economically operating company that does not depend on any kind of subsidies or thinks about any excellent research concepts (translated by author).

readily developed products or developments in a too short time from his institute. Different from the companies' intramural research for trademarked product variations, the development of new technical functions implied longer development periods and the reduction of uncertainty through entrepreneurial experimentation. The established companies were probably not used to this extent of innovation activity and possible failures. These negative experience and disagreement in expectations on collaboration with science could explain the critical attitude on the side of companies.

The firms' widespread orientation to economies of scale was another controversial habit against the exploitation of scientifically developed new functions. Although the description of the market analysis shows that such technological fibers offered higher sales, they are used only to a low amount in specific products. This did not match with the fiber producers' belief in mass production. PrivIn offered the additive technology for functional cellulosic fibers to large companies in form of a joint venture or as a licensing agreement.

> *Dann haben sich die Großen der Industrie das angeschaut und haben gesagt: ‚Na ja, wie viel Tonnen sind das?' – Mal hundert Tonnen oder vielleicht mal fünfhundert Tonnen. ‚Ja wenn das 50.000 Tonnen wären, dann würde das für uns interessant sein.' – Also kein Interesse […], weil die ausgerichtet sind auf hunderte von Tonnen oder tausende von Tonnen pro Tag zu verkaufen. (Mr. R)*[51]

Contrary to this, the fiber producers had a highly innovative image at textile customers. They were considered the main innovators and the winners in the development of technical textiles (Knecht 2003b: 14). Success stories like the one of Goretex, Sympatex or Lycra created expectations at the buyer side (Reinhold 2003: 212 et seq.). These fiber and material producers had revolutionized the fiber and textile industry in the 1980s and 90s. They established own brands of functional material (e.g. membrane fabrics) that were recognizable independent from the textile end-product. However, for this image, the firms had invested enormously in marketing addressed towards business customers as well as consumers (ibid. 213 et seq.). This led to high expectations on the side of retail and other producers along the textile chain that were, on the other hand, not willing to invest to such an extent in innovation. Moreover, the retail and end-producers were suspicious because of the flood of new complex technologies. But not all producers from the textile pre-stage had the financial sources, or they saw no pay off for such investments, as they remained unknown in the textile supply chain (ibid. 217). Nevertheless, huge expectations on innovation and investments lasted on the fiber industry. An article about the importance of functionality in the clothing retail refers to the retailers' awareness of fiber producer as a decisive factor, because retail alone is not able to communicate these new functions (ibid. 214). An unknown brand therefore faced high entrance barriers on the market (ibid.), which was also likely for new firms, as well.

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51 Then the large companies of the industry watched at us and asked: 'How many tons?' – Sometimes 100 tons or sometimes 500 tons. 'Well, if it was 50,000 tons, then it would be interesting for us.' – Hence, no interest because they are oriented to selling hundreds or thousands of tons a day (translated by author).

Altogether, ambiguous oriented informal institutions can be observed that are not necessarily compatible with the identified market or technological opportunities from above. Scientific R&D as a source for innovation was valued highly ambiguous by economic and scientific actors in this sub-sector similar to the fragmentation in the broader analysis of the TIS (Chapter 4). Negative experiences with research institutions point to a disillusion of the fiber producers due to long development periods and pending market success of first new functional technologies. This might explain the reluctance in entrepreneurial experimentation. In sum, an entrepreneurially orientated culture cannot be assessed for the profit and non-profit organizations in this sub-sectoral system of innovation.

Tab. 4 Indicators for business conditions in the man-made fiber industry

Manufacture of man-made fibres in Germany	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Share of personnel costs in production (in %)	20.3	21.8	21.7	20.8	20.6	19.7	18.5
Value added at factor cost in production value (in %)	30.0	27.8	26.6	28.9	28.8	27.0	22.8
Investment rate (invest./value added at factors cost in %)	14.2	14.2	13.0	12.2	11.7	11.0	11.1

Source: Eurostat (NACE code DG 247, Rev.1.1).

With regard to the *formal institutions* as the political system (layer 2), regulations and policies for financing or competition etc. (layer 3), several challenging and unsettling business conditions can be found for the man-made fiber producers, but no specific programs supporting entrepreneurial innovation activity. The general business conditions at the domestic market remained relatively stable. For instance, the real wage costs and unit labor costs as well as the capital costs and interest levels for capital goods evolved moderately in the first years of the 21st century (Löbbe 2008: 29). Nevertheless, the value added at factor costs in production and investment rate declined by almost a third in this period (cf. Table 4). The share of personnel costs in production decreased a little by 1.8% under the rate of 20% (ibid.). At the same time, the number of employees was reduced by more than 26% to 13,739 in 2006 (Eurostat). The labor market was further thinned out by sales of companies or business units to foreign countries (Löbbe 2008: 78/80).

The market liberalizing regulation was oriented to downsizing overcapacities and strengthening consumer and importers' interests (ibid. 28). Since the 1980s, a strict subvention prohibition has been in force with respect to the European man-made fiber industry. The law was enacted to the multi-sectoral framework on regional aid for large investment projects on the European level and should accelerate the downsizing of overcapacities (ibid.). Between 2000 and 2006, the international agreements on trade liberalization in the textile industry nearly came into effect. This market liberalization should lower the trade barriers for the export oriented man-made fiber industry in Germany, but at the same time the pressure to import fibers and material increased. Simultaneously large emerging economies, like China, kept barriers of import and subsidies for the domestic textile industry. Additionally, the study about the man-made fiber industry in Germany (Löbbe 2008: 63 et seq.) identified uncertainties with respect to environmental regulations for energy-intensive industries and the erratic European anti-dumping policy. The European Commission realigned the anti-dumping policy and stopped some current proceedings in favor of strengthening the consumers' and importers' interests (ibid.). Against the background of this regulative situation, no sector-specific public start-up programs could be found for the man-made fiber or textile industry as formal *entrepreneurship enhancing institutions*. Altogether, neither formal entrepreneurship enhancing institutions in general nor a structural institutional opportunity matching the outlined technological and market opportunities can be assessed in the innovation system of the man-made fiber industry.

Proceeding to the fourth layer of *institutional arrangements*, several aspects about contracts, patenting and licensing of the involved organizations are to be mentioned. As already described for the sub-sectoral knowledge base, patenting, licensing and trademarks were common practices for the development of technologies, innovations and products in the man-made fiber industry. Generally, the meaning of patents differs between research institutes and companies in this field. Mr. R, the director of PrivIn, faced difficulties marketing the patents of the institute, because half of the patent's runtime would be elapsed at least before any patented technology is used in new products. And even at this time the return on the patent investments has not paid off.[52] This example illustrates the difference between scientific R&D activity and entrepreneurial experimentation. It explains the companies' low valuing of the scientific patents for application and the difficult arrangements between research organizations and fiber producers. These difficult conditions for PrivIn's patent licensing certainly contributed to the decision to organize the exploitation of the new technology in a spin-off.

Against this background, networks of research institutes and firms in this field did not seem to be a common institutional arrangement. Quantitative data about industry-science collaboration is not available on this aggregation level. In the case of PrivIn, the research institute addressed its contract research to end-producers instead of yarn producers from the next processing step of the textile supply chain. End-producers have a central position because of their direct contact to the user market.

52 "[Beim] Patentverkauf sagt jedes Unternehmen mit dem Sie da zusammenarbeiten, welche großen Aufwendungen sie da noch haben werden und dass das Patent schön ist, aber es ist nichts wert. Also bekommen Sie auch aus dem Patent nichts" (Mr. R.). [Translation by author: Selling a patent, each company you collaborate with says which huge investments they will still have and that the patent is fine but it is not of value. Hence, you do not receive anything from the patent.]

Once these central players in the textile supply chain have been won for the development of a new fiber, their articulated interest arranges the collaboration on innovation through the whole value chain.[53] A similar arrangement was assessed for innovative fiber producers. These collaborated closer with clothing manufacturers than with fabric producers from the pre-stage of the value chain (Reinhold 2003: 218). Consequently, an institutional arrangement of traditional vertical integration cannot be assumed for the implementation of innovation in this field.

In the specific case of the German cellulose fiber industry, another institutional arrangement was decisive. First of all, patents held by a company had a crucial strategic function for the position in the market above all and not necessarily for the exploitation of new knowledge for innovation. In this specific institutional arrangement, a monopolist held the patent rights for the basic cellulose processing technology. The central player was not interested in the exploitation of the new cellulosic additive technology, but its agreement built a necessary condition for any innovation activity in the field of the new cellulosic fiber processing.[54] This institutional arrangement could be sensed as an institutional barrier by new entrants, but also by established firms. That is most likely why PrivIn faced troubles in finding any contracting partner. Moreover, institutional arrangements of vertical integration or collaboration with clothing manufacturers were not relevant from the monopolist's point of view because of its central position.

This leads over to the last layer of *individual actors* and their mental maps, habits and routines. First, the general data found on activities of man-made fiber producers are described before portraying the monopolist and the private research institute as specific actor conditions for the emergence of KIE in this case.

[53] Mr. R admitted:"Ich würde nie mit einem Garnhersteller reden. Da drücke ich dann etwas in ein Rohr rein, wo aber der Garnhersteller das Ventil zugedreht hat. Da können Sie drücken, wie Sie wollen, da geht nichts mehr durch das System durch. Der da hinten, der hat Kunden. Wenn der sagt, das lässt sich durch mein Marketing und meinen Vertrieb sehr gut verkaufen und der sieht da eine neue Marktchance, dann öffnet der den Hahn". [Translation by author: I would never talk to a yarn producer. You can push as long as you want, there is nothing passing through this system. The one at the back, he has customers. If he says that he can market and sell it, well, and if he regards it as a market opportunity, then he pulls the plug.]

[54] The meaning of this monopolistic arrangement is becoming clear in the case of a joint venture that was founded some years before FuncFiber. A chemical plant construction firm (PlaCon) operating in the field of fiber production among others founded a joint venture (JoVen) together with the institute PrivIn. Two years before the foundation of FuncFiber, the monopolist finally sued PlaCon for patent infringements. At that time the institute had already exited the joint venture which became a 100% subsidiary of PlaCon. PlaCon claimed to use an own developed technology. Beforehand, researchers involved in the transformation of the new basic cellulose process technology into industrial manufacturing had been set free by the monopolist and recruited by JoVen. These researchers knew how to circumvent the patents of the monopolist. Finally, there was a settlement between the companies and a license agreement that allowed PlaCon to use key patents for the construction of cellulose manufacturing plants. One year later, JoVen changed its title and focused its business activities on the commercialization of a specific seaweed fiber. In consequence of restructuring within the PlaCon group, JoVen was finally offered for sale. This incident illustrates quite well the actor constellation within the market niche of cellulose fiber.

After the gestation and shrinking phase of the man-made fiber industry, the corporate structures had become more heterogeneous (Löbbe 2008: 78/122 et seq.). A few big companies were left with up to 1000 employees after the big chemical concerns had withdrawn from this sub-sector in the middle of the 1990s and focused on their core business (ibid. 19/23). Subsequent to this shake-out phase, mainly medium sized companies and a few small ones with less than 50 employees remained (ibid. 123). Thereof, subsidiaries from the big concerns were of less importance then (ibid. 122 et seq.). After concentration in the advanced industrial life-cycle, Löbbe (2008: 13) assesses a form of deconcentration as a result of company splitting and spin-outs. The statistics of Eurostat confirm this argument. The number of firms in the man-made fiber industry grew from 33 in 2000 to 55 registered companies in 2006 (Eurostat). This increase was due to splitting and outsourcing activities within restructuring and specialization processes of incumbent companies in order to reduce business risks (Löbbe ibid.). In consequence of the restructuring, the corporate structure of owners became more international, especially European, as many concerns sold their unit of fiber production to European firms (cf. ibid. 69-80). Thus, the increased number of firms in the man-made fiber industry cannot be simply taken as an indicator for growing entrepreneurial or innovation activities. Unfortunately, on this sub-sectoral level the number of innovative companies is not available by Eurostat or the Mannheim Innovation and Enterprise Panels for describing the routines, habits and mental maps of innovators. Although the firms realized that a considerable change in processing and technology was necessary for keeping pace with competition (Löbbe ibid. 94), common indicators for R&D like the firm's investments in R&D point to a negative trend in innovation activity between 2000 and 2006 (cf. Table 3; also Löbbe 2008: 94 et seq.). But this data does not necessarily represent the practices of individual innovative actors.

In addition, the corporate structure for the total man-made fiber industry in general does not necessarily describe the situation in the field of cellulosic fiber production. Different to the described heterogeneous corporate structures with mainly SME and a few bigger subsidies, the monopolist still kept a central position as a large foreign company group with more than 5000 employees (in 2006). Further data on other companies in this specific product field is not available on this level of aggregation.

The monopolist is a big chemical manufacturer. At this time it was running three manufacturing plants among others as the only places worldwide for the basic processing of these cellulosic fibers. It held numerous patents for the basic cellulose processing technology with a term of at least 12 years at the time of FuncFiber's foundation. When PrivIn developed the new technology for additives, the monopolist was not interested in the offered patent. From the monopolist's point of view as a mass-producer, the exploitation of low volume but high-price fibers was not profitable enough. Besides, the exploitation of the new additive-integrating technology would have implied additional investments to adapt the manufacturing process.

From the point of view of FuncFiber, the monopolist's disinterest was a crucial condition to enter the market. That the emergence of FuncFiber draws on research activity of a scientific organization corresponds with the argument of increased research activity of institutes in the fiber industry (Löbbe 2008: 93). PrivIn's alternative research in the field of cellulose fibers was another existential precondition for KIE in this case. The private, non-profit research institute was founded after the German reunion. Since the middle of the 1990s, it had adjusted its strategic research agenda on applied research in new material development for small and medium sized enterprises in textiles. After projects with plant construction firms, it was equipped with a pilot plant for fiber production on where later also the new fibers for FuncFiber were tested. As a result of collaboration with the industry, it gained experiences in the foundation of a joint venture and in testing of industrial processing activities as well as in contracting with end-producers. The access to these material and immaterial sources of PrivIn built later on an important *institutional opportunity* for the set-up of FuncFiber.

In particular, the development of the new technology of additives was financed by public. But given the restricted industry-specific regulatory conditions the sources of funding came not from the textile innovation system but from general promotion programs oriented to specific scientific research organizations or science-industry collaborations. Partly a European regional economic growth promotion program was used, and later another one addressed non-profit research institutes in Eastern Germany. This program was launched by the Federal Ministry of Education and Research and focused on initial research and market-oriented research. Based on these funding sources from the national and European level, PrivIn carried out projects for first applications of the new functional fibers together with other scientific and industrial partners. A pilot plant at PrivIn was installed that helped to test first fibers with specific additives and assess the market potential of the new material. First risks could be anticipated this way. As the state agency was interested in the commercialization of this applied research activity, it can be considered supporting entrepreneurial experimentation. Nevertheless, after the ending of the project, PrivIn could not find any buyer for the commercialization. The research director Mr. R traced the decision for the spin-off to Privin's participation at the market oriented research program.[55] The program's request for the implementation of R&D activity led to the emergence of FuncFiber after established actors from the industry could not be won for this.

[55] "[...] das hat eigentlich den Endanstoß nur noch gegeben, weil man uns, bei unserer Teilnahme in dem Wachstumskern [Förderprogramm] dazu aufgefordert hat, 'Na wie macht ihr denn jetzt konkret die Umsetzung?' und das war so der letzte Anstoß" (Mr. R) [Translation by author: … actually this just gave the final impulse, because when we were attending to the growth program we were asked how to deal with the implementation, and this was the last impulse.]

5.1.4 Interim conclusion

Summing up, the environment of the man-made fiber industry indeed offered technological and market opportunities for KIE. Although the industry faced a serious crisis in sales and profits, the analysis of several institutional layers strengthen the argument that the majority of firms were not open to tensions or opportunities created by new technological research and development at that time. New technological fields occurred, influenced by the internationalization of textile markets. According to the advanced stage of the man-made fiber industry, firms developed routines in firm-specific product variation and specialization. In the ferment stage of various new functional fibers, these established innovation practices encountered differently oriented practices of research institutes. The institutes developed various technological approaches for these functions, but still these needed to be transformed into industrial manufacturing. The firms were not used to such entrepreneurial experimentation anymore. Failures and a missing dominant technological design led to uncertainty and negative experiences on the part of the firms. Also, developments of big companies fell short of the industry's expectations, because time to market took longer and was more costly than usually. Finally, the first implemented functional fibers revealed that their appropriability was limited to niche markets. The initial enthusiasm at the customer market was followed by disillusion and sometimes disappointment, because either the new functional sales argument could not be kept in the industrial application, or they were too complex for salesmen and consumers. Formal institutions of the political system were mainly focused on market liberalization and downsizing of overcapacities so that no institutional orientation can be observed in this respect.

Additionally, the monopolistic institutional arrangement in the field of cellulosic fibers depicts a barrier, even if the monopolist showed no interest in the exploitation of niche markets. The majority of established actors did not sense this situation as a valuable economic opportunity. Only in the individual case of the private research institute PrivIn the activities were oriented towards entrepreneurial experimentation. This orientation together with the reduction of uncertainties in the commercial technology exploitation resulted from absent interested firms and expectations of the public funding party. The implementation oriented program can be understood as a form of institutional opportunity, because it was oriented towards entrepreneurial experimentation. In other words, it contributed to the matching of technological and market opportunity. However, it was not part of the TIS but of the national innovation system.

In conclusion, neither an institutionalized entrepreneurial orientation nor a systemic entrepreneurial opportunity can be assessed in the field of the man-made fiber industry. From the systemic view, the investigation of the case could end here, because if "there [is] no mutually compatible set of structural opportunities[,] enterprising individuals by themselves will not be able to generate entrepreneurship activities" (Radosevic et al. 2011: 15). The analytical dimensions of institutional entrepreneurship concept, however, offers further insights from the micro perspective on the industrial environment and the emergence of KIE in this case.

5.1.5 Entrepreneurs

For this case, two entrepreneurs can be identified with complementing skills and capabilities: The managing director of the private research institute PrivIn and an experienced entrepreneur from outside the TIS. Mr. R is an entrepreneur in the wider Schumpeterian understanding, because he holds no interest in the spin-off. Mr. R can be described as an actor embedded in multiple fields. Beside his position as the director of the non-profit research institute PrivIn, he became the chairman of FuncFiber and responsible for production and R&D. Entrepreneurial characteristics of undertaking things and dynamic activism go for Mr. R as well as his interest in research as a scientist. His *motivation* for the spin-off sprang from his position as the director of PrivIn. According to him, his "driving force" was the middle-term securing of the institute's financing, because it receives no basic public financing like larger private research groups, for instance, do. When he took over the chair of the institute in 2002, there had been a cut of state funding by 5%, which had been existence threatening for the private research institute. After this incident Mr. R decided to provide for the future of the institute and never get into such a situation anymore. Accordingly, acquisition of funds from the industry comes first and second, the acquisition of additional subsidies for absorbing risks. The option of a spin-off became attractive to him, because he also made bad experiences with patenting and licensing activities with companies that bought patents not for exploitation but to keep them shut away from competitors.

> *… und deswegen ist meine Philosophie hier dann mich lieber mit Unternehmensausgründungen zu beschäftigen, oder […] sich daran zu beteiligen, das Ganze auch nur temporär zu machen oder, wenn es eben gut funktioniert, kann man eben auch drin bleiben. Ich meine, ein paar Prozent kann man immer behalten, und wenn da mal ein paar Gewinne transferiert werden in die Forschung. (Mr. R)*[56]

His education and work experience reveal *skills* in further fields. First of all, Mr. R studied chemical engineering, because he wanted to study something that is not so restricting but with a relatively broad perspective. He started to work as a project engineer at a man-made fiber combine in the German Democratic Republic where later PrivIn and FuncFiber were located. There he already started to work in the intramural research field of man-made cellulose fibers as a lateral entrant, because usually staffs skilled in polymer chemistry work in this field. It was also in this combine where he supervised 800 employees in the manufacturing area. Later he took over the set-up of a pilot plant into a manufacturing plant. After the German reunion he became managing director of a viscose fiber producing company that came out of the com-

[56] … and that is why my philosophy is to prefer dealing with spin-offs, or to participate in a company foundation […] either temporarily or to go on participating, if it is working out fine. I mean, you can always keep some shares for transferring profits into research (translated by author).

bine. Mr. R knew PrivIn from previous collaboration with this firm. Finally, he transferred to the institute and became its director in 2002. As a result from these former work experiences, Mr. R had access to multiple organizational fields going beyond his current *position* as a director of a research institute.

Consistent with the described institutional culture and risk averse habits of the firms (cf. Chapter 5.1.3), Mr. R sometimes experienced "catastrophic" talks with customers from the end of the supply chain.[57] Often ideas or inventions of the institute ended up in the drawer, because he could not win any potential buyer. Mr. R sees the reason for this in the missing creativity and entrepreneurial spirit of the decision makers in the industry.[58] Altogether, these experiences brought Mr. R to the estimation that there were not enough creative and enterprising people in the industry for taking up and exploiting the institute's technological developments. Together with his financial concerns he wondered where he can still gain profits "[…] und da war die einzige Chance hier wirklich aus eigenen Entwicklungen Produkte in den Markt einzuführen" [59] (Mr. R), because none from the established long-term participants in the industry was willing to do this.

The skills Mr. R developed in his work experience and different positions widely contributed to the entrepreneurial process and points in the direction of an institutional entrepreneur. Firstly he organized a part of the seed capital for the foundation of FuncFiber through the subsidiary MaTest. When he recognized his staff's and his own limited skills in marketing and business, he looked for an entrepreneurial partner for compensating this weakness. Later, in the operative development process of the new fibers, he knew who of the researchers from the institute was basically able to think about technical issues and solve them. According to him, his strengths are his organizational skills and care for the transfer between science and industry. His technical expertise in plant construction later helped to set up the manufacturing process of the new fiber types at FuncFiber. Moreover, the production partners for the implementation of the newly created consumer products came from the contacts of his business network.

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57 „… die wollen immer alles geschenkt haben, manche Firmen zumindest. Die denken immer, alle Entwicklungen führen dazu, dass alles billiger wird. […] und wenn hier [in den Entscheidungsgremien] zu viel Betriebswirtschaft sitzt, ist das tödlich für ein Unternehmen." (Mr. R) [Translation by author: They always want to get everything for free – at least some firms. They think that all developments lead to cost reduction. […] and if there are too well pronounced business economists [in the steering board], this is fatal for a company.]

58 "Es lag an den Entscheidern, […] nicht jeder Mensch ist ein Unternehmer […], sondern da haben viele Ängste. Wenn ich das jetzt anschiebe, was kann denn dann passieren? Das geht schief. Dann verliere ich meinen Job hier. Also mache ich das doch gar nicht, wenn da ein Risiko dahinter steckt." (Mr. R) [Translation by author: It was down to the decision makers [...] not everyone is an entrepreneur [...] but many have a lot of fears. If I initiated this, what could happen then? This goes wrong. Then I lose my job. So I do not make it, if there is a risk behind it.]

59 … and the only chance really was to introduce products from own developments into the market (translated by author).

As Mr. R was fully aware of his marketing weaknesses, which also held true for the people from his social network, he had clear expectations of the potential business partner. Not least because he could, to some extent, already estimate the big challenge of introducing new products in a new market niche. Accordingly, he needed someone to organize the sales and distribution of the fibers with a clearly entrepreneurial vision of the product and its value, optimally with a connection to marketing and the ability to fascinate capital. “Das ist auch eine Schwäche, die die Forscher haben, weil Forscher stellen in der Regel Risiken dar, und sobald sie das Wort Risiko nur einmal in den Mund nehmen, wenn Geld in der Nähe ist, ist das Geld weg.“[60] (Mr. R) When Mr. R met Mr. L, he had the feeling that this experienced entrepreneur had an excellent insight in how products have to be traded on the market and how distribution has to be set up, although he did not know him before.

Mr. L became the second chairman of FuncFiber, responsible for marketing, sales and product launching. He held an interest of almost 25% of the stock company, when it was founded. His *position* in the field of cellulose fibers can be described as a lateral entrant, but he can also be characterized as a multiply embedded actor, as a result of many start-up activities in different industries. The *motivation* of Mr. L did not arise from any economic motive. Rather, it can be described as an intrinsic motivation. At this time he was 51 years old and had earned enough money by his former entrepreneurial ventures to retire. When he met Mr. R, he had already taken a break of three years from any business activity. He was fascinated by PrivIn’s platform technology and its numerous fields of application. While Mr. L was enthusiastic about the fibers, he was nevertheless aware of this huge effort to exploit this opportunity successfully. He felt challenged by this risky situation that no one else in the industry felt encouraged to join this venture.[61]

Before Mr. L decided for participating in FuncFiber, he talked to a chairman of the monopolist who recommended this venture in case the spin-off was able to produce it. At this time the monopolist was neither able nor interested in doing it. Mr. L was optimistic, because in one case of additives the institute had already succeeded in

[60] This is also a weakness that researchers have, because researchers usually are seen as risks, and as soon as they utter the word risk when money is around, the money is gone (translated by author).

[61] „Weil, ein guter, cooler Geschäftsführer und Macher hat in der Regel seinen Job. Der hatte Glück, dass ich meine Firma verkauft hatte und gesagt habe, ich mache drei Jahre nichts. […] Aber ich sage mal, ein anderer kann das sicher genauso oder besser als ich. Aber man muss unglaublich viel Einsatz bringen, nie über Zeit nachdenken, auch an Wochenenden unterwegs sein. […] Ich fahre im Monat 15.000 km auf der Straße plus Flüge. Hey! Das muss alles egal sein. Aber ich tue es, da kommen wir auf einen wichtigen Punkt, weil ich unheimlich Freude daran habe.“ (Mr. L) [Translation by author: Since a good, cool executive director and man of action normally has his job. He [Mr. R] was lucky that I had sold my company and said I was doing nothing in the next three years. […] But let’s say, somebody else can surely do it like me or better than me. But you must put your back into it, never think about time, be on the road on the weekends as well. […] I drive 15,000 kilometres a month plus flights. Hey! You shouldn’t care. But I do it – here we get to the point – because I terribly enjoy it.]

producing this fiber type in a pilot plant in a small batch size. Another type with climate regulating additives promised to be even more expensive and profitable. There were no practical values for the technology and fiber type in industrial scope yet, but a market for climate regulating clothing and textiles had already emerged. Mr. L conducted an own market analysis for six months and finally recognized a market opportunity.[62] For most cases, Mr. L assessed no competition for the new technology of additives with respect to existing functional fibers and technologies.

Mr. L has no formal *education*. He broke off his secondary education and a professional education as a mechanic, and worked as a vendor and purchaser without any formal commercial apprenticeship. He picked up his commercial know-how on the job. At the age of 22, he founded his first company. Before the establishment of FuncFiber, Mr. L sold a former start-up to a leading company for metal fittings and took a timeout from business. In total, Mr. L has been an experienced entrepreneur for 36 years. He founded 14 companies in different industries like IT, electronics, communications, publishing, leasing services, but he had no business experience in the fiber or textile industry so far. With this work experience, Mr. L felt not comparable with a studied business economist or a skilled "simple merchant who approaches as required at school. This is not my case." In turn, he stressed a slogan, his personal motto, that he had picked up in a sales training when he was young: "Do everything different than others." His entrepreneurial attitude shows up in his several founding activities. After he had established a firm successfully, he sold it again for financing the next, larger venture. This attitude of financing independently from any credits only for the initiation of the business also arose from negative experiences with banks.

During the entrepreneurial process of FuncFiber, he experienced "a whole new world" in the fiber and textile industry. On the one hand, he learned about chemistry and fibers; on the other hand, he felt a huge difference in the actors' speed of decision making compared to the electronic and IT industry. "[…] [E]s war für mich schon heftig, aus einer Welt zu kommen, wo alle, die ich als Partner hatte, ultraschnell Entscheidungen getroffen haben. Und da, in der Textilwelt, geht eine Entscheidung mitunter ein Jahr."[63] (Mr. L) According to him a "Zockermentalität", a gambler's mentality, was necessary for this venture. In the field of textiles he was considered a "verrückter Hund" [mad dog] that the industry had missed. In his opinion, most of the established firms are missing this mentality and courage for fast decision making as well as the sensitivity for new markets.

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[62] „Aber ich kann in den Laden gehen, in ein Sportgeschäft, und ich kann da hingehen und lese auf Produkten, wie Sie auch, auf Schuhen oder Jacken, klimaregulierend, Wohlbefinden, alle reden darüber. Der eine macht Luftschlitze da rein, der andere macht Membrane da rein, aber niemand reguliert das Klima. Also ist da ein Markt. Das ist einfache Logik." (Mr. L) [Translation by author: I can go into stores, into a sports outfitter, and I can go there and read the product labels on shoes or jackets, as you can do. Climate regulating, wellness, everyone is talking about this. One puts in venting slots, another one uses membranes, but no one is regulating the climate. So there is a market. That is simple logic.]

[63] It was fierce for me to come out of a world where everyone I had as a partner made ultra-fast decisions, and in the world of textiles a decision occasionally takes one year (translated by author).

Mr. L contributed mainly with his marketing, communication and creative *skills* to the KIE process of FuncFiber. More precisely, he was able to explain things very well. This was a basic requirement to convince potential buyers with limited knowledge in this new technological field. The fact that the lateral entrant had to learn the technological process as well gave him the advantage of explaining the new fibers more empathetically to customers and users. Mr. L's creativity was especially important for the implementation and legitimacy of the fibers. Probably because he was less embedded in science and the fiber industry (cf. Maguire 2008: 675), he was able to translate the fibers' new features into concrete consumer products that illustrated their economic value. His capability of building networks was another crucial skill for the market introduction of the fibers. As a lateral entrant, he had no previous business contacts in the textile industry. Above all, Mr. L's *social capital* was a necessary condition in the entrepreneurial process. He was aware that the introduction of the fibers and the establishment of FuncFiber would need another huge amount of seed capital. For that reason, he convinced Mr. R to found FuncFiber as a stock company where he and friends from his previous social network invested. Without these contacts it would not have worked out and he would have never started it. Mr. L had known these friends for many years. They are former or retired CEOs and CFOs from large manufacturing companies with sufficient resources at their disposal for such risky investments.

Notable for the two entrepreneurs is that they both came from the so-called periphery or fringes of the textile fiber industry: One from the applied science and one as a lateral entrant. Following the institutional entrepreneurship literature (Pacheco et al. 2010: 986), for that reason both were not socialized in the halting industry's investment and innovation practices and thus more likely to question and deviate from them than long-term field participants.

5.1.6 The KIE process

After Mr. R had decided to exploit the new technology in a spin-off, he got in touch with Mr. L through a common contact of the growth project. Mr. L indicated that he received a hint from a friend that PrivIn had to spin-out because of the high amount of invested research funds from the state and the European Union. A few months later, the collaboration was decided. Mr. R agreed on Mr. L's proposition of a legal stock company. The subsidiary MaTest held the main interest of 49% in the spin-off. The rest of the shares and stock capital was organized by Mr. L. From Mr. R's point of view, it was crucial not just to employ somebody for the marketing but to offer investment in the business "weil er dann ein ganz anderes Interesse kriegt als nur als Angestellter"[64] (Mr. R).

[64] … since then he will have a very different interest than if he was merely an employee (translated by author).

In the KIE process of this case, a new organizational form as well as an institutional project and further mechanisms from the institutional entrepreneurship concept can be identified. The reason or object of a *new organizational form* was to appear in a convincing form at the customer market or to potential buyers. The institutional conditions referred to the expected suspicion of companies towards collaboration with research institutes and towards the use of scientifically created technological opportunities. The subsidiary MaTest had already existed for testing services and patent licenses of PrivIn. However, to convince investors for the commercial exploitation of the fibers, even the 100% testing subsidiary was not convincing enough, according to Mr. R. "Ich habe ein tolles neues Produkt und das verkauft die [MaTest]? Klingt ein bisschen langweilig, oder?"[65] For Mr. R, it was quite important to create a new organization sensed as a company with an independent structure on the market; "damit wird es auch im Markt ganz anders sichtbar, […] wird als echter Partner akzeptiert"[66]

(Mr. R). Nevertheless, the subsidiary MaTest was necessary as an investor, because PrivIn was not permitted to act as a non-profit organization. Finally, in the outsider's view it was not a testing company anymore that produced the new products. The manufacturing was formally transferred to FuncFiber with an own market focus and different possibilities for growth. In practice, the facilities of MaTest were further used and rented out to FuncFiber. This way, FuncFiber could acquire other, private investors.

In order to *mobilize* supporting allies, PrivIn and MaTest took first risky steps of entrepreneurial experimentation, such as the first processing of the fibers in a pilot plant so that first applications could be presented to potential buyers. Necessary investments at this early stage were financed by MaTest and publicly available funding, because economic investors could not make any profits at this stage, according to Mr. R's argument. Because FuncFiber could rent the already installed (pilot) plant from MaTest, the seed capital was reduced almost to the costs of the company's registration. This way, investors should be attracted before the foundation.

> *… normal läuft das ja sehr klassisch ab: ich hab eine Idee, mache diese Gründung, hab die Gründungsfinanzierung. Dann habe ich die erste Zwischenfinanzierung noch mal und dann komme ich irgendwann in so eine Wachstumsgeschichte. Was wir machen, wir schneiden eigentlich diesen Ast eins und zwei ab. Wir steigen schon bei drei ein.*[67]

This strategy enabled FuncFiber to produce and to deliver potential customers with first exemplary material right from the beginning. In case something went wrong, then nothing more than a sales company is buried, according to Mr. R. Following him,

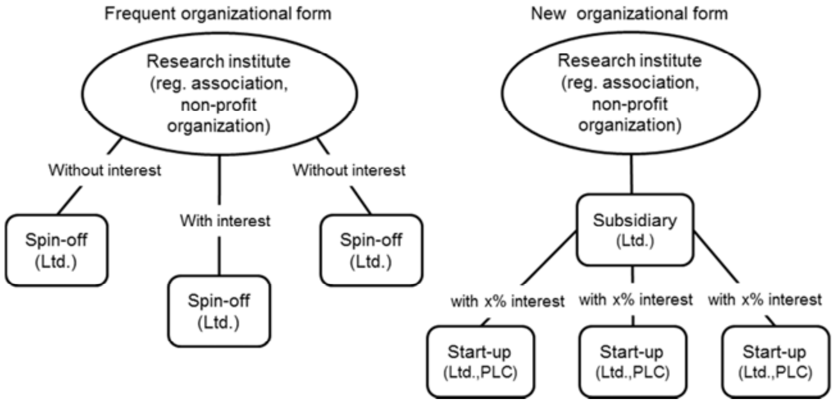
65 I have a great new product that is sold by the MaTest, a material testing company? Sounds a little bit boring, right? (Translated by author)

66 … therewith, it will become differently visible on the market, [...] will be accepted as a real partner (translated by author).

67 Usually it works out very classically: I have an idea, do this foundation, have the seed funding. Then I have the first interim financing again, and then some when I'm entering this growth story. What we are doing is we actually cut off this branch one and two and we already step in at three (translated by author).

other research institutes as non-profit organizations or non-profit companies, at least in Eastern Germany, were said to be closely interconnected with their spin-offs so that they did not have this exit option. This way, the new organizational form was *deviating* from the common institute's transfer and outsourcing practices (cf. Figure 20/21). This organization was not only applied in the case of FuncFiber; afterwards, PrivIn and MaTest organized further spin-offs in other fields of application (cf. ibid.).

Fig. 20 Common academic spin-offs vs. new organizational form



Source: Own illustration.

With this new organizational form, Mr. R was responding to the hesitating investments of the existing actors in the fiber industry. He reduced the risk and financial burden of the small and medium-sized enterprises through shifting them into a form of cooperative relation where MaTest was carrying the risk that was reduced by public funding for the first stage. Compared to existing industrial firms, MaTest had the advantage of being well versed with possibilities of the discharge head and hierarchies in public funding for firms doing research. From the point of MaTest and PrivIn, the risk of investments was relatively limited, because their purchased equipment could be used for further exploitations of the platform technology. After FuncFiber had sold a few tons on the market, its value was significantly rising for further investors or potential buyers.[68] With this strategy, a market should be established. After

[68] „[W]enn wir jetzt zu BASF hingehen und sagen, wir haben da so eine Idee, dann sagen die: ‚na ja, wie viel? 50.000 Euro? Na ja, da geben wir auch 20.000 dazu oder so. 'Wenn der Markt aufgebaut ist und die Firma hat einen Name, dann sind das etwas größere Beträge, über die man hier redet, wenn man sich hier einkaufen will." (Mr. R) [Translation by author: If we go to BASF and say, we have an idea, then they say: 'Well, how much? 50,000 Euros? Well, we give 20,000 or something.' If the market is built and the firm has a name, then there are higher sums you are talking about, if one wants to buy in here.]

FuncFiber had entered the next level of the growth phase, it should have been offered for sale to larger companies on the market. Those firms had different possibilities to finance higher investments in machinery and equipment at the industrial scale, e.g. a scale for weighing 5,000 tons. “Das ist auch der Punkt, wo dann ich und [Herr L] aussteigen, weil das dann nicht mehr unsere Spielregeln sind.“[69] (Mr. R) In other words, the new organizational form was created for handling the risk and uncertainties of the commercialization of technological and market opportunities. The research institute conducted not only research activities, it also took over entrepreneurial experimentation (cf. Bergek et al. 2005; Carlsson/Jacobsson 2004). This way, necessary resources and new supporting actors were organized for the spin-off.

The new organizational form was a necessary but not sufficient step in the establishment of FuncFiber. The original plan was that a sales company should market five tested types of fibers in the field of industrial functional applications without an own production facility. These specific industrial fibers were only produced in very small batches that could be taken over by MaTest’s pilot plant. It should start with the most profitable antibacterial fibers. When Mr. L began to market the fibers, he firstly learned that his sales activities addressing yarn producers were useless. They were not able to sell such yarns with the innovative, higher priced fibers to the next buyer in the supply chain. Then Mr. L addressed his efforts directly to textile manufacturers or end-producers. But here he also had problems to convince potential users. He tried to directly establish contact with the CEOs and high-level decision makers. Many of them declared him insane. Antibacterial textile material had already emerged on the market (cf. Mieck 2001: 72/77), but based on different material or technology. Hence, he was the hundredth salesman who tried to sell something in this field the customers were tired hearing of. First fails and the absence of a dominant technology had caused uncertainty in potential customers and a barrier for new entrants like FuncFiber.

Acting from this necessity, the idea of an antibacterial cleaning towel made of the new fibers came to Mr. L’s mind. “Das habe ich aus Spaß gemacht, um die Wirkung der Faser zu zeigen.“[70] (Mr. L) This way, he illustrated the superior features of the new fibers/material as a unique selling point. Hence, he succeeded in what Walgenbach and Meyer (2008: 142 et seq.) had called linking innovation to “known structures of meaning and value”. Mr. L used the known cleaning functionality and framed the new, complex technology of additives and their antibacterial fibers into a simple known product: a cleaning cloth. Apart from the common cleaning towels, its antibacterial property lasts for one year. Then he let it be produced in a small batch by a manufacturing partner and used it for demonstration at his customer pitches. One potential customer manufacturing clinical textiles and clothing referred back to him half a year after Mr. L’s first attempt.

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[69] That is the point where Mr. L and I exit, because then it is not our rule of the game any longer (translated by author).

[70] I did this just for fun to show the effect of the fiber (translated by author).

Er sagt, ‚ich habe ein Problem. Ich habe diese Tücher meiner Frau gegeben, die will nur noch diese Tücher haben. Wo kann ich die kaufen?‘ – Da habe ich gesagt, okay, die COOP hat gerade 70.000 Packungen gekauft. Kaufen Sie es da.‘ Da sagt er, ‚[Herr L], noch etwas, ich möchte Ihnen jetzt einen Termin geben. Sie sind der erste, der nicht gelogen hat, wir arbeiten ab jetzt zusammen.‘[71]

With this idea of a simple consumer product, the new fiber was what Pacheco et al. (2010: 990) also described as closely incorporated “with commonly accepted narratives”. Moreover, this framing activity laid the ground for the fibers’ and FuncFiber’s legitimacy on the customer market. In conclusion, this initiative turned out a successful *institutional project* for the establishment of FuncFiber’s innovation.

Further notable is that not necessarily typical theorizing *mechanisms* like, for instance, scientific measures were needed. Rather, a crucial condition for professionalization to convince customers and supporting partners was proving the professional application and functioning of the new fibers in a product that FuncFiber was capable of setting up and selling on the market. Thus, theorizing in this case did not mean a particular scientific background or proofing. In its place, the new functional fibers had to be practically proven “in such a way that it will resonate with the interests and values, and problems of potential allies” (Leca et al. 2008: 12) from the industry.

The institutional project finally led to an extension of FuncFiber’s former business strategy, “weil Konsumerprodukte mit solchen Alleinstellungsmerkmalen, das konnte niemand anderes, das konnte niemand so richtig schön nachmanchen […] und das hat die [Investoren] schon begeistert.“[72] (Mr. R) In consequence of the cleaning towel project, the chairmen decided to base their business not only on the production of fibers but also on the launching of further consumer products.

[…] das war die Idee von dem Herrn [L]. Also […] der geniale Weg, den der Herr [L] gesehen hat, indem er gesagt hat, ‚okay, mit dem bisschen Faserproduktion kann ich zwar auch ein paar Euro verdienen, aber das wird es nicht sein. Ich muss eigentlich aus dem, was ich jetzt an tollen Materialien habe, an Fasern, muss ich eigentlich eigene Endprodukte kreieren als kleine Firma‘.[73] *(Mr. R)*

Afterwards, the patents of the new end-products were planned to be licensed to big companies, because they promised a comparably higher income than just for the fibers, according to Mr. L. The reorientation of the business strategy was conducted together with the three chief partners of the stock company (FuncFiber). The con-

[71] He said, ‘I have a problem. I gave these towels to my wife. She only wants to have these towels now. Where can I buy them?‘ – Then I replied, ‘ok, the COOP has just bought 70,000 packages. Buy it there.’ Then he answered, Mr. L, ‘one more thing, I would like to arrange an appointment with you. You are the first who did not lie to me. We will collaborate from now on’ (translated by author).

[72] ... because consumer products with such unique characteristics that no one else could do, no one else could really imitate well [...] that has fascinated them [the investors] (translated by author).

[73] That was the idea of Mr. L. Well, […] the brilliant way that Mr. L saw by saying, ‘ok, with this small production of fibers I may earn some Euros, but this won’t do. Actually, I must make something out of the material that I have […] of these fibers, I actually must create own end-products as a small company’ (translated by author).

sumer products strategy implied that a new, bigger amount of fibers with a fuller volume was necessary. The first idea of the decision makers was not to invest in a new facility but to let the monopolist produce the higher amount of fibers. The monopolist, however, was technologically not capable of producing these fibers in its plant. At that time, the plant of the subsidiary JoVen of the plant construction firm (PlaCon) was offered for sale. FuncFiber took over the plant and parts of the staff. Those and Mr. R mainly contributed to developing and establishing the new process in the production plant. Although the price for taking over the existing plant was certainly cheaper than building a new plant, the investments amounted in the single figures of millions. Unexpectedly, it took one year and further huge investments for the development and necessary adaptations before the full volume fibers could be produced in the plant. This illustrates another time the high barriers of innovation in manufacturing. Additionally, it shows that the indecision and risks of potential buyers from the beginning were not unreasonable. On the other hand, it demonstrates the high value of Mr. L's social capital, since it was very likely that other investors had exited in such a situation. In its place, Mr. L was able to organize additional, necessary investments.

Moreover, it finally illustrates the critical importance of the relations to the research institute. Due to the constellation of the personal union of Mr. R as the chairman responsible for R&D at FuncFiber and his position as the research director of PrivIn, the spin-off had an excellent access to new scientific developments for the setup of the fiber production and product development.[74] FuncFiber's R&D staff carried out product improvements and product development based on existing technologies, while PrivIn further developed the whole process technology. The spin-off's access to these developments was arranged in a license agreement. Accordingly, new developments in the field were firstly offered to FuncFiber. On the other hand, Mr. R stressed that in case FuncFiber decided on this new development, they had to prove that there was a certain market volume and that MaTest could expect certain revenue from this licensing.

Notable for this case was the completely new strategic orientation during the entrepreneurial process. FuncFiber turned from initially being a sales company for specific fibers into a manufacturing company with an own facility and a considerably broader introduction of functional fibers on the market. In the following, further consumer products in the field of clothing and household textiles were launched based on Mr. L's creative ideas. Therewith FuncFiber took over development steps that are usually

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[74] "Also ohne diese Rückendeckung des Institutes zum Schluss [würde] das natürlich auch nicht […] funktionieren. Sie können nicht einfach nur ein Unternehmen gründen und dann sagen, ich hab da jetzt fünf, sechs Mitarbeiter und dann entwickle ich so eine komplizierte Technologie mit all den Anwendungen, die dahinter stecken. Mit diesen fünf Leuten? Das können Sie vergessen. Ich habe hier 160. Die arbeiten zwar nicht alle dafür, aber man kann immer wieder auf diese Wissensdatenbank zurückgreifen." (Mr. R) [Translation by author: Well, without the backing of the institute in the end, of course, this would […] not work out. You cannot simply found a company und say then, I have five, six employees and then I develop such a complicated technology with all these applications that are behind it. With these five people? You can forget about this. I have 160 here. Indeed, all of them do not work for this, but you can always have recourse on this knowledge base.]

done by manufacturers of end-products. In fact, FuncFiber still solely produced the fibers, whereas the following steps of manufacturing were outsourced to manufacturing partners. This was organized through Mr. L's and Mr. R's social networks. For sales, the small sales team of FuncFiber was internationally supported by salesmen working on commission. These relationships originated from L's social network as well. Altogether, these activities describe a process of a *new institutional arrangement* in the man-made fiber industry in order to establish new fibers on the market. This process was further accompanied and enabled by Mr. L's strategy towards existing actors in the field. First of all, he succeeded in building a coalition with the monopolist. The monopolist agreed on FuncFiber's strategy of serving a very small market of industrial applications. The monopolist itself had neither the technological capacity nor an interest to invest in this. Following Mr. R, a clear contractual base was established. FuncFiber agreed on a license contract because of the similar basic processing of cellulose fibers. Later on, the monopolist received some plant construction patents that FuncFiber purchased from the buy-in of JoVen. In turn, FuncFiber was free to extend production capacities from this point on. In addition, they agreed on a cooperation and commercialization contract where both parties recommend each other in their distribution and sales activities. FuncFiber referred to the monopolist on its website, for instance.

The next critical aspect with respect to the discursive dimension was FuncFiber's strategy towards customer markets. Based on the experience that Mr. L had made in previous ventures, he purposefully decided against the exploitation of the fiber types for industrial (high-tech) applications.[75] In its place, he turned towards the clothing industry, because this industry was used to reacting more quickly to the market. Innovation cycles and developmental periods are shorter due to seasonal consumer demands in contrast to technical applications in the industry.[76] This way, he turned towards an established sub-industry with existing frames and habits that were more compatible with his ideas and expectations about time to market. Another thing was to concentrate on customers that had already focused on established high-price market segments with low purchasing volumes so that FuncFiber could realize high prices as well. "Wenn Sie eine 4000-Tonnen-Anlage dann bauen müssen, plötzlich 4.000 Tonnen unters Volk bringen müssen, da bekommen Sie Preisdruck. Da spielen die

[75] „Da habe ich viele Anfragen. Die wollen mit uns arbeiten. Ich lehne es ab. Ich sage, ‚hey Leute, ihr entwickelt mit uns, ihr raubt mir viel Zeit.' Ich habe früher mit solchen Leuten gearbeitet, mit der Elektronik, und kenne es daher. Das Letzte, wenn es fertig ist, wollt ihr mich an die Wand drücken […], weil es muss immer billig sein." (Mr. L) [Translation by author: There have been many requests. They want to work with us. I say, 'hey guys, you develop with us, you take too much of my time.' I worked with many of such people in electronics once and thus know it. The last thing is, when it's ready, you want to squeeze me against the wall [...], because it must always be cheap.]

[76] "Ich mag Leute, die kreativ sind. Die Modeleute sind klasse. […] Die sind so schnell und die bringen jedes halbe Jahr eine neue Kollektion. […] Die passen zu mir." (Mr. L) [Translation by author: I like people who are creative. The fashion people are great. [...] They are so fast and every six months they launch a new collection. […] They fit in with me.]

anderen Leute mit Ihnen, die Einkäufer. […] Es geht nicht um Masse. Wir müssen nicht die Größten werden. […] Wir wollen fein sein.“[77] (Mr. L)

Although manufacturers of fibers are usually positioned at the very beginning of the textile supply, the marketing of FuncFiber was not directed towards processors from the next level of the value chain, e.g. yarn producers or spinning mills. Instead, FuncFiber bypassed the hierarchical business relations of the supply chain and talked directly to clothing and textile manufacturers or outfitters. Once a clothing manufacturer had been won over to produce new antibacterial socks with the innovative fibers, a spinning mill was charged to process the fibers into the yarn. Without this backward-initiated demand, the spinning mill could not have been convinced to buy and use the innovative fibers. Moreover, in many cases, Mr. L identified a weakness of these processors in marketing such high-price material. He could fascinate them about the new fibers and potential product innovations, but then they were not capable or did not have enough financial resources for promoting such new upstream products.[78] To win these potential buyers anyway, Mr. L decided to support them in their marketing activities. What was probably helpful for Mr. L again was the fact that his wife started working as a marketing professional at FuncFiber. This support was not only addressed to the next processors of the value chain. The marketing department of FuncFiber also worked for textile manufacturers. In the case of launching new pants made of fibers with zinc additives, FuncFiber developed a tag equipped with nutritional supplement tablets of zinc, for instance. This nutritional supplement tablet that customers consume should convince especially sensitive target groups of the tolerance of the new antibacterial material compared to conventionally used triclosan for antibacterial properties. Here, again, it was important to translate the complex new functions of the fibers and the new product comprehensibly to customers upstream the value chain and to consumers. The use of extraordinary advertising gimmicks to market complex functional product innovations are also indicated in the textile literature. Reinhold (2003: 220) recommends such collaborations between textile manufacturers and producers of fibers for the development of marketing material.

Finally, the reach of an institutional threshold for the new fibers and the legitimacy of FuncFiber can be assessed with regard to the monopolist as well as the customer market. Because of rising orders, FuncFiber was stretched to its limit of production capacity and extended the cooperation with the monopolist. Since 2011, the monopolist proceeds to produce the new fiber type of FuncFiber. The company’s plant was transferred to the monopolist’s location. This means that the technology and new

[77] If you have to build a plant for 4,000 tons, suddenly place 4,000 tons on the market, then you get pricing pressure. The other people, the purchasers, play with you. It is not about quantity. We do not need to become the biggest. We want to be discriminating (translated by author).

[78] “Die können das nicht. Die haben das Geld nicht für eine gute Agentur. Also muss ich viel unterstützen und muss das bringen. Und das mache ich halt. Und das kann ein Institutsboss nicht oder ein Techniker.” (Mr. L) [Translation by author: They are not able to do it. They don’t have the money for a good marketing agency. So I have to support them a lot, and this is what I do. And this cannot be done by any institute’s boss or technician.]

practices took another step towards institutionalization of a common product-field specific knowledge base beyond the scope of FuncFiber.

5.1.7 Conclusions from the case of FuncFiber

The case of FuncFiber illustrates that new scientific knowledge is important for new technological developments in the textile industry, but not sufficient. The entrepreneurs overcame the restrictive environmental conditions through institutional entrepreneurship activity, creating a new organizational form, an institutional project, and deviating from existing institutional arrangements.

The deviation from established practices to functionalize fibers through specific additives randomly occurred during research activities on cellulosic fiber at a private research institute. It describes a case of exaptation where randomly new functions of cellulose fibers were discovered, which high absorption and keeping of functional additives are superior over conventional fibers and technology. The trigger for KIE activities at the research institute were on the one hand expectations of a public funding agency from the national innovation system, and on the other hand cuts in general public funding for private research institutes. Hence, a form of crisis stimulated the actor's entrepreneurial action and the motivation to become more independent from changes in public funding.

The case illustrates that discoveries in science and new resulting scientific knowledge alone are not sufficient for KIE. The inventing institute could not found any interested company, although a technological and market opportunity existed for the commercialization of the innovative fibers. Even though the environment of the man-made fiber industry did not support KIE in terms of mutually corresponding technological, market and institutional opportunities, the entrepreneurs succeeded in establishing their innovative fibers and let it finally be produced by the monopolist of the affected market segment. The missing systemic entrepreneurial opportunity and orientation of the man-made fiber industry was overcome by actors from the periphery and a field external entrepreneur. They were more risk taking and prone to initiate KIE than the established monopolist (cf. Dorado 2005: 405).

The most challenging factors have been the financing for the commercialization, the transformation into a manufacturing process of industrial scales, and to convince reluctant customers from the textiles markets. Both entrepreneurs contributed with crucial, complementary resources to the KIE process. Mr. R developed a new organizational form to win over investors and later organized the setup of the manufacturing process in industrial scales. Mr. L organized the further necessary financial resources and contributed to the market introduction with his creative and communicative entrepreneurial skills.

Notably, the established industrial actors from the textile industry were neither willing to risk nor able to exploit the new scientific knowledge for this market niche – despite the opportunities existing in the TIS. In this context it is referred again to Radosevic (2010) who stresses that market articulation is usually underdeveloped in changing industries and new technological fields. However, the entrepreneurs overcome this kind of mismatch, developing consumer product innovations. They illustrated the invention's superior benefits and economic value of the various complex technological opportunities. Through this institutional project and professionalization, the innovative fibers as well as the new firm gained legitimacy on the customer market. The customer market was characterized by uncertainty due to various new technologies and failings so that the customer firms were suspicious about the next innovative fibers. The experienced entrepreneur applied two strategies, on the one hand, the marketing activities departed from the institutional arrangement of established interactions, following the uni-directional division of labor along the textile supply chain (textile pipeline). Mr. L directly addressed manufacturers of consumer products. Once these powerful actors had been won over, their legitimacy and demand helped the new firm to persuade the rest of processors from in between the supply chain. This way, the interests of fragmented groups and actors were aligned. On the other hand, FuncFiber persuaded these processors by supporting them in the marketing of their new products. Based on these strategic mechanisms, the difficult environmental conditions were unconventionally overcome.

What remains to finally point out is that the experienced entrepreneur preferred to implement the technological innovation at the clothing industry instead of any high-tech customer market, because it better corresponds with his perceptions on time to market and profits. This is an interesting aspect, as it is contrary to the widely held assumption on low-tech industries' benefits through collaboration with high-tech industries.

5.2 The case of E-Thread

This case was identified through internet research with the words 'pioneer', 'innovation' and 'textile industry' which led to an article about a federal state's innovation award that the company (E-Thread) received for collaborating with a service provider for innovation.[79]

In this case, KIE emerged through collaboration of a traditional producer of elastic threads and a service provider specialized in innovation processes of SME after the low-tech firm could not find any research institute for cooperation. Hence, the case of E-Thread can be considered complementary to the first case where a research institute could not find any interested party from the industry.

[79] For this case study, the managing director (first contact in November 2010, 1.5 hours) and the former manager of the new business unit (1.5 hours) were separately interviewed in January 2011. In addition, two managing directors of the partner company involved in the innovation process could be interviewed together (2 hours) in January 2011.

In the course of the corporate succession, the initial family business, fictionally named E-Thread, became part of a shareholder group as a legally independent subsidiary. In the 1990s, the group made significant investments in new machines, equipment and facilities on site. These investments were related to the shareholder's expectation of significant following innovation activity, because the firm's main product, elastic compression stockings, had entered an advanced product life-cycle. Against this background, the collaboration with the service provider, fictionally named InnoServ, started at the end of 2001. Four years later, a new business unit was established at E-Thread to market the newly developed conductive flexible yarn that was patented in 2006. In the following, four applications were introduced on the market as trademarks.

Knowledge-intensive activity occurred through the development and introduction of a new, electronically conductive flexible thread. It is unique in its construction and features in the emerging industrial fields of so-called conductive textiles and wearable electronics. Other conventional metal-yarn combinations, for example in the field of fencing clothing, do not provide the sufficient flexibility, conductivity, processability or have a limited washability. In the process of knowledge-intensive activity, existing sectoral- and firm-specific knowledge in elastic thread production of E-Thread was newly combined with electronic knowledge. Between 2002 and 2003, the innovative thread was invented in collaboration with researchers from InnoServ. Subsequently, different applications were developed in several cooperative research projects with research institutes and potential customers from the textile, biomedical as well as automotive industry.

E-Thread was founded in 1953 as a family business in the South-West of Germany. In 2009, it employed 83 mostly skilled and semi-skilled employees; the small company has a low fluctuation rate. The main products presented on the firm's webpage are medical threads, threads for socks, flat knitting and, since the KIE process, also technical threads. Beforehand, the small company was specialized in elastic thread for compression stocking. Nowadays E-Thread defines itself as a quality supplier of special yarn, especially elastic thread for niche applications. The manufacturing of E-Thread is classified as so-called secondary spinning process, whereas FuncFiber applies the primary spinning process (cf. Figure 07). Accordingly, the main suppliers are fiber producers. The main customers are manufacturers of compression stockings, woven-products and fabrics. The innovative conductive and elastic threads opened up new fields of application in the automotive, biomedical and technical textiles markets.

5.2.1 Sectoral knowledge base and technological opportunities

The sectoral knowledge base of the thread industry draws on a long manufacturing history and established technological domains. However, the emerging field of textiles with technical functions offered a technological opportunity to thread producers as well.

As shown in the textile knowledge base (Figure 07), yarn or threads build the basic starting material for products in the textile supply chain. They are produced through spinning processes of fibers and twines. The *knowledge domain* of industrial spinning has developed since the beginning of industrialization in Europe (Schenek 2006: 8). Various types of yarn, basic materials and process technologies (ibid. 9 et seq.) show the advanced stage of this sub-sectoral knowledge base. The technical lexicon (ibid. 181 et seq.) distinguishes, for instance, several types of yarns by origin of material (silk, man-made fiber, cotton), way of manufacturing (winding, air jet spin process), refinement or type or twine. It refers to the DIN standard 60900 from 1988 to describe these basic characteristics. The last additional part to the DIN standard for "systems of concepts according to spinning process" is from 1990. Hence, major changes in types or basic spinning processes have not emerged since that time.

The main product of E-Thread is elastic thread described as specific yarn with high elastic and good recess properties (Schenek ibid. 130).[80] The established process technologies for this specific type of threads are winding and air jet spin processes (ibid. 130 et seq.). The first elastic yarn was developed for tights with a texturizing process technology. Texturized polyamide and polyester yarn are more widespread, because they are cheaper than elastic thread (ibid.). Elastic threads are commonly applied in stretch fabrics, elastic knitwear, corsetry, support tights, support stockings, swimwear, medical bandages, stockings, sportswear or leisure wear (ibid.).

The general trend towards technical textiles can also be observed for threads (cf. Möhring 2006; Planck 2003). Textile experts indicated that functional textiles would not be thinkable without continuous further developments of fiber, yarn and material design (Knecht 2003b: 17). Because fibers and threads are important "Ausgangsmaterial" [primary material] (Schenek 2006: 7) for textiles, many new fibers and yarns were developed for the emerging field of functional textiles at the turn of the millennium (Planck 2003: 57). But again increasing efforts in knowledge creation cannot be deduced from figures of the companies' R&D investments. According to Eurostat's annual, detailed enterprise statistics for the sub-section 'preparation and spinning of textile fibres', the share of R&D expenditure in value added constantly remained at around 0.7% between 2000 and 2006 (cf. Table 5). Hence, this textile sub-industry corresponded with the common low-tech classification (below 1%). The companies' share of R&D employment stayed at around 0.5% in this time (ibid.). The basically low figures of the total intramural R&D expenditure reveal a declining trend. An explanation for reserved R&D activity on the side of the firms might again be that research institutes were the main source for the production of new technological knowledge in this field.

80 The stretch of this type of thread is higher than 25-30%; pure elastic thread can have a stretch up to 450% (ibid.).

Tab. 5 Thread industry's knowledge base measured in R&D indicators

Preparation & spinning of textile fibres in Germany	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Share of R&D expenditure in value added (in %)	0.7	0.7	0.8	0.7	0.7	0.6	0.7
Share of R&D employment (in %)	0.5	0.6	0.6	0.4	0.4	0.5	0.6
*Total intramural R&D expenditure (with thousand separator)**	4,2	3,7	3,8	2,4	2,4	2,0	2,2

**Unit of measure: Monetary data are expressed in millions of Euros (Eurostat[81]).*
Source: Eurostat (NACE code DB 171, Rev.1.1 D).

General literature on new developments of fiber and yarn in technical textiles (Planck 2003; Koslowski 2006; Möhring 2006) addresses refinement processes such as coating or specific treatment above all. Professor Planck (2003: 59), director of the Institut für Textil und Verfahrenstechnik Denkendorf (DITV), reports on threads with softer surfaces due to improved spin technology or a function of shrinkage for specific industry application. But in case of the new, conductive function he only responds to developments in fibers, for example to metal fibers and metalized fibers (ibid.) to avoid static charge, provide supply with energy or transfer data (ibid. 61). Rather than threads, fibers seem to be the first starting point in research on electronic textiles at that time.

In the specific new field of conductive textiles, different ways of textile electronic combinations were approached. Thereof, “textile-adapted”, “textile-integrated” and “textile-based systems” can be distinguished[82] (Möhring 2006: 318). These different systems point to an era of ferment in which no dominant technological design had emerged at that time. The state of the art reveals limits of application of different approaches mainly driven by scientific research institutes. Since the 1990s, the institute for special textiles and flexible material (TITV), for instance, had researched on systems for the integration of conductivity in textile surfaces (Möhring 2006: 320). According to Uwe Möhring, director of TITV, these efforts early led to patents and first applications such as textile circuit boards (ibid.). But experiments with copper wire of high conductivity led to the insight that their application is limited due to their low

81 http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/EN/sbs_esms.htm#unit_measure, accessed 12/12/2013.

82 An example for adaptation or so-called transposition and translation (Maguire 2008: 675) is the re-use of cord lacing or facing ribbons that are equipped with wires (cf. Möhring 2006: 324). Here a round cord is connected to a flat cord and the wire needs only be added to the round cord (ibid. 324 et seq.). Examples for a textile-integrated system are, e.g. electronic components in clothing textiles to monitor body functions. (Planck 2003: 61). Textile based systems are, for instance, metal-covered fibers that are electrostatically charged (ibid.).

bend-break-resilience [Knick-Bruch-Beständigkeit] (ibid.). Other developments using covered metal wire, metal components or conventional yarn construction were not able to compensate the low power rating (ibid. 320 et seq.). Alternatively, another path of metalized fibers and yarns emerged. But material based on this alternative method had a low conductivity, as well (ibid.). For this reason, the institute developed electro-chemical treatment to raise the conductivity of such galvanized yarn. What remained was the problem of insulation (ibid. 322 et seq.) that the specific, winded design of E-Thread's elastic threads solved later on.

These technological developments being mainly driven by research institutes from the TIS, while the rise of the interdisciplinary micro-system technology offered new *technological opportunities*. Along with the emerging technological domain, researchers newly discovered the micro-properties of fibers and yarn and their advantages of higher flexibility or mechanical stability than other material used in electronic products. According to the director of TITV (Möhring ibid. 320), these properties could not be fully used, because the appropriate conductive material or components such as electrodes or sensors for microelectronic systems had been missing before. This emerging field offered opportunities and challenges (ibid. 318 et seq.) "dessen gesamtes Potenzial erst ansatzweise erkennbar wird"[83] (Meyer-Stork 2006: 45). Additionally, this new technological combination offered a broad variance in the fields of application (Möhring ibid.).[84]

In practice, textile adapted systems were mostly realized at those times. But the non-textile materials used could not be optimally integrated in textiles due to their disadvantages of being less flexible, less elastic and heavier (ibid. 319). "In vielen Fällen kann man nur von einem adaptierten System sprechen, welches auf das Textil aufgebracht wurde."[85] (Ibid.) As will be shown in the following, E-Thread's design of elastic and electrically conductive yarn particularly responded to the problems of bend-break-resilience, flexibility and isolation as a textile-based solution.

Although textile research institutes seemed to be mainly active in knowledge creation for this new technological field and patented their inventions, the technological opportunity for conductive elastic threads was given to firms in this field as well. Mr. IS1, the general manager of InnoServ (E-Threads cooperation partner), indicated that the invention of the conductive yarn had been possible in the 1950s when the basic pro-

83 … which potential [was] becoming just rudimentarily recognizable in total (translated by author).

84 „Die optimale Integration von mikroelektronischen Systemen in Textilien stellt jedoch eine große Herausforderung dar, bietet aber gleichzeitig große Chancen für die Erschließung weiterer Anwendungen von Textilien in der Technik. So sind textile Strukturen mit integrierten Funktionen von großem Interesse, die für lichttechnische Applikationen, Bus- und Heizsysteme sowie Sensorik angewendet werden können." (Möhring 2006: 318 et seq.) [Translation by author: The optimal integration of microelectronic systems in textiles depicts a huge challenge, yet at the same time it offers opportunities for the exploitation of further applications of textiles in technology. Hence, textile structures with integrated functions applied for lighting engineering applications, bus or heating systems as well as sensor technology are of great importance.]

85 In many cases it can only be referred to adapted systems that are affixed on the textile (translated by author).

cess technology of entwisted yarn was invented by the big chemical company Dupont. But no one had considered or exploited the advantage of the winding features for conductive yarn in this industry so far. This can probably be traced back to the argument of missing microelectronic components necessary for the threads' integration into electronic supplying systems (cf. Möhring 2006: 320). The technological opportunity was inter-subjective as a subsidiary of Dupont conducted similar efforts at that time; it actually applied a patent with different technical parameters a few weeks later than E-Thread. In conclusion, a technological opportunity existed because of the limited application of first approaches that focused on fibers and textile based systems, overlooking the opportunity of elastic threads.

5.2.2 Market conditions and market opportunities

The German manufacturers of threads were worse affected by market internationalization than the fiber industry. Hendrik van Delden (2006: 26) attests an "inevitable decline" of sewing threads along with the shrinking of the European textile manufacturers. As many buyers in the textile industry relocated their production abroad, they also started to purchase on site (Löbbe 2008: 13 et seq.). Hence, the initial outward processing was substituted by relocating the full manufacturing process to low-cost countries in Asia (van Delden ibid.). These difficult *market conditions* are confirmed by the annual detailed enterprise statistics. The number of firms preparing and spinning textile fibers into threads came down from 139 in 2000 to 93 in 2006 (Eurostat). The turnover decreased by around 32% from 1.9 in 2000 to 1.3 million Euros in 2006 (ibid.). Likewise, the production value declined from 1.8 to 1.2 million Euros in this period. Following the Gesamtverband der deutschen Textil- und Modeindustrie (2006: 47), the incoming orders for spinning relate to this negative trend. While in 1996 the orders amounted 15.3% higher compared to the benchmark year of 2000, it was only 64.8% of the benchmark's rate in 2005 (ibid.). The import prices for textile spinning material and yarns slightly decreased by 2.4% between 2000 and 2005 due to market internationalization (ibid. 50). However, import prices for synthetic spinning material and yarn increased by 15% in this period. Manufacturers of threads faced declines in demand and could not benefit from partly falling import prices of their buying material.

In the case of elastic threads, the pressure on customers to relocate their production was also foreseeable for E-Thread – at least in the common fields of socks and lingerie. Following the product-cycle theory, E-Thread's main product of surgical stockings was expiring and promised no longer significant growth rates. Nevertheless, threads for medical or technical textiles remained on some niche markets. Regine Schulte Strathaus (2003: 173) still mentions surgical stockings besides textiles for allergy sufferers or dermatological textiles in her report on medical textiles. She identifies a general growing offer and demand in the field of medical textiles, e.g. deep vein thrombosis stockings for frequent flyers (ibid.). Thus, there was still demand in some high-price market niches for high-quality textile products. More generally, van Delden (2006) attests producers of technical threads and ropes a relatively secured position in niche markets, as quality and reliability of threads in those technical or medical applications are of vital importance. These niche applications are sold on high-price markets but with a sufficient seize for profit margins among the few surviving specialists on the domestic market.

Especially elastic conductive threads open up several *market opportunities* regarding the substitution of existing technologies in established markets (e.g. in the field of electric blankets) as well as opening up new markets (data transport through conductive textile fabrics) for E-Thread.

5.2.3 Institutional environment and institutional opportunities

The institutional environment of E-Thread can be characterized as highly institutionalized and by institutional barriers for KIE, but likewise stimulating due to economic *crisis*. The yarn industry was probably affected by the crisis in the textile industry more than other sub-sectors. The production of textile material from the beginning of the supply chain was first and more easily taken over by producers in low-cost countries. Additionally, many buyers of threads relocated their production abroad and started to purchase on site (Löbbe 2008: 13 et seq.). In case of E-Thread, at least the critical situation led to questioning existing economic practices.

Starting with relevant *informal institutions*, a generally innovation-hostile culture of price calculation is to be mentioned that corresponds with vertically disintegrated institutional arrangements. The clothing industry as the biggest purchasing industry of threads follows a particularly restricting price calculation policy. Producers of textiles usually receive about 20% of the consumer prices (Froitzheim 2009: 2), which is further passed upstream to thread producers. Retail usually calculates with high gross margins, as it fears losses after the end of season (cf. ibid.). According to the managing director of TITV, the "Bekleidungsindustrie baut gern Zusatzfunktionen ein, bleibt aber bei ihrer Kalkulation […] sie sind auch meist nicht bereit, die Entwicklungskosten zu tragen"[86] (Möhring in Froitzheim ibid.) The external development partner of E-Thread explains the consequences of this informal practice:

> *Das ist ein Spezifikum in der Textilindustrie, da wird das knochenhart einfach sozusagen multipliziert über jede Wertschöpfungsstufe. Der Einkäufer schlägt noch was drauf und der Nächste noch mal und noch mal und noch mal. Und selbst wenn man [die Technologie] 20 Euro zusätzlich kostet, die kostet dann im Geschäft auf einmal 100 oder 150 Euro zusätzlich. Und da kann auch keiner über seinen Schatten springen und sagen, okay, es ist immer noch dieselbe Jacke oder ich verdiene immer noch an der Jacke gut, dass sich die jetzt vielleicht einfach besser verkauft und jetzt speziell an dem Akku möchte ich jetzt nicht auch noch mitverdienen. Aber das ist praktisch nicht durchsetzbar in den Handelsketten. (Mr. IS2, managing director of InnoServ)*[87]

[86] The apparel industry likes to integrate additional functions but remains at its calculation […] [and is] usually not willing to carry the expenses of development (translated by author).

[87] This is a peculiarity of the textile industry. It is ruthlessly multiplied across each value-added step, so to say. The purchaser is adding, and the next again and again and again. And even if the tech-

E-Thread and InnoServ were probably not conscious about the effects of this habit on their innovation venture. E-Thread had no experiences with such distinct developments and their calculation through the supply chain before the KIE process. The same holds true for InnoServ as a lateral entrant into the textile industry. According to Mr. IS2, the majority of textile companies gain for cost leadership but not for innovation leadership. In accordance with the "Tayloristic structures" of low-tech firms (cf. Hirsch-Kreinsen 2005: 158), the pressure on efficiency at the firms was most innovation-hostile, as the other managing director (Mr. IS1) added:

> *Die sind ja bis auf die letzte Ausfallminute am Tag durchstrukturiert und die hängen überall die Dokumentation der Ausfallzeiten von Maschinen und sonst was raus. Und das ist ein Denken, das ist dann in allen Köpfen drin, weil […] da ist niemand in der Lage, sich da rauszunehmen, den Blick nach vorne zu richten, was kann ich denn noch erreichen?*[88]

A new drive for innovation emerged through membrane and functional textiles in the 1980s. Only a few firms from the beginning of the textile supply chain benefited from this, like Sympatex and Goretex or clothing manufacturers that used the innovative textiles in their products. Most thread producers remained isolated from potential innovation partners (cf. Reinhold 2003: 217), as the overall innovation culture oriented towards other actors of the innovation system. While we learned from the case of FuncFiber that fiber producers do not talk with producers of yarn and threads, likewise, relations to research institutes were missing in case of these firms. Research institutes as well as textile processors oriented almost exclusively towards developments from the fiber industry (cf. Hübner 2001: 283; Knecht 2003b; Koslowski 2006; Planck 2003). Before the cooperation between E-Thread and InnoServ, the managing director of E-Thread tried to win over textile research institutes as a partner for innovation. But according to him, none of them was interested in cooperation with the traditional elastic thread producer.

Further inconsistencies of institutional orientations can be particularly found in the emerging field of electronic textiles where KIE emerged in this case. Froitzheim (2009: 1) puts straight the incompatibility of informal institutions and practices: "'Wearable Electronics' oder 'Smart Fabrics' sind nämlich ein Paradebeispiel für Probleme, die auftreten, wenn zwei Technikbereiche verheiratet werden, die so gar nichts miteinander zu tun haben – weder bei den Innovationszyklen noch in der Produktion, weder in der Kalkulation noch in den Vermarktungsgeflogenheiten."[89] He

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nology additionally costs 20 Euros, then it additionally costs 100 or 150 Euros in the store. And no one can change his spot and say, 'ok, it is still the same jacket or I still make good money out of the jacket. It may be better sold now and I do not particularly want to make money out of the battery'. But this is not effectively executable in the trade chain (translated by author).

88 They are structured up to the last minute of fault time a day and everywhere they release documentation of fault times of machines and other things. And this is a way of thinking that is in the minds of the people, because there nobody is able to make oneself free and look ahead, what can I still reach? (Translated by author)

89 'Wearable electronics' or 'smart fabrics' are in particular a prime example for problems arising when two technical fields are married that have nothing in common – neither in innovation cycles

further describes this new field as “ein Zukunftsmarkt in der Möglichkeitsform, mit zig Produktideen von bodenständig bis exaltiert, genährt aus nationalen und europäischen F&E-Förderprogrammen.“ (Ibid.)[90] Mr. IS1 confirms the central role of public financing policies that Froitzheim indicates. In his opinion, a mentality of more far-reaching innovation and development activities without any public promotion and research hardly exists among firms in Germany. This mentality is hard to prove but points once more to the uncertain and ferment situation of this field at those days. The institutional environment in this emerging field was still open and controversial, not only with respect to technical and market conditions and opportunities, but also to institutional orientation and sense making.

The national and European R&D programs promoting this emerging field lead over to the *formal institutions*. For the thread industry, no particular formal institutional conditions can be added from the case analysis that differs from the general conditions presented before. The regulative situation for thread producers was likewise determined by market liberalization. National and European promotion programs focused on interdisciplinary R&D fields, such as new composite material or micro-systems. Specific promotion programs on textile firms did not exist according to Mr. C and his partners from InnoServ. Around 2002/03, the funding was not well-marked in this respect (cf. also Begemann 2004). The promotion by national and European R&D programs mentioned by Froitzheim (2009: 1) refers to a later period. Following InnoServ’s estimation general cuts in research programs for textile research institutes led to lobbying to secure research infrastructure and struggling institutes but not necessarily to industry oriented funding. Neither one of the multiple sources reviewed gave indications for entrepreneurship enabling institutions, for instance, to rebalance uncertainties from new technical fields.

The overall *institutional arrangement* for thread producers displays the informal and formal institutions. Thread producers are part of the traditional “textile pipeline” (Rouette 2006: 23). Many value creation processes had become highly structured and institutionalized practices over decades that make it difficult to break out (Mr. IS1). Mr. IS1 describes the overall fragmentation, including the thread industry from the external perspective of a lateral entrant:

> *Also, ich war absolut überrascht. […] Die kennen ihren Lieferanten und die kennen ihren Kunden, aber die kennen niemanden darüber hinaus, niemanden […] und das quer durch die ganze Branche. […] In der Textilbranche ist es wie in keiner anderen Branche, oder es war zumindest damals so, diese wahnsinnige Arbeitsteiligkeit. Also, da hat jeder so ein absolutes mini-mini-mini-Spezialgebiet und jeder macht nur ein kleines Eckchen und sonst gar nichts mehr.*[91]

nor in manufacturing, neither in calculation, nor in habits of commercialization (translated by author).

90 … an emerging market in form of possibility with countless ideas of products ranging from being grounded to eccentric and nourished by national and European R&D promotion programs (translated by author).

91 Well, I was quite surprised. […] They know their supplier and customer, but no one in addition to it, nobody [….] and this across the whole industry […]. In the textile industry it is like in no other industry or at least at those times, this incredible division of labor. Well, everyone has an absolute

Thread producers that do not directly deliver sewing threads to consumer markets usually produce for producer of fabrics or sometimes supply directly manufacturers from the clothing industry. Major marketing activities are usually not conducted, as it is for most thread producers to expensive and unprofitable (cf. Reinhold 2003: 217). In consequence, spinning mills and yarn producers are generally said to have the destiny of a no-name supplier, because most of the small and medium-sized firms cannot afford to spend money on marketing (ibid.). Another consequence from this fragmentation is the ineffective communication among the specialized firms along product supply chains. Reinhold (ibid.) compared it with “Stille Post” [Chinese whispers] with regard to information or feedback on new products. For that reason, producers from the pre-stage usually have limited information and knowledge about user markets (ibid.).

A specific institutional contract arrangement emerged already more than 50 years ago against the disadvantaged market position of thread producers towards the clothing industry. The “Deutsche Garnkontrakt” [German Yarn Contract] was developed in collaboration with the clothing and retail industry and revised in 2002 (cf. Annex in Schenek 2006). It seeks to equal the business conditions for members of the “Konvention für Gewebe und Textilien e.V.” [Convention for Fabrics and Textiles]. Those commit to follow the agreements on supplying and purchasing conditions, for instance on fabrics and textiles, technical basics on avoirdupois weight, color tests, and arbitration codes or identifications. Moreover, violations of the conventions are regularly controlled and sanctioned by the association. It cannot be proven, how effective this is in practice. Basically, it supports members and is probably only effective on the domestic German market. This specific arrangement points to disintegrated, vertical market relations among actors. However, it does not cover rising export activities and internationalization of textile supply chains.

In conclusion, the institutional arrangements refer to various, heterogeneous actors that do not necessarily support innovation or in particular entrepreneurial innovation activity. Instead, it discloses a serious competitive environment for thread producers. Accordingly, the number of firms preparing and spinning textile fibers came down from 139 in 2000 to 93 in 2006 (Eurostat). More specific data to describe the corporate structure and *individual actors* in more detail is not available on this aggregation level. Likewise, innovators and their practices or start-ups are difficult to assess from statistics and literature. The indicators of R&D expenditures in share of value added disclose that the average of firms preparing and spinning textiles constantly remained around 0.7% between 2000 and 2006 (cf. Table 4). Contrarily, total intramural R&D expenditures came down from 4.2 in 2000 to 2.2 million Euros in 2006 (Eurostat). Mental maps, innovation habits on creativity and learning cannot be concluded from this to describe innovators or thread producers in general.

mini mini mini special field and everyone is doing only a little particle and nothing else (translated by author).

Corresponding with the sectoral analysis, the technical association Industrieverband Garne, Gewebe und technische Textilien (IVGT) seems to react slowly to the trend of technical textiles. An extra department on technical textiles was not installed at the association before 2003 (Kraatz 2008).

All in all, the analysis of E-Thread's institutional environment discloses different implications: On the one hand, an innovation-hostile culture could be observed that conflicts with newly emerging fields. These new fields together with the critical situation could have been an *institutional opportunity* to deviate from existing institutional practices. On the other hand, this kind of institutional opportunity did not necessarily enable or support the match of technical and market opportunity components.

5.2.4 Interim conclusion

The analysis of E-Thread's environmental conditions reveals that technological and market conditions for elastic threads were established and relatively stable (van Delden 2006; Schulte Strathaus 2003) against the overall shrinking in the ordinary threat production. Indeed, technical and market opportunities could be identified for elastic threads. The emerging field of wearable electronics and smart fabrics offered technical as well as market opportunities to elastic thread producers.

Moreover, institutional *tensions* can be observed that could have stimulated the questioning of existing institutional practices and deviation from it. But the new field of electronic textiles was an unfamiliar field for yarn producers and also for producers of fabrics and clothing manufacturers. Institutional tensions between the merging fields of textiles and electronics contributed to an uncertain institutional environment that missed orientation for innovation activity and entrepreneurship enabling institutions as well as institutional arrangements. Informal institutions structured actors' orientation to innovators and prevailing interaction in this field in a disadvantaging way for thread producers. The actors mainly involved in new knowledge production and technology development, research institutes as well as fiber producers initially overlooked (elastic) thread producers. They even rejected cooperation with them. The heterogeneity of actors and institutional arrangement in the division of labor generally reduced the thread producers' interest in knowledge on textile products and user markets (Reinhold 2003).

Industry-specific institutions in terms of free utilities or enhancing entrepreneurial experimentation or entrepreneurial alertness were not assessable. Likewise, no hints on entrepreneurs or start-ups can be identified among the innovators in this field. The same holds for formal regulating institutions. Textile-unspecific national and European R&D programs mobilized resources on new material and composites from which mainly textile research institutes could benefit, but not traditional thread producers. These programs were generally not entrepreneurially oriented and cannot be described as entrepreneurship enhancing or legitimizing institutions.

After analysing environmental conditions and opportunities existing independently from the KIE organization, the next section especially deals with corporate-specific conditions and more individual opportunities in the situation before the emergence of KIE.

5.2.5 Corporate conditions and corporate opportunities

In the 1990s, the family business was taken over by a family business group from the region that sought to diversify in a new business. After agreements with the most important customers of E-Thread, the group decided against relocating the firm to emerging markets abroad and invested in new facilities and cutting-edge equipment on site. According to Mr. C, the managing director of E-Thread, the motive for KIE was born from the new investments in the company. The shareholder group expected to use this new equipment for developing new products or new market fields.

Regarding the *initial economic situation*, E-thread was sound and the production was working to capacity, when the innovation process started. In the 1990s, however, the rising pressure at the textile markets had already been present. Thus, it was foreseeable for the management of E-Thread that they would lose customers to cheaper suppliers from low-cost countries which they had to respond to. E-Thread should be prepared for times of *crisis* with the help of innovative products. Mr. C characterized E-Thread as “different or anticyclic”. They were always on the “track of quality”, no matter how high the pressure on prices was, because this pressure had always been present. Nevertheless, the forthcoming 50th company’s anniversary reminded the managing director of the ending of the main product life-cycle (threads for surgical stocking). This in turn let to a prospective view corresponding to Deutschmann’s argument (2008: 111) that lock-in of technological paths can stimulate new activity. Mr. C did not take it for granted that the same product is used for further 50 years. Although the ending of surgical stockings had not been perceptible (cf. also Schulte Strathaus 2003), it was the “predictive duty” for Mr. C to look for “something really new”. In addition, he wanted to turn away from the company’s “graue Maus Image” [mouse image]. Added value should be created under the condition of the firm’s existing strengths in the spinning of elastic threads and with the new equipment. At the same time, these corporate conditions can also be considered as an opportunity for a venture that needed huge seed capital in equipment and machinery. In comparison, a start-up probably would not have these financial resources and process know-how at command.

The *firm-specific knowledge base* was shaped over decades and mainly consisted of practical, implicit knowledge. The developers, Mr. O and later Mr. P, in the position of the firm’s head of development, had specific competences in spinning elastic threads. They had more than 20 years of experience in the functionality of the machines, the process performance of threads and the combination of yarn for custom-specific adaptations. This internal knowledge resource was an important prerequisite for the KIE process. However, there was no skilled textile engineer at E-Thread. Most of the staff was initially non-specialized and stepped into the business by training on the job. The majority of the workforce worked at the firm for many years and became experts in their field. The workforce is described as a big family and it was the last wish of the founder that their employment was secured. The developers of E-Thread were used to incremental changes in the design and construction of elastic threads in the market niche of surgical stocking. Mr. C compared these routine innovation activities with a restaurant creating new recipes.

> *Durch diese Nischenfokussierung, die wir da hatten, […] entstanden immer wieder neue Anforderungen an die Fäden, neue Kombinationen, die wir dann wöchentlich umgesetzt haben für unsere Kunden. Das hatte für uns schon gar nicht mehr den Charakter von Neuentwicklung. Es sind Weiterentwicklungen und wir wollten dann etwas schaffen, was wirklich einen neuen Bereich eröffnet.*[92] *(Mr. C)*

For this reason, Mr. C started to inform himself about innovation management literature and attended lectures. He talked to experienced inventors and innovators in search for people who could give E-Thread a hand for ideas or the concrete implementation of an innovation. In other words, in this case the decision to innovate was made proactively before a concrete opportunity for an innovation was consciously sensed.

It took a while until Mr. C found an interested and willing partner for support. The textile research institutes that he approached rejected collaboration at that time. Likewise, consultants could not really help E-Thread. These experiences confirm the conjecture about missing institutional arrangements between yarn producers and other relevant actors for innovation. In 2001, Mr. C met Mr. IS3, one of the former founders of InnoServ, at an information event of the regional chamber of commerce. Under these circumstances, it was not random that the only willing partner for collaboration came from outside the TIS.

The service provider *InnoServ* was founded a few years before – in 1996. It was a newcomer in the textile industry. The founders of InnoServ were motivated by the challenge of E-Thread's case. They had never operated in this industry before, but they defined themselves as unconventional thinkers, which actually was their business model.[93] They won important expertise and legitimacy from this collaboration

[92] Thanks to this niche focus that we had, or this specific orientation, new requirements for the threads emerged, new combinations that we implemented weekly for our customers. This didn't have the character of a new development for us anymore. It was a further development, and then we wanted to create something that really opens up a new field (translated by author).

[93] „Wir beschäftigen uns ja mit der Frühphase von Innovationen und da geht es ja sehr viel um Querdenken letztendlich. Das heißt, wir arbeiten nahezu durch alle Branchen und dann kriegt man natürlich sehr viel mit, was wird in der Textilbranche gemacht, was wird in der Automobilbranche gemacht, was tut sich im Kunststoffbereich […] und da kann man oftmals Technologien, Materialien von einer Branche in die andere transportieren und dann versuchen wir wegen dieser Branchenblindheit oder Unternehmensblindheit, neue Akzente reinzubringen." (Mr. IS2, managing director at InnoServ) [Translation by author: We deal with the early stage of innovation, and finally, the point there is mainly creative/lateral thinking. That means we work in almost all industries and then one catches on a lot, of course, what is done in the textiles industry, what is done in automo-

with E-Thread, and after the KIE process they concluded further contracts in the textile industry. But at the beginning, E-Thread was one of their main customers for a while. InnoServ, a small knowledge-intensive firm, was founded by three chemists. During their studies, the chemists observed through industry contacts that especially SME fear to contact research organizations, because they traditionally employ neither graduates nor academics and have no access to universities or do not speak their technical language. The initial business strategy of InnoServ was to become an interface between universities and SME and to support firms in the early stage of innovation from the idea finding to the pre-maturity phase of new products. Against this background, the collaboration with the external innovation specialist was a new organizational form among the arrangements in the TIS. InnoServ can be considered as an existing institutional opportunity at the actor level, because it supported the incumbent firm in matching technological and market opportunities into an entrepreneurial opportunity. As InnoServ offered its service to SME across industries, it can also be termed an objective opportunity that Mr. C found outside of E-Thread's industry-specific environment.

The *capacities and firm-specific knowledge* of InnoServ offered necessary complementary resources to E-Thread, especially in the new interdisciplinary field of technical textiles. The team consisted of 11 natural scientists, engineers and a business graduate (one of the later managing directors). Furthermore, it had access to a network of 30 freelancers from diverse natural sciences. A further advantage of this supporter was that its external position enabled a reflective and distanced stance from conventional practices in the established field of elastic threads (cf. Pacheco 2010: 986; Maguire 2008: 675) and E-Thread. Mr. I, head of the later established business unit, described InnoServ's contribution to the process of innovative deviation with a metaphor of someone who opens a window and shows that there is still more outside. The external partner was crucial to changing the thinking away from the core business. "Weil, wenn man 50 Jahre das Gleiche macht, dann ist das auch etwas eingefahren. Vor allem dadurch, dass wir relativ schmal aufgestellt sind. Meine Kollegen können Ihnen alles erzählen über Elastate und Windegarne, aber links und rechts davon, das ist einfach nicht unsere Welt."[94] (Mr. I)

5.2.6 The entrepreneur

The most important role and driving force in this case was Mr. C, the managing director of E-Thread. He understood the claim of the shareholders as a mandate to create

tives, what is going on in the field of plastics […] and often technologies or materials are transferred from one industry into another one and then we try to introduce new accents because of the blindness of industries and firms.]

[94] Because, if you do the same for 50 years, then it is routine business […] because we are relatively narrowly positioned above all. My colleagues can tell you everything about elastane and entwined yarn […] but left and right from this is not our world (translated by author).

something significantly new. Moreover, he organized important missing resources from InnoServ and further supporters.

Mr. C mainly contributed to the maintenance of the location and jobs during the investment planning of the shareholders who had also considered relocating the plant abroad. This occurrence was also his main *motivation* for KIE. He wanted to create something new that opened a new field and sustainably secured the location and the workforce. For that reason, he addressed innovation management literature and started to visit lectures. He was concerned about the market development. Through innovation he wanted to proceed against the bad reputation of the industry's "graues Maus-Dasein" [mousy existence] and find something appealing. In context of the firm anniversary he concluded from the situation that the firm could not proceed as in the 50 years before. Based on this reflective stance towards the institutional environment, he began to organize resources that the firm missed for such substantial or innovation process in order to consolidate the future of the firm.

Mr. C is a *skilled* export merchant and was active in another industry before he started working at the distribution division of E-Thread in 1979. He worked for ten years in this position and expanded the export division. In 1989, he became managing director beside the owner, and four years later he became the leading and sole managing director of E-Thread. Mr. C had a difficult standing at the company with his eagerness for innovation and change. According to him, he was denoted as a weird person. He risked a lot, when he charged the scientists for the innovation move, since he informed the shareholders later. This was not done before a prototype and first application of the new thread had been developed. At the same time he knew that as far as he had something promising to present, he would have the full support of the shareholders. As the managing director, he held the formal *position* for such strategic decisions and access to resources as well as the formal authority to mobilize these internal resources.

Mr. C. is described as sales-oriented. Moreover, with his attitude to change and organizing financial resources and implementing this venture in the firm against opponents and concerns from E-Thread, he crucially contributed to the emergence of KIE. According to his own statement, he was enthusiastic in becoming a pioneer and had the necessary faith in this venture. His strong willingness to try out something new and to enforce it against persisting forces within the company was of great importance. He risked a lot, when he initially started the innovation process without informing the main shareholder. But without the external technical support and later also the shareholder's commitment it is likely that he had not been able to succeed in this venture. Furthermore, he could not benefit from his former *social network* in this case and not necessarily from his *previously earned legitimacy* or authority towards external actors.

5.2.7 The KIE process

The motives why Mr. C, E-Thread and InnoServ decided on collaborating for innovation were presented above. The next important query is again, how the actors recognized or created further opportunity components themselves (cf. Fligstein 2001: 111).

The researchers of InnoServ had an important function during the KIE process. They opened up E-Thread for new ways of thinking and the idea of innovation. Due to their active companion, especially at the early stage of the innovation process, they crucially supported Mr. C in convincing the staff of this venture. This worked out through the involvement of the most important functionaries at E-Thread in the search and selection process of innovation. The managers of InnoServ strategically showed capabilities as they were aware of resistance and the "not invented here syndrome". Also, they applied the necessary skills, known from description of institutional change, to persuade the staff: "Innovationen in so ein Unternehmen reinzubringen, das ist auf jeden Fall ein People Business… und das hat mit Begeisterungsfähigkeit zu tun. Das hat was damit zu tun, ob man Leute überzeugen kann."[95] (Mr. IS1, managing director of InnoServ)

They began the process with the aim to rethink E-Thread's strengths and to look for existing opportunities. The premise of focusing on the existing technological capabilities of the established machines and combining threads reveals the technological path-dependency of KIE in this case. This comes also close to the *mechanism* of effectuation where the means at hand determine the ends (cf. Pacheco et al. 2010: 1003). After the analysis of machines and activities, InnoServ explicitly stressed the linking activity of different threads and properties:

> *[A]uf dem Denkmuster kann man ja dann weiter machen. Also, wenn wir Dinge grundsätzlich miteinander verbinden können, was könnten wir noch miteinander verbinden und wie können wir auch die Maschinen im Konkreten dazu nutzen oder welche sonstigen Maschinen könnten wir erwerben, um in diesem Verbinden-Thema zu bleiben und da Mehrwert zu schaffen? […] und mit dieser Ausrichtung sind wir dann eben auf die Suche gegangen.[96] (Mr. C)*

What we can observe besides this effectuation logic is that changing activity was aligned with the existing cognitive frame of entwining threads at E-Thread. This kind of theorizing helped to legitimize the unconventional innovation activity of the staff. In the idea finding process, more than 100 ideas were firstly collected from the staff in workshops and brainstorming. The workforce was included in the assessment of the ideas in order to achieve a broad acceptance. A network of scientific experts from InnoServ was additionally consulted. Most of the ideas were excluded again. Then

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[95] To introduce innovation in such a company is in any case a people business [...] that is about capacity for enthusiasm, that has to do with convincing people (translated by author).

[96] … on this pattern of thinking one can go on. Well, if we can basically connect things, what else could we link with each other and how can we concretely use the machines or which other machines could we acquire to stay in this topic of connecting and to create added value there […] and with this orientation we began to search (translated by author).

the ideas left were systematically grouped and filtered. In the end, five ideas were considered promising. The strategy was to focus first on one of these promising clusters, which was electricity. They began to look for technological commonalities.[97] "Und da sind halt durch diesen Forschungsansatz und dieses Denken der Forscher, was da an Funktionen entsteht durch diese und jene Kombination, das war die Option, eine Funktion Stromleiten da mitreinzubringen."[98] (Mr. C.) Hence, Mr. C and InnoServ generally sensed the opportunity of emerging technologies and the market of smart textiles. Mr. C confirmed the emerging field, indicating that it was occasionally talked about at that time, but quite at a futuristic level.

For a significant innovation, the field of electronics was newly combined with E-Thread's core competence of entwining threads. Initially it had to be clarified, how one can introduce conductivity into these elastic threads, as no solving scheme existed in practice or theory of the sectoral knowledge base (cf. Chapter 5.2.1). InnoServ conducted research on property rights of conductive textiles as well as an analysis of the state of the art. The external partner was central to taking a reflective stance towards routine processes at E-Thread and to deviating from them. In practice, the researchers from InnoServ looked at the design and construction of the elastic thread through a microscope and discovered that the multi-winded yarn construction offered new and unique properties for the integration of electrically conductive material. The winding yarns spread evenly, like liquid on the surface of the winded core yarn. For the researchers, this was a remarkable observation and aha experience, whereas for the experts from E-Thread it was trivial or natural. But it was an important insight to apply covering metal wires smoothly with material or to evenly block conductive material. Mr. IS1 described the different perception as "Branchenblindheit" [limited perception of the industry], "das sind eigentlich Beobachtungen, die hätten die Leute seit den fünfziger Jahren machen können. Die hat niemand gemacht, und niemand in den Zusammenhang gestellt, weil niemand da drauf geschaut hat."[99] As mentioned above (Möhring 2006: 320), this blindness or (re-) discovery of textile micro-structures and properties can be explained by the missing micro-electronic systems for their application in products and electronic systems in the time before the appearance of micro-electronics. In addition, this example also illustrates the cognitive frames used in specific technological fields that might have kept long-term field participants from seeing it (cf. Faulkner 1994: 441 et seq.). The knowledge-intensive activity can be described with de- and re-contextualizing from institutional

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97 "Wenn etwas mit Strom zu tun hat, dann braucht man eigentlich eine elektrische Leitfähigkeit. Und da hatten wir die Überlegung, wie bringt man elektrische Leitfähigkeit in diese Garne rein?" (Mr. IS2) [Translation by author: If something is connected to electricity, you actually need electrical conductivity. And then we had the deliberation how to implement electrical conductivity in these threads.]

98 … and simply based on this research approach and this thinking of the researchers about the emerging functions by this or those combination […] one option was to implement a function of electronic conductivity there (translated by author).

99 … and these are actually observations that people could have made since the 1950s. Nobody made it, and no one put it into context, because nobody looked at it (translated by author).

entrepreneurship literature. The field-external researchers had a more abstract view on the construction of the winded threads. The integration of conductive material in the construction of elastic yarn and their production on existing machines point to the mechanism of effectuation where means at hand are newly combined and produce new ends (cf. Pacheco et al. 2010: 1003). Likewise, the process of *deviation* describes the *mechanism* of exaptation with regard to the re-use of existing elastic feature of the winded thread construction in the new, useful context of conductive textiles (ibid.). Hence, the original function of elastic threads was used for the different purpose of transferring electricity.

After the first contract for finding an idea, the experts of E-Thread should exploit the new thread on site – partly accompanied by Dr. IS1. They started experiments on a special testing machine, which Mr. C called "Prinzipversuche" [schematic trials]. Therefore, "diese Expertise im Unternehmen ist enorm wichtig. Also wenn ich da keine, ich habe keine Ahnung von dem Prozess. Ich kann mir das vorstellen, indem ich das ansehe, oder wir können uns das vorstellen, aber wir wissen nicht, was geht dann wirklich. […] Solche Dinge, das muss der Experte vor Ort, das muss der, der wirklich diese Verfahrenskompetenz hat, einbringen."[100] (Mr. IS1) At the beginning of the exploitation stage, the head of development was not convinced by the idea of winding a wire. Mr. O was close to his retirement and could not imagine starting such experiments that he considered as being too dangerous.[101] Following Mr. IS1, these concerns were unjustified and inhibited the exploration process for a few weeks. It even went so far that Mr. O did not buy the wires which Mr. IS1 had asked him for. The team of InnoServ knew such kind of opposing behavior from previous business and found support in Mr. P. He had the position of the substitute head of development at that time. Mr. P was open-minded and approachable for this venture. He became the technical promoter at E-Thread. When Mr. O went on holidays, the team started the experiments. Mr. P conducted them mainly besides the daily work. This incident illustrates once more how actors, who are long term embedded in a field with certain cognitive frames about technologies, face difficulties in deviating from such institutional practices and cognitive frames. On the other hand, Mr. P showed that embedded actors are also able to break with this routine and practices. Finally, as Mr. P was younger and the successor of Mr. O, he had a different interest in the prospect plan of the firm.

At this time, the shareholder group had not been involved in the process. First of all, the managing director wanted to test the invention, because they "could not estimate if it is something reasonable" (Mr. C). Therefore, their partner InnoServ organized

[100] The expertise of the company was hugely important. Well, if I do not have an idea of the process […] we can imagine something, but we do not know what is really working. […] the expert on site has to contribute to such things, who really has the process competence (translated by author).

[101] „Das war für ihn völlig undenkbar, dass man so etwas in einem Unternehmen ausprobieren kann, also nicht mal versuchsweise." (Mr. IS1) [Translation by author: It was entirely unthinkable for him to test something in a company – not anywhere close.]

presentations at different congresses and fairs. After this feedback from the market, Mr. C understood that it must have an interesting potential. In other words, E-Thread sensed the general market opportunity again with the help of its partner. Furthermore, InnoServ took in hand important functions in *mobilizing* resources and supporting allies at the beginning of the KIE process. Their access to scientific networks and skills in establishing cooperative networks was like a door opener for E-Thread to physicists, textile and mechanical engineers, for instance, opening doors that had been locked to E-Thread before.

As the innovation offered numerous possibilities of application in emerging markets (data transfer, biomedical textiles, heating or blocking electromagnetic radiation), it was difficult for E-Thread to anticipate which of them could be most profitably exploited. InnoServ received a follow-up order for consultancy. According to the partner, the development in the following two years went haltingly, until they applied for an interdisciplinary research project of the Bavarian Ministry of Economics on 'advanced materials'. According to Mr. C, their patent enabled the realization of the project. The project acknowledged the innovative thread as such an advanced material. Accordingly, the use of the term 'Neue Werkstoffe' [advanced materials] and the participation at the research project worked as a form of theorization and professionalization which helped to gain the shareholder's support.[102] Mr. C. admitted that they were not experienced in applying a proposal at that time and that one of the motives for participating was the financing for further development activity. Several experts and professionals were involved in the project, developing first prototypes of products such as a heatable sports jacket. Additionally, E-Thread met first potential customers through this project. As described in the literature (Maguire 2008: 677; Leca et al. 2008: 17), multiple actors were linked in the project, offering access to necessary resources. Moreover, it provided the applicants InnoServ and E-Thread with legitimacy. The articulated interest of the industrial project partners was understood as a further indication of the market potential. This market opportunity encouraged E-Thread in their selection process regarding their exploitation focus. After this successful *institutional project*, InnoServ indicated that E-Thread put its back much more into the implementation of the innovation. Subsequently, the shareholder group decided to invest more in this field. Along this further step in the process of institutionalization, the shareholder recommended to establish a new business unit and to deploy an own head. The management decided on Mr. I for this position. It gave him credit for this pioneering, because the skilled industrial clerk had successfully proven himself in the purchasing department and administration at E-Thread for 10 years.

102 "Herr C hat innerhalb seiner Möglichkeiten operiert. Der hat einfach versucht, Mittel zur Verfügung zu stellen, die er zur Verfügung stellen konnte, aber das war einfach nicht wahnsinnig viel. […] Und erst dann ist es eigentlich wirklich losgelaufen, nachdem wir dieses große Fördermittelprojekt […] gestartet haben." (Mr. IS2) [Translation by author: Mr. C operated within his possibilities. He just tried to provide resources, but this was not a fantastic amount. […] and then it really went off after the huge publicly funded project had started.]

But soon after the development of first prototypes in 2005/2006, E-Thread faced difficulties in the market introduction of the yarn. In case of the heatable apparel, E-Thread could not draw on an existing market structure. A huge lack of knowledge how to apply the invention prevailed at the textile manufacturers. Additionally, potential market participants and brand manufacturers in the apparel industry reacted in a noncommittal way. Their willingness towards innovation was initially narrowed towards fashion and changing collections according to Mr. I, responsible for the marketing activities of the new business unit. In his opinion, the demand for high technologies in apparel was rather limited, as the firms were very cautious with taking risks and investments in innovation. According to the presentation of the conductive thread in a technical journal in 2005, InnoServ and E-Thread still suggested cooperative developments with intermediate producers taking over the development of applications and the end-producer product tests and integration. But in fact, Mr. I experienced that "es macht keiner den Weg zu Ende. Also, wenn ich zu einem Bekleidungshersteller gehe, dann will der einfach das fertig sehen, womöglich TÜV-abgenommen […] und, und, und. Und im Endeffekt haben wir, um das Ganze in die Bahn zu bringen […], haben wir uns mit so Sachen beschäftigt, welche Batterien können noch verwendet werden."[103] In consequence, E-Thread dared to move downstream the value chain and decided to offer its own heatable vest.

> *Wir müssen den Weg jetzt aufzeigen und gerade wenn es um die Bekleidung geht, wollen die, also der Anspruch dieser Zielgruppen war dann ein ganzes System zu haben, ansonsten haben die gar nicht darüber nachgedacht. Und System hieß dann, Fadenkabel sozusagen als Zuleiter und die Kontaktierung dann zwischen dem Draht, also Metall und Textil, diese Lücke da zu schließen, und dann noch eine Stromversorgung zu sichern.*[104] *(Mr. C)*

What becomes obvious here, is the textile industry's specific culture of cost reduction and the innovation-hostile policy of pricing along the textile value chain. This specific institution, primarily legitimizing product differentiation and division of labor, was opposing the cooperative implementation of the new thread in products along the value chain. E-Thread took this into consideration in its framing activity, when it decided on adding value to existing apparel products (e.g. the vest). This way, the new thread was aligned with commonly accepted frames in order to legitimize the new material (cf. Pacheco et al. 2010: 990). Moreover, they tried to respond to the price policy by concentrating on high-price clothing. They assumed that an innovation-induced increase of price could be better placed in these calculations (Mr. I). But in the case of the vest de-institutionalization, such as enclosing grievances (cf. Leca et al. 2008:

103 … nobody completes the developmental path. Well, if I go to a clothing manufacturer, then he likes to see it ready, possibly certified with TÜV [Technical Inspection Association] […] and so on and so on. In the end we started to deal with things like which batteries can be used in order to bring the whole thing on track (translated by author).

104 We have to show the way now, especially if it is about clothing […] the claim of this target group was to have an entire system, otherwise they had not even thought about it. And system meant then to close this gap between yarn cable so to say as supply and contacting between the wire, well, metal and textile, and then still to secure a power supply (translated by author).

12) or disapproving of the profitability of existing institutional practices, did not grip. Indeed, the reframing initially caused some difficulties. In one case, the developers from a manufacturer of skiing apparel first showed interest. Then the management withdrew from the buying interest, arguing that a heatable winter jacket did not comply with the sports image of the firm. As an established actor, the firm did not risk delegitimating the heating function of its conventional heating jackets next to the new jackets. Later on, when E-Thread exploited the automotive market, it was much easier to win over potential allies, referring to the existing frame of light weight construction and weight reduction, because the conductive material is significantly lighter than conventional cables for the electrical supply in cars (cf. Möhring 2006: 324)

Furthermore, mechanisms of professionalization and theorization in terms of research projects with scientific partners were not convincible enough for potential business partners in the textile industry. For instance, the development of prototypes was not sufficient to prove the value of the innovative yarn. Therefore, E-Thread took over the system integration up to a first low volume serial production of vests. This implied further knowledge-intensive activity, as the state of the art at that time showed that especially the supply with electricity had not been satisfyingly solved (cf. Möhring 2006: 321). The potential customers or processors of the yarn were not willing to create and invest in new knowledge in this new, unfamiliar field. In response to these problems and interests of so-called potential allies (cf. Leca et al. 2008: 12), E-Thread took over this knowledge-intensive development. This situation corresponds with an article in a technical journal where E-Thread is described as a firm that took a step forward towards innovative functional textiles, which many of the traditional buyers from the clothing industry still dread – though it promised a growth impulse and higher added value.[105]

Given the absence of an institutional opportunity for matching the technological with the market opportunity on the customer side, E-Thread decided to become the driver of innovation and to reposition itself as a system supplier in this emerging field of electronic textiles. This risky takeover strategy was not recommended by InnoServ, because such support costs extra time and financial investments (cf. Hübner 2001: 283 or the example of Goretex's high expenses on their marketing strategy). However, InnoServ supported E-Thread in establishing the necessary new technology at the low-tech firm. Firstly InnoServ hired physicists and electrical engineers on this purpose. Later E-Thread sought to become more and more independent from its partner. It hired textile technicians, electrical engineers for own development activities and quality assurance. As a result, the new business unit grew from two to eight people.[106] "Das war definitiv ein neuer Schritt, wo wir vor 10 Jahren im Traum nicht

[105] This source cannot be indicated for reasons of anonymization.

[106] The business unit has an own name and internet presence. One business unit manager and seven employees worked there. Some of them were exempted from usual business and some electronics and textile engineers were hired especially for this venture.

daran gedacht hätten als Textilunternehmen, da hatten wir eher gedacht, wir müssen die Textilingenieure oder Textilfachleute verstärken."[107] (Mr. C)

Later E-Thread admitted to have underestimated the situation when it decided on the problem solver strategy. Mr. I disclosed that they partly did not know what they had to do in order to generate turnover at the market at first. According to Mr. C, the task to establish these intermediate steps until marketability of the product was achieved had been underestimated. The supply with electricity, for instance, appeared as a new challenge, "weil es da einfach nichts gab und auch bis heute nur beschränkte Möglichkeiten, kleine Batterien mit hoher Leistungsfähigkeit. Nur, ohne diesen Zusatz oder ohne diese Geräte konnten wir keine Heizung verkaufen. Und somit sind wir dann zwangsläufig in diesen elektronischen Teil reingerutscht und mussten das anfertigen lassen, und haben das auch hier entsprechend getrieben, dass das zusammengepasst hat."[108] (Mr. C) E-Thread firstly had to define the requirements for the batteries and their enclosure such as energy output in watt, or when the heating function should turn itself off.

Furthermore, the setup of the heatable vest in serial production was not only a technological but also a financial challenge for E-Thread. The single development costs for the cable reached up to a few ten thousand Euros. They had to order large numbers (in thousands) of controlling devices for the vests, because the supplier of electronics refused to produce only hundreds of these custom-made devices. From the former position in the value chain as a yarn producer, E-Thread was not used to this supplier market. The same held true for the new customer markets, as Mr. I noted: "Wir waren ja noch nie so nah am Kunden dran."[109] The arrangement of existing interest and values of so-called dominant coalition members was called a crucial process for institutional entrepreneurship in mature fields (Suddaby/Greenwood 2005; et al. in Leca et al. 2008: 14), which becomes even more demanding if the entrepreneurs have to address "fragmented groups of diverse dominant fields members" (Leca et al. ibid.). This was also the case for E-Thread, as the textile industry has been much diversified. Moreover, the position of E-Thread in the matured business field of textiles neither allowed for organizing processors downstream the product supply chain nor for so-called supporters from the field of electronics, e.g. "isolated agents who are unable to act on their own" in the new field of wearable electronics (Leca et al. 2008: 15 et seq. according to Fligstein 1997). In consequence, E-Thread addressed finishers or end-producers, as we already observed in the case of

[107] This was definitely a new step which we would not have dreamt of ten years ago. As a textile company, we rather thought that we had to reinforce textile engineers or experts in textile (translated by author).

[108] … because there was just nothing and still until today there are only limited possibilities for small batteries with a high performance. But without this supplement, without these devices, we could not sell any heating. In this way we unavoidably slid into this field of electronics and we had to get it made and we accordingly urged that it fits (translated by author).

[109] We had never been so close to the customer (translated by author).

FuncFiber. In addition, the threads' broad diversity for applications caused problems at E-Thread.

> *[…] dann ergaben sich da wieder eine Reihe von Varianten und Ansprüchen, die jeder Kunde unterschiedlich haben wollte mit seinen Anforderungen. Der eine wollte Heizpads hier haben und da. Es ließ sich einfach nichts vereinheitlichen, und alles musste aber von uns dargestellt werden, also bewiesen werden, dass es funktionsfähig ist und dass wir die Auslegung machen können. Und das hat uns dann da schon ziemlich gefordert, aber natürlich auch bereichert, weil wir viel gelernt haben dabei und einiges an Kompetenz dann auch gewonnen haben.*[110] *(Mr. C)*

It becomes clear here that E-Thread missed legitimacy and that it was still not used to this entrepreneurial experimentation at that time. Additionally, the remark about customer requirements that could not be standardized discloses the effect of existing frames from mass production and rationalization at E-Thread. Altogether, these occurrences display the discursive dimension of the entrepreneurial process. Different from the supplier of electronics, the customers were only willing to order a few hundreds of the vests. "Da war immer so die erste Frage […], ‚ja, kriegen wir das exklusiv?' – Ja, okay. Exklusiv, wenn du 10.000, 20.000 Teile in einer Saison abnimmst, können wir darüber reden. – ‚20.000 Teile, du spinnst, 10 Prozent davon!'"[111] (Mr. I) The initial ambition of driving the market implementation of the thread into a finished product was followed by disillusion. Mr. C acknowledged that they "haben doch vieles dann auch weiterentwickelt im Vertrauen darauf, dass die Aussagen so mancher Interessenten dann schon stimmen und dass das dann schon auch abgenommen und übernommen und gekauft wird und dass es Aufträge gibt. Und da hat es dann doch viele Ernüchterungen gegeben."[112] E-Thread had initially started with the idea to become a system supplier for heating systems comparable with the status of Intel with its computer chips, as stated by Mr. I. "Nur, wenn man dann im Nachhinein die Bekleidungsbranche anschaut, wer hat es wirklich geschafft als Komponentenhersteller vom Endverbraucher im Bekleidungsbereich wahrgenommen zu werden? Dann fällt uns noch Goretex ein, aber dann wird es eng."[113] (Mr. I) In conclusion, the position of a producer of innovative components in the textile-specific institutional environment is challenging.

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110 There was a range of variants and claims that each customer with its specific requirements wanted to have in a different way. One of them wanted pads of heating here or there. Nothing could be standardized, yet we had to demonstrate everything, well, to prove that it is functioning. And this was quite challenging. Of course, this enhanced us as well, because we learned a lot and gained expertise (translated by author).

111 The first question always was […] if they can have exclusiveness. 'Yes, alright, if you take 10,000, 20,000 a season, we can talk about it.' – '20,000 pieces? You are crazy! 10% of that!' (Translated by author)

112 We developed many things in confidence that the statements of quite a few interested parties are also correct and that it is bought and absorbed. After all, there were many sobering (translated by author).

113 But if you look retrospectively at the apparel industry, who has really made it, as a producer of components, to be noticed by the users in the field of textiles? We then think of Goretex, but that's it (translated by author).

However, E-Thread's position changed along the process of KIE. The firm's publicity grew enormously with the participation in research projects and fairs. They applied for and established research projects without InnoServ. Moreover, E-Thread was acknowledged as a pioneer and expert in the emerging field of conductive threads. After it had turned out that market penetration of their heating system at the textile market would take some time, E-Thread turned towards a new customer market. The automotive industry was basically interested in light systems of electronic supply. For E-Thread, this was a more attractive market field as they presumed higher sales in this mass market. They have become known at the R&D departments of big automotive companies. But with respect to technical complexity in this customer market a longer forerun until market introduction had to be expected.[114]

Because of these difficulties arising from the market penetration and outstanding profits, the share of this new product group in total sales was still in single figures in 2009 (company questionnaire). When the firm noticed that the emerging market of conductive elastic threads could not be developed in medium- or short-term, the enlarged business unit was downsized again. In consequence, some of the staff returned to regular business at E-Thread. An extra hired engineer with former work experience in aerospace exited the firm again. The managing director has taken over the resting business and marketing activities.

At the beginning of the KIE process, Mr. C assumed a considerable pull encouraging other businesses to contribute to the electronic part or setting up products downstream the supply chain. But this was still left much to be desired and progressing slowly in 2010. Mr. C welcomed more vitalization in form of more businesses for the development of the emerging markets in electronic textiles. In the meantime, some firms emerged in the field of heating technologies for apparel and a competitor in the USA was bought up from a bigger company. Further market participants were assumed in Europe and Asia, but E-Thread did not observe this systematically. However, these occurrences could be an indication for the institutionalization of this emerging field.

5.2.8 Conclusions from the case of E-Thread

The case of E-Thread illustrates that an established specialized actor is able to deviate from its routine and carry out KIE with the help of an industry-external supporter.

The crisis of some customers – due to their relocation to emerging markets – made E-Thread question existing cognitive frames and practices and think about a distinct innovation to maintain the location of the firm. Again no systemic institutional opportunity for matching the technological and market opportunities could be found in this case. The technological opportunity of conductive elastic threads had been over-

[114] At the time of inquiry in 2010, the development of automotive applications was an ongoing process.

looked. Market opportunities and demand for conductive textiles were just emerging and mainly based on information asymmetries. Missing institutional arrangements between research institutes, fiber industry and few remaining thread producers depict an institutional barrier.

E-Threads resources and position were restrictive at the beginning of the KIE process. The more impressing is the development of this firm in extending its firm-specific knowledge base as well as strategic and entrepreneurial competences towards dynamic innovation enabling capabilities. At the beginning of the KIE process, E-Thread underestimated the efforts to transform such an abstract idea of conductive threads into real products – not least due to the limited experiences in such entrepreneurial innovation activity. After the KIE process, the firm indicated to have profited from this experience in terms of a prospective orientation towards new things or problems that require deviation from the routine. Besides, the established firm initially had problems to identify reasons for convincing supporting allies like research institutes or customers of collaboration (cf. Garud et al. 2007: 962). In the course of the KIE process, the firm improved these necessary competences with the help of the external partner. Indeed, the social position of entrepreneurial actors is a key factor that influences the access to relevant resources (cf. Leca et al. 2008: 7). But E-Thread managed to change its initially restrictive position due to KIE activity. In conclusion from this case it is necessary to keep a dynamic view on established actors and not exclude them from investigations only because of their initial position in the field. Despite the disadvantaged position of the established firm, the entrepreneurial managing director was able to organize access to relevant missing resources through the collaboration with InnoServ.

The multiply embedded external actor (InnoServ) assisted E-Thread to sense an opportunity for KIE. In addition, the researchers from InnoServ helped to frame and translate the invention into practices and logics of the company (cf. Maguire 2008: 675). But different to usual innovation practice of transposition in mature fields such as importing and rearranging practices from other fields (ibid.), the innovation of KIE can be better described by mechanisms of effectuation and exaptation. Accordingly, the idea finding process was affected by the logic or technical frame existing at E-Thread – namely elastic thread production. Starting from this, the firm discovered a new end for its main product. The solution for incorporating the new, conductive function into the threads, however, was just being created during the KIE process.

Moreover, the mechanism of professionalization was applied in specific ways in this case. The first publicly funded joint research projects helped E-Thread to build a professional identity towards researchers and innovators active in this new field. This kind of institutional project helped E-Thread to gain legitimacy and support from the main shareholder group. In other words, E-Thread organized together with InnoServ an institutional opportunity to finance entrepreneurial experimentation and built networks through a regional interdisciplinary funding program outside the TIS. This institutional work helped to match the technological with the market opportunity. Nonetheless, this kind of professionalization was not sufficient to convince potential users from the established field of textiles. In addition, the translation of the new threads into practical ideas and applications was necessary for their implementation at established customers. Again, institutional barriers from absent cooperative institutional arrangements downstream the textile supply chain inhibited the implementation. Because of the difficulties to convince established actors to exploit E-Thread's innovative threads, the company decided to become a driving force. In response to absent backers downstream the textile supply chain and several fragmented groups with different interests, E-Thread took over this knowledge-intensive exploitation activity. It developed a heatable vest and organized its serial production as a convincing institutional project. With this form of professionalization, the firm circumvented the discourse with established actors and hoped to convince them.

In conclusion, the mobilization of resources and mechanisms for KIE were shaped by its difficult (entrepreneurship-hostile) environment in this case. The central supporter was an external constituency (InnoServ) and later some research organizations, partly from the TIS. Putting it differently, a central, established constituent actor from the textile customer market could not be won during the KIE process. As a result, E-Thread decided to take over the initiative. Compared to the first research project it organized this practical institutional project widely autonomously. Accordingly, in this case agency differed at different stages during the KIE process.

5.3 The case of MultiTex

The company, fictively named MultiTex, was identified through internet research, as it was awarded for two pioneering innovations in the textile industry.[115] In this case, KIE emerged in the course of knowledge-intensive activity of an established, traditional textile manufacturer of medical and interior textiles. MultiTex developed an innovative process technology that solved a technical problem in the emerging field of advertisement on conveyor belts. In 2004, a subsidiary, fictively named TecTex, was founded to better market the innovative belts and additionally newly developed functional work-wear, because the innovations did not fit to the existing product groups anymore.

Knowledge-intensive activity appeared as a solution in the new field of advertised conveyor belts that enables distortion-free and permanent printings on conveyor belts. For about 20 years, marketing firms and manufacturers of conveyor belts had tried to produce advertisement on conveyor belts but could not sufficiently solve the

[115] For this case study, the managing director of MultiTex, Mr. A, was interviewed for about one hour in July 2010. Additionally, short telephone interviews were carried out with a representative of the German Retail Federation and a researcher of the Institute for Consumer and Behavioural Research at Saarland University in December 2010.

problem of distortion and detachment of prints. The invention is based on a specific design of a multi-layered structure and thermal treatment of fabric made of two types of fibers with different melting points (patent specification). The development of this process technology took two years and was registered for patent in 2005. The capabilities of MultiTex in manufacturing and refinement of decoration textiles, like curtains, was a necessary condition for this new process technology.

In 2009, MultiTex and the subsidiary TecTex together employed 40 full-time and 20 part-time employees. Both firms are independent from bank capital or any other form of debt capital. The traditional family business came out of a business share in 1956 as a limited company (Ltd.). Originally two brothers founded the company in 1921. In the 1950s, the five heirs divided the family business into two textile companies. One part had to establish a new company, MultiTex. The company started with bedding clothes. In the mid-1990s, the firm already diversified in the field of functional medical textiles for hospitals and care facilities. In this business field MultiTex maintained many processing steps like cotton weaving, refinement and finishing. In addition, it was operating in home textiles like decoration fabrics and curtains. Customer markets were specialist textile retail, interior decorators, and manufacturers of furniture. This vertical integration was uncommon for German textile manufacturers (cf. Rouette 2006: 21). But especially these multiple technologies of fully integrated production and technological capacity of MultiTex contributed to the KIE process in the unfamiliar product field.

TecTex markets the advertised belts with an integrative operator concept, which includes the rent of the belts at the checkout areas in the supermarkets, their country-wide exchange and maintenance as well as the coordination of bookings for supermarket retail chains and brand owners. In the meantime an international network of key account managers is operating in 34 countries in Europe as well as in Canada, Russia and China.

5.3.1 Sectoral knowledge base and technological opportunities

First of all, a short overview is given about the main relevant *knowledge domains* according to MultiTex's different fields of production. The affected technological domains and fields in this case are 'cotton-type weaving', 'manufacturing of fabrics for fashion', 'interior textiles', and 'fully integrated production for bedding textiles including yarn production', 'textile refinement and finishing'. In addition, the knowledge base of the product field of conveyor belts is presented to comprehend the technological opportunity exploited by MultiTex. Because of so many technological fields it is quite difficult to fully reconstruct existing technological opportunities of the corresponding TIS before the start of the KIE process around 2002.

A first look at the formal R&D indicators (Table 6) describes the research intensity and dynamics of the knowledge domains in which MultiTex operated prior to the KIE process. Generally, these indicators do not fully operationalize and measure knowledge creation and dynamics in the sub-sectors. However, they disclose first insights in different dynamics among these fields. Compared to the technological field of ‘cotton-type weaving’, the product fields ‘finishing textiles’ and ‘manufacture of made-up textile articles except apparel’ indeed show dynamics in increased expenditures on R&D (see Table 6). Although the share of R&D personnel did not change, both the total and intramural expenses on R&D increased between 2000 and 2006. Contrarily, in cotton-type weaving all three indicators drooped significantly in this period and point to a stagnating development in this field-specific knowledge base.

Tab. 6 Sub-sectoral knowledge bases measured in R&D indicators

Germany	**Cotton-type weaving**			**Finishing textiles**			**Manufacture of made-up tex. articles, except apparel**		
	2000	2006	Change	2000	2006	Change	2000	2006	Change
Share of R&D employment in no. of pers. employed	1.2	0.4	-67%	0.9	0.9	0%	0.4	0.4	0%
Share of R&D expenditure in value added	1.5	0.8	-47%	1.2	1.6	33%	0.4	0.7	75%
Total intramural R&D expenditure (with thousand separator)	8,7	3,1	-64%	6,8	7,3	7%	3,5	5,5	57%

Source: Own processed data based on Eurostat (NACE Rev.1.1).

The literature review reveals further distinctions in knowledge creation and conditions of the knowledge domains. At the beginning of the new millennium, the traditional product field of bedding was still profitable in Germany (Neuper 2003: 195). New developments in breathable fabrics, temperature compensation, antibacterial finishing was absorbed from the field of functional sportswear and transferred to additional functions of bedding (ibid. 197/198). Thereby, Dietram Neuper (ibid. 195) stresses that these new developments could not be solved with conventional “recipes”. To assert oneself at the market, the bedding manufacturers had to be creative and adventurous (ibid. 197). This might indicate entrepreneurial experimentation; however, at no point in the literature it is referred to new firms but rather to established firms.[116] It stands to reason, if these activities can be already understood as entrepreneurial experimentation in case of corporate entrepreneurship, or if it is rather a form of creative accumulation (cf. Schumpeter Mark II). Already in the first years of the millennium, manufacturers of home textiles had applied a variety of new technologies, fibers

[116] Only in the sub-sector finishing textiles, the number of firms increased by 25% to 862 firms between 2000 and 2006 (Eurostat). This might be traced back to entrepreneurial experimentation. But these numbers do not clearly disclose if this growth was based on innovative new firms or asset stripping for legal or strategic reasons of firm groups that retreated from this business field.

and equipment and applied for new trademarks (Neuper 2003: 200). Adding value to table linen was actually nothing new in this field, since for many years the industry worked on non-iron and easy-care products with specific finishing (ibid.). Neuper concludes that the bedding industry was used to R&D activities and new technologies in their daily work (2003: 197).

Likewise, MultiTex exploited some of these technological opportunities of additional functions to add value to their bedding products. In the mid-1990s, the company specialized in medical bedding textiles. Textiles for surgery were also listed among the research foci of the textile industry research board (cf. Begemann 2003: 263). More specifically, it was addressed to further developments in coatings of surgery textiles or the improvement of thermo regulation, transport of humidity or pressure relief (ibid.). In addition, the combination of conventional textiles and systems of membrane were indicated as a field of development for new textiles with regard to longer durability and sufficient germinal density (ibid. 264). MultiTex seized these technological opportunities of new features and combined them into a multifunctional medical textile product. The firm further developed its bedding textiles in adding protective functions for the mattress or caring function for the patient. "Das ist das, was wir uns in den ganzen Jahren immer wieder zur Aufgabe gemacht haben, nicht das Rad neu zu erfinden, sondern einfach Funktionen, die man auf jeden Fall schon definiert hat, in einem Produkt zu vereinen. Also mehr Funktionen in ein Produkt zu bringen."[117] (Mr. A, managing director of MultiTex) This combining did not seem to be a firm-specific exception but a common innovation practice among the innovative textile manufacturers at that time. Begemann (2003: 263), for instance, recommended combining the newly established effects reasonably for new textiles. This way, he expected new growth also in clothing and home textiles comparable with the field of technical textiles (ibid. 268). This innovating activity proceeds along newly defined solving schemes and known risks. The textile parameters were adjusted to the new functions by creative accumulation but cannot be compared with entrepreneurial experimentation or knowledge-intensive activity creating new solving schemes. In its place, this innovation practice can be better described with transposition as the import of practices from other fields (here new functions from the field of sportswear) and their adaptation or tailoring to the existing field (cf. Maguire 2008: 675).

The new combination of different new functions points to the technological field of functionalizing textile surfaces – also called refinement. Basically, textile refinement creates effects of utilization of textile raw material (Rouette 2006: 19) and this way it can equip conventional textile surfaces with extraordinary features (Mieck 2001: 73). The refinement with multiple functions was mostly implemented with established processes (Begemann 2003: 265; Gottwald 2006: 67). For many years chemically modi-

[117] That is what we set ourselves to do in all these years, not to reinvent the wheel but just to combine functions in one product that were already defined in any case. Hence, to get more functions on a product (translated by author).

fying processes and mechanical processes have been used in combination and in several steps of treatment to improve the textile's performance characteristics (Schneider 2003: 69). But more and more this was also done with new technologies of biotechnology, nanotechnology as well as physical and chemical process innovations (Begemann 2003: 265 et seq.). Hence, beside new fibers and constructions, the refinement of surfaces was expected to contribute significantly to innovative functionality in diverse fields of application (Gottwald 2006: 67). Some of these new features could not be technologically gained by new fibers or processes of production (ibid.). The demand for new functions and broadening technological requirements could be considered a new technological opportunity for refiners.

Traditionally the refinement of textiles is linked to other sectoral knowledge bases and said to live off knowledge from other sciences (Rouette 2006: 11). Textile refinement is an applied science based on insights from chemistry, physics and different engineering sciences. Typical for this knowledge base is the focus on the synergies, interaction and reaction of single elements in the process of textile refinement (ibid.). Many processes are recurrent and require "cybernetic thinking" (ibid.). Accordingly, textile finishers, like MultiTex for instance, have to deal with problems up- and downstream the textile product supply chain. An "[i]ntegrale Sichtweise über alle Stufen hinweg ist daher essenziell."[118] (Ibid. 14)

There are mechanical processes of finishing such as thermosetting, calendering or soaping as well as processes of chemical treatment (Gottwald 2006: 68). In other words, the knowledge base of refinement comprises several technical domains. In accordance with the variety of process technologies, a huge number of different machines are also used in this field (Rouette 2006: 18). Treatment of coating is one of the most important equipment technologies (ibid. 67). Multi layered compositions comprising support material and coating supports (as applied for the invention of this case) are an established method of this sub-sectoral knowledge base (Gottwald 2006: 70 et seq.; Schneider 2003: 78 et seq.). The composition of coatings determines the feature of the material's surface such as abrasion resistance (Schneider ibid.) and offers various technological opportunities. "Entsprechend der Zusammenstellung der Beschichtungen, Auswahl an Beschichtungschemikalien und Additiven […], kann ein breites Spektrum von Eigenschaften und Einsatzmöglichkeiten realisiert werden. Anwendungen finden sich sowohl für modische bis hin zu den High-Tech-Materialien."[119] (Ibid. 78 et seq.) Indeed, requirements like corrosion resistance of effects or no interference of the materials' color, as it was required for the advertised conveyor belts, were known from other applications. Likewise, they were considered to not be easily set up in new technological textiles (Gottwald 2006: 69). For

118 An integral perspective across all steps is thus crucial (translated by author).

119 According to the composition of coatings, the selection of chemicals for coating and additives […], a broad range of features and possible applications can be realized. Applications are found both in fashion and up to high-tech materials (translated by author).

the solution of these problems, chemical knowledge and long-term experience as well as deepened skills of the process were inevitable (ibid.). In addition, not only a high variety of processes existed in this field, also the combination of various systems and chemical knowledge was requested in response to the grown demand for technical coatings (ibid. 80 et seq.). In conclusion, the determination, adaptation and coordination of these parameters seemed to be an established practice in the field of textile refinement and finishing.

In the field of manufacturing of ready-made clothing and textiles usable end-products, such as medical beddings or curtains, were produced as well as textile end-products or intermediates that are further used in other industrial fields, such as interior textiles for furniture (cf. Rödel 2006: 119). The manufacturing process also includes refinement. When semi-finished products should be connected by thermal processes, for instance, a necessary requirement is the manufacturer's knowledge about the materials thermoplastic properties and their coating (ibid. 132) as it influences the durability of use. The change of textile structure during thermal treatment is considered a critical point where most defects of the surface appear (ibid. 133). Beside effects of refinement, the manufacturer of ready-made clothing or textiles needs knowledge about technical and design requirements, suitable compositions of fiber and fabrics for the product design (ibid. 119). Consequently, also in the field of manufacturing ready-made clothing and textiles, knowledge distributed across other textile sub-sectoral knowledge bases is an established, necessary condition. In particular, manufacturers of technical textile products, such as conveyor belts, are said to differ mainly from traditional manufacturers of clothing in technologies and techniques (ibid. 136). The requirements of industrial customers are challenging and deserve intramural research of manufacturers and research organizations (ibid. 136). In this respect, Hartmut Rödel (ibid.) expects higher demands on the creativity of engineers and scientists and their collaboration with potential users.

Finishing and manufacture of interior textiles like curtains was probably the bridging link or the reason why MultiTex sensed a new textile printing technology that they then used for the process innovation in conveyor belt advertisement. The use of inkjet printing technology in the product field of textiles started at the beginning of the 1990s in Europe (Schulz 2002: 154). A few years before, this technology had been exclusively thought in use on paper (Böhringer 2000: 10). "Direct digital printing on textiles was deemed impossible." (Weiser 2001: 330) The new technology opened up various new fields of application in decorative fabrics, fabrics for curtains and furniture, interior textiles up to table linen and bedding (Böhringer 2000: 22), for instance. "Die gesamte Heim- und Haustextilienbranche, Raumausstatter, Innenarchitekten, Dekorateure, Schneider, Textil-, Betten- und Möbelhäuser. Designbewusste Modehäuser entdeck[t]en den Service als günstige Möglichkeit, auch kleinere Kollektionen qualitativ hochwertig zu produzieren."[120](Ibid.) Moreover, it offered the opportunity for simpler and more economic printings on textiles (Schulz 2002: 154). Under the condition of more individual and exclusive pattern [Dessin] together with shorter repayment periods, costs and time to make up samples of pattern could be reduced by this technology compared to the conventional processes of pattern and textile printing (Böhringer 2000: 10; Weiser 2001: 334). Initially, this technological opportunity was valued promising by hardware and software producers and the chemical industry so that they invested in process technologies for textile based products, systems and inks adapted to the new textile support material (Böhringer ibid.; Schulz ibid. 158). Then this new printing technology became a technological opportunity for textile printers and mechanical engineering in this field above all (Schulz ibid.). In consequence, new techniques of inks and printers had been established and available around the millennium. "Bei aller Hochtechnologie basiert die neue Technologie jedoch nach wie vor auf den fundamentalen Prinzipien der Textilchemie. Daraus ergeben sich Notwendigkeiten, Grenzen und Möglichkeiten für den Einsatz des digitalen Drucks."[121] (Ibid. 154) The knowledge about the way of proceeding, the pre- and after-treatment was again central (Böhringer 2000: 16). Scorching, a known process from the field of refinement, for example, improves and secures the quality of the print and process safety (Schulz 2002: 154). Hence, the link of textile printing with the knowledge base of textile refinement was again an important requirement and offered a *technological opportunity*.

The literature review shows that in the first years of the new millennium the new printing technology had not been established in industrial production. Still in 2000 Böhringer (2000: 11) indicated: "In der Ferne kann man bereits erkennen, dass die digitale Drucktechnik mit den neuen Inkjet-Druckern in abschaubarer Zeit Einzug in die Produktion erhält."[122] For the broad establishment in manufacturing, the costs per square meter (Weiser 2001: 335) and of acquisition were still too high. For another reason, the adjustment of inks with the respective system of printing was still a challenge for manufacturers due to complex and yet fully defined determining factors at that time (Schulz 2002: 159). Accordingly, Konrad (2001: 391) noted in those days that numerous new processes and technologies offered technological opportunities to designers of textiles in the future, but that these were likewise increasingly required to look for new, first call solutions. In other words, for the exploitation of this technological opportunity, knowledge-intensive activity was necessary, meaning to develop new

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120 The whole industry of home textiles, decorating firms, interior architects, interior decorators, tailors and furniture shops […] Fashion houses discover[ed] service as a favorable opportunity to produce even small collections in high quality (translated by author).

121 Despite all high technology, this new knowledge is still based on the fundamental principles of the textile chemistry. That implies necessities, limitations and opportunities for the application of digital printing (translated by author).

122 The digital printing technology with new inkjet printers will eventually find its way into manufacturing in the foreseeable future (translated by author).

solving schemes of reliable processes for the industrial application of this technology in different textile products. MultiTex was one of the first firms carrying out this new process on conveyor belts (cf. Chapter 5.3.7).

At last, the conditions and technological opportunities in the field of conveyor belts and especially advertised conveyor belt are pointed out. Previous to the KIE process, no technological link had existed in this knowledge domain in the technological environment of MultiTex. The product field-specific knowledge base regarding the checkout system and the production process of conveyor belts is described in patent DE8910 884, for instance. Conveyor belts at checkout counters in supermarkets were known for a three layered design at least (cf. ISO 14890 Conveyor belts – specification for rubber- or plastics-covered conveyor belts of textile construction for general use). Another technical condition is that no standardized lengths of belts exist for checkout counters (Liening 2005: 50 et seq.). For this reason, belts with advertisement cannot be simply exchanged and reused in other supermarkets (ibid.). For advertised conveyor belts, two technological paths of development occurred: on the one hand, advertisement printed on foils and non-permanently adhered on the belts, and on the other hand, direct, permanent printing of advertisement on the belts. One of the German competitors with a marketing and advertisement background was exploiting the technique of specific foils. The firm, called FoiPi in the following, had started development activities at the end of the 1990s (Konrad 2009: 52). At first glance, this technique is cheaper and more flexible to apply than to print the advertisement on the belts. But it had led to problems of adhesion and the drive of the belt. Linked to this, problems of warranty occurred and original manufacturers of established belts rejected to further guarantee their warrantee in this case (Liening 2005: 50). Apart from this, existing approaches of direct printing used belts of a thermoplastic basic structure with a one-sided given fabric at least. The exterior surface of the belt was usually printed with applying pressure transfer printing at that time. Thereof, either the basic structure or the (multilayered) fabric was printed and then covered with an abrasion resistant thin coating. According to the patent specification of MultiTex, the disadvantage of conventional “Transfer-Druckverfahren” [transfer printing] or “Transfer-Sublimationsverfahren” [transfer sublimation process] were that the colors were printed with high temperatures and gaseous. Afterwards, the dispersion paints immigrated into the protective plastic coating. In consequence, the colors and contours blurred and the whole print image on the belt became blurring after a short time. After a while, the molecules of pigments arrived at the surface of the protective coating. When the printed belts were packaged one superimposed over the other, the inks even migrated to the surface of the other belt and displayed the image there. Another disadvantage was the distortion of fabrics during the conventional printing and the following processing that led to a distorted display of the print image. Compared to conventional plastic belts or foils, the micro structure of textile layered belts has superior, more flexible properties and a higher mechanical stability (cf. Möhring 2006: 320). Thus, a technological opportunity for a clearly distortion-free and lasting print of images on conveyor belts existed that required a new process solution. Begemann (2003: 261), managing director of Forschungskuratorium Textil (1993-2008), summarized the technological *opportunities* of refining more generally as “Chancen in der Funktionalisierung textiler Materialien durch gezielte Oberflächenmodifikationen und in der Verarbeitung zu innovativen Produkten für neue Anwendungsfelder“.[123]

In summary, established domains of textile finishing/refinement have the advantage of interdisciplinary, integrative knowledge frames across single stages of production. Compared to the specific field of elastic thread production in case of E-Thread, the knowledge base of refining reveals a variety of technologies and dynamics in process technologies. These characteristics offer important sources for innovation and KIE. Additionally, technological opportunities by new technologies from other sectoral or product fields, like digital printing, required entrepreneurial experimentation and knowledge-intensive activity, because dominant designs and solving schemes had not been established for processing at industrial scales at that time.

5.3.2 Market conditions and market opportunities

First of all, the conditions of MultiTex’s diverse established customer markets are introduced. Afterwards, the market conditions and opportunities of the new market of advertised conveyor belts will be disclosed.

As part of the market and trade liberalization, many German companies in weaving or manufacture of made-up textile articles went bankrupt or shifted their location to emerging economies. Between 2000 and 2006, the number of cotton-type weaving mills dropped by a third (cf. Table 7). The number of manufacturers of textile articles etc. fell even worse, by 44% in this period (ibid.). Against these major negative trends, the number of textile finishers increased by 25% to 862 companies in this time. Specific statistics about start-ups are not available for this level of aggregation so that one can only speculate, if these numbers are based on new market demand/or can be traced back to strategic divesture or buy outs, as assumed for the man-made fiber industry (cf. Löbbe 2008: 13). The employment rate shrank in all three fields comparable with the overall number of the textile industry (cf. Chapter 4) – except for manufacturers of textiles, where the rate went down by ‘only’ 16%. Again, also the development in sales occurred differently in these industrial market fields during 2000 and 2006 (Table 7). Typical for markets of textile material and the pre-stage of the textile supply chain that was affected first by newly emerging markets in low-cost countries, the turnover in cotton-type weaving decreased most of all

[123] … chances particularly in the functionalization of textile materials through targeted surface modification and in the processing of innovative products for new fields of application (translated by author).

(-32%). This shrinking was certainly caused by the rise of synthetic textiles. Textile finishers had a decline of 11% and textile manufacturers of 8% in this time.

Tab. 7 Sub-sectors' corporate structure

Germany	**Cotton-type weaving**			**Finishing textiles**			**Manufacture of made-up textiles articles, except apparel**		
	2000	2006	Change	2000	2006	Change	2000	2006	Change
No. of companies	224	151	-33%	692	862	25%	2,093	1176	-44%
No. of employees	14,364	9,139	-36%	15,868	12,098	-24%	25,042	20,919	-16%
Turnover in Euros (with thous. sep.)	1,866,9	1,275,4	-32%	1,557,7	1,381,1	-11%	2,592,3	2,380,3	-8%

Source: Own processed data based on Eurostat (NACE Rev.1.1D).

At the same time, the output of production declined by around 20% for finishing and manufacture and 27% in the field of weaving between 2000 and 2005 (Table 8). Also, the income orders developed negatively in all three fields in this period (cf. Table 9). In cotton weaving, the orders dropped by even more than a third, in finishing the income order amounted only 76.1% in 2005, compared to the benchmark in 2000. In case of the textile manufacturers, the number went down by 21% in this period (cf. ibid.). Altogether, these facts show stagnation of demand and growth in these traditional fields of the German textile industry in the first years of the millennium.

Tab. 8 Output development of the German textile industry

Branch of production	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Weaving	116.4	119.5	120.4	105.3	100.0	99.2	90.6	83.1	79.6	72.8
Finishing	120.6	111.8	107.8	98.3	100.0	94.1	85.1	78.6	79.8	77.1
Manufacture of textile articles…	100.5	97.0	98.2	97.6	100.0	91.0	89.6	88.6	85.1	79.3

Note: Measured in deviation from benchmark in 2000 (in %).
Source: Gesamtverband der dt. Textil- und Modeindustrie, output index (2006: 47).

Tab. 9 Income order development of the German textile industry

Branch of production	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Weaving	104.8	107.1	106.3	94.0	100.0	91.8	83.0	78.2	76.1	67.7
Finishing	127.0	120.9	112.4	96.2	100.0	96.5	90.4	81.1	80.6	76.1
Manufacture of textile articles...	90.9	89.9	95.8	96.7	100.0	96.7	92.3	90.9	85.2	78.6

Note: Measured in deviation from benchmark in 2000 (in %).
Source: Gesamtverband der dt. Textil- und Modeindustrie (2006: 48).

In addition, to these figures, the literature review revealed a broad offer of producers for the classical field of home textiles, for example. Retail dealers were confused by this variety (Hömske 2003: 203). Clearly, fashion trends were missing in curtains, decoration textiles or upholstery fabrics (ibid.) so that promising market opportunities were rarely perceivable in this field. Corresponding with the industrial life-cycle theory (ILC), the product range of these matured markets broadened (Peltoniemi 2001: 352), but product developments offered no significant market opportunity or unique selling position with an attracting return on investment. The application of adding value strategies on beddings and other home textiles had started in the mid-1990s so that equipment of traditional home textiles with functions of climate regulation etc. (cf. knowledge base above) had been mostly known and widely exploited by manufacturers before the KIE process. Consequently, at the beginning of the millennium, these markets promised no longer a unique selling point for German textile manufacturers or entrepreneurial opportunities of significant growth. Compared to this, the market of advertisement on conveyor belts looked fairly new and promising in growth, although it emerged in the 1990s, as well. In general, marketing at the so-called point of sales (POS) increased at this time (Knecht 2003a: 239). The main argument here was less spreading loss compared to classical advertisement (like on TV, radio or promotional brochures) (ibid.).

The earliest publication about advertised conveyor belts reported that more and more supermarkets refine their conveyor belts with media as they are considered close-contact advertising spaces (Liening 2005: 50). At that time, not only MultiTex sensed the POS marketing innovation as a valued market opportunity. Particularly in the German retail market, this relatively new marketing form had been hardly implemented (ibid). The market interest was shown by studies, like the European Consumers Buying Habit Study (POPAI) from 1999[124] that approved positive consumers' response to advertisement while waiting at the checkout (Liening 2005: 50; Nolan

[124] http://www.popai.de/POS_Forschung/Shopper_insights1.html.

1996). Ten years later, the situation was still described with a missing breakthrough of this new form of POS marketing in the German food retail market (Konrad 2009: 52). There had been a few attempts by small firms and also large trading groups to launch advertised conveyor belts in Germany (ibid.), because the checkout point has been a fiercely contested point of sales in general. A little bit earlier than MultiTex, in 2003, the pioneering marketing firm FoiPi introduced advertising foils for belts on the market. One year after MultiTex had established its subsidiary TecTex for the marketing of its promotional belts, an original manufacturer of conveyor belts from the Netherlands offered advertisement on belts for the first time at the Euroshop fair in 2005 (Liening 2005: 50). There had already been a few customer requests to manufacturers of conveyor belts, but following Liening (ibid.), none of them had exploited this business opportunity at that time. Yet, even in 2009 it was reported that most of the firms had failed and that "Kassentischbänder als Reklameträger noch all zu oft ungenutzt [bleiben]"[125] in the German retail market (ibid.).

From the retro-perspective, this development reveals, on the one hand, a considerable market interest and shared value; on the other hand, firms from the field of marketing and production of conveyor belts had not found any adequate technical solution at that time. In other words, a market opportunity existed and demonstrated the significant necessary identification and match with technical and institutional factors in this case.

5.3.3 Institutional environment and institutional opportunities

Describing the relevant institutional environment and opportunities in this case, first of all, the direct environment of MultiTex will be presented, followed by the conditions of the new institutional field of advertised conveyor belts.

As mentioned before, the first technical innovations had occurred in textile materials and in man-made fiber at the period around 2000 (Baldin-Erbe 2001: 79). The processors of these materials, like manufacturers of textiles or clothing, were often unable to cope with this unusual huge number of new developments in these fields (ibid.). More and more of these innovative fabrics could not be processed with the conventional standards and advice for the optimal processing were rare at this stage of production (ibid.). These uncertain institutional conditions remind of an era of ferment at this time. Due to missing established processing schemes of the product-field specific knowledge base, the manufacturers tried to rig up their own solutions which were costly and time consuming (Baldin-Erbe 2001: 79). "Diese Kosten werden jedoch nur selten erfaßt [sig.], und verschwinden in der Regel in den Gemeinkosten."[126] (Ibid.) This might explain the manufacturers' generally low figures in R&D investments (cf. Table 6). Finally, when the manufacturers mastered the new materi-

[125] … cash desk belts [were] still all too often left unexploited as promotional media (translated by author).

[126] These expenses, however, are rarely captured and usually they disappear in overheads (translated by author).

al, the next innovative material showed up so that they were often too slow (ibid.). These first experiences had likely led to resignation in many cases, and to a reluctant culture of innovation.

Formal institutional conditions in terms of the political system, laws or policies appeared not especially relevant in this case and in the literature review. New, far-reaching environmental regulations like REACH evolved later in 2006/2007 and can also be excluded as a jolt for KIE activity at around 2002. Further *formal institutions* in terms of regulation and policies can be assumed similar to the previous cases (cf. Chapter 5.2.3). Corresponding with the interviewees from the other cases, the managing director of MultiTex stated that he did not know any textile-specific supporting program for start-ups from that time. Likewise, he was not interested in such external funding.

A new *institutional arrangement* tried to address exchange and institutionalization of new knowledge at the industry specific knowledge base. The objective of the Dialog Textil-Bekleidung, launched in 1982, was to improve the communication and collaboration along the textile stages of production (Baldin-Erbe 2001: 86/79). Annual meetings of manufacturers of textiles and clothing as well as of machines should give concrete recommendations for the processing of new materials (ibid. 79). In 2001, this initiative dealt with processes of standardization and declaratory procedures. During the time of absent standard values, empirical values were collected in a database as a basis for technical inspections and benchmarks "[b]is es hier einen einheitlichen Lösungsansatz in der Industrie gibt"[127] (ibid. 2001: 85). This form of institutional work of adaptation can be better ascribed to routinized innovation regimes with established actors than an institutional opportunity that matches market and technological opportunities for entrepreneurial or KIE activities. Actually, the new arrangement of this dialogue reduced single entrepreneurial experimentation in favor of the new knowledge's institutionalization at the common sectoral knowledge base.

The situation was different with refiners of textiles. They were used to technological trajectories in terms of permanent technical changes in product requirements and variety of processes, as outlined in the sub-sectoral knowledge base (see Chapter 5.3.1). The refiners permanently had to adapt their process technologies to the new textile products or "selber textilgestalterisch [zu] agieren"[128] (Rouette 2006: 19). The dynamic environment of the textile refinement industry described in 2006 probably did not greatly differ from the environmental conditions in the years before – thus for the time analysed. This is additionally supported by the higher and increased R&D expenses in value added compared to the field of weaving or manufacturing textile articles between 2000 and 2006 (cf. Table 6).

[127] … until a common problem solving approach for the industry exists (translated by author).

[128] … or to act textile-creatively, themselves.(translated by author).

Compared to the common flow of goods that was exclusively heading for effects downstream the “textile pipeline”, a deviating institutional arrangement of supplier relations could be identified in the field of textile refinement (Rouette 2006: 23). More precisely, “jede Stufe beliefert i.d.R. nur nachgelagerte Stufen und erhält i.d.R. nur Waren von vorgelagerten Märkten.”[129] (Ibid.) Typically, the direction of search for innovation was bound backward to the fiber industry upstream the textile supply chain (Hübner 2001: 283). “Innovationen im Flächenbereich beruhen fast ausschließlich auf Entwicklungen der Faserindustrie.”[130] (Ibid.) This also reveals specific expectations towards fiber producers and a rather passive, supplier-dominated habit of textile and clothing manufacturers in innovation activity. This expectation went so far that even manufacturers of fibers were called to help clothing manufacturers and participate in the marketing of the end-products (cf. Knecht 2003a: 242; Reinhold 2003). The institutional arrangements in the field of refinement deviated from this uni-directional effective direction of action. A typical organization has been textile verticalization with manufacturers charging refiners for contract processing of textiles (Rouette 2006: 21). Sometimes they may deliver refiners with fabrics that are redelivered to the customer after their refinement. From time to time, refiners outsource processes in case of peaks of production or when the firm’s equipment and machines were not specialized in the demanded effects of refinement (ibid. 22). Thus, institutional arrangements of vertical disintegration as well as vertical integration existed in the field of refining. These heterogeneous arrangements supported the more and more required collaborative innovation activity across different stages of production and sub-industries. Indeed, this field-specific institutional structure promotes the new organizational form of innovation but does not necessarily enable entrepreneurship or promote entrepreneurial actors.

The trend in technical textiles with more multiple functions from that time required knowledge about the different components and materials and their useful coordination (Hübner 2001: 283). Particularly refiners had almost all attributes to do this. Their knowledge base with wide technical and cybernetic frames in this field connected with knowledge of physics or chemistry, for instance, built a beneficial structural condition for the handling of new, interdisciplinary knowledge. “Während der Textilfachmann bis vor kurzem den Effekt der verschiedenen Materialien zu deuten und zu kombinieren wusste, braucht es heute Fachwissen aus anderen Disziplinen (Physik, Chemie u.a.).”[131] (Ibid.)

With raised technical complexity of the functional products, their marketing also became more challenging (Knecht 2003a:242). The multifunctional products needed

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[129] ... each stage of production usually supplies only stages downstream and usually receives only goods from markets upstream (translated by author).

[130] Innovations in the field of fabrics were almost exclusively based on developments in the fiber industry (translated by author).

[131] While the textile technician knew to interpret and combine the effect of diverse materials until recently, nowadays specialist knowledge from other disciplines (physics, chemistry et al.) is needed (translated by author).

additional explanation to the customer but also to the retail and salesman (cf. Hübner ibid.). Hence, for the successful implementation of such innovations, existing technological opportunities needed to be matched with the opportunity of emerging markets of so-called smart textiles. "Die Durchsetzung einer Textil-Innovation bedingt deshalb eine Verknüpfung der vorgelagerten Stufen mit nachgelagerten Kooperationspartnern und auch mit seitlichen Disziplinen."[132] (Ibid.) This implied close communication across diverse stages of production. The intercession of a technical product's know-how to manufacturers up to retail with the help of "aussagekräftige Demonstrationsmaterialien" [convincing material for demonstration], for example, was considered a crucial factor (ibid.). However, this implied additional investments in time and costs (ibid.). The reality was obviously different, as Hübner (ibid.) calls for more promotion and practice of this collaboration along the textile supply chain, meaning, the communication had to be intensified on each stage (ibid. 283). That this required collaborative innovation activity was not an established institutional *practice* was also confirmed by the guiding themes of the Industrielle Gemeinschaftsforschung (IGF) (cf. Begemann 2003: 262). In consequence, refiners or finishers basically had a better position with respect to emerging requirements of innovation than weaving mills or textile and clothing manufacturers in the institutional environment at that time.

Also remarkable for the practices described in the literature is that entrepreneurial or founding activities are not mentioned at all. Most practices indicated necessary for innovation point, indirectly, to existing firms and collaboration between existing firms. It was only referred to creative innovation activity that partly involved the reduction of uncertainties in new introduced materials and fibers. Obviously this did not automatically imply the creation of a new firm. Instead, advanced experiences in the processing and properties of textile materials and their combinations across stages of production were promising sources favored by corporate entrepreneurship in the field of refining firms or finishers.

Finally, the conditions and existing institutional opportunities of the new institutional field where the KIE process emerged are analysed. Although advertised conveyor belts were relatively new in marketing, they emerged in a highly institutionalized market shared by a few market players in retail. The business culture in this market is characterized by distinct power relations in favor of a few big retail chains or big brand manufacturers of groceries. Advertisement at the point of sales (POS) like in supermarkets was already described as fiercely contested (Konrad 2009: 52). The retail either sold the close contact POS to brand industries or promoted its home brands and activities (Liening 2005: 50). An established practice at the retail firms was to have a mix of advertisement of branded products and home brands in their supermarkets (ibid. 52). Interests of customers from the brand industry had to be traded off against own interests in marketing of home brands (Gödl 2008: 16; Prignitz

[132] Implementation of a textile innovation is thus conditioned by the connection of the upstream stages with cooperation partners from downstream and sideway disciplines (translated by author).

2010). With respect to the unexploited market opportunity of advertised conveyor belts, a representative of the German Retail Federation stated (in a telephone interview, December 2010) that the area of the checkout counter might be still seen as a neutral zone in Germany where retailers like to avoid a brand product being laid down on a conveyor belt with advertisement of a competing brand or home brand. Special studies or publications on this issue could be not found. Knowledge about consumer behavior is generally sensitive and a critical business factor for competition in this market. The European Consumers Buying Habit Study (POPAI) that is regularly conducted faced problems, because big retailers resigned from their participation in the study. They are not interested that such market knowledge is more broadly disclosed (Nolan 1996). This example illustrates their powerful position in the market.

Beside the positive results of the POPAI from 1999 (ibid.; Liening 2005), later publications about POS marketing in general also found negative effects. So-called crowding and density effects explain stress that appears when the consumer is affected by too much environmental stimulation (Gröppel-Klein 2006: 681 et seq.). In addition, the belts provide only limited space for advertising texts, as said by the marketing expert, and pictures alone would not be effective enough. For that reason, marketing messages from other advertisement media or campaigns had to be adapted and very pointedly compared to other forms of advertisement. In consequence, these technical conditions also implied challenges on the customer side of professional marketing. Many retailers used it, for instance, for campaigns of discount or debit cards. As POS marketing is quite an expensive effort, costs and effects had to be in the right relation.

After some first tests of FoiPi, the pioneer in the foils technique, with some discounters in 1999, a few retailers started own experiments with adhesive foils and failed (Konrad 2009: 52). The technological requirements were obviously underestimated in the beginning. This introduced another technological opportunity of an alternative technical solution, but it also had a negative effect on the market: According to FoiPi, the failed attempts of the retailers harmed the implementation of the innovation, "danach war das Thema kaum noch zu vermitteln"[133] (Managing director of FoiPi in Konrad ibid.).

This episode additionally reveals a specific *institutional arrangement* in this field. FoiPi started as a full-service provider of this innovative form of POS marketing, focusing on regional retail chains. But this way, the new market entrant tried to enter the sensitive business field of POS marketing shared by a few large retailers and branding industry. The own trials of some retail firms showed that these established dominant actors obviously were not willing to let these critical POS be run by a third party. The reconciliation of the divergent interests by the brand industry and retail should not be left to a small marketing firm. Against this, FoiPi was more successful at smaller, regional family ran grocery chains (Konrad 2009: 52). With respect to

[133] … thereafter the issue was difficult to communicate (translated by author).

general POS marketing, a technical journal (Gödl 2008: 16) recommended marketing agencies to inform about the retailer's guidelines and restrictions and to include the retailer right from the beginning of planning.

Altogether, the investigated conditions reveal no *institutional opportunity* for matching technological and market opportunities. MultiTex probably did not sense these institutional barriers and situation, because at the beginning of the KIE process it was not familiar with this institutional environment.

5.3.4 Interim conclusion

Summing up the environmental conditions of this case, established innovation practices in home textile no longer promised growth or market opportunities. Heterogeneous institutional arrangements in the field of refining as well as specific characteristics of the refining knowledge base (variety of technologies, links to other knowledge fields and cybernetic thinking) favored competences necessary for innovation in new distinct functional textiles.

Given these technological opportunities for textile refiners, an increasing number of firms could be assessed against the general negative trend. A concrete new market opportunity in the advanced field of home textiles, however, could not be identified from the literature. Rather, at those days new functions in climate regulation or hygienic had already entered the market or required too costly research for firms. Explicit information on start-ups or entrepreneurs could not be found. Likewise, entrepreneurial orientation in terms of entrepreneurship enabling institutions could not be identified from statistics and literature review.

Though some technical opportunities existed, MultiTex decided to exploit an innovation in an external market. A reason for this might have been the increasing number of market actors in textile refining that reduced overall innovation benefits in this field. Against this, the entrepreneurial opportunity in conveyor belt marketing promised higher return on investments from the point of MultiTex. Indeed, a technological and market opportunity could be disclosed for the emerging field of advertised conveyor belts. However, the institutional environment and arrangements revealed challenging for new entrants after first failures and with regard to the actor constellation and power relations.

Refiners have generally been described on the institutional level of actors. Beyond these general environmental conditions, the specific corporate conditions of MultiTex are presented in the following.

5.3.5 Corporate conditions and corporate opportunities

The characterization of the environmental conditions discloses that the vertical range of manufacture of MultiTex was no longer common in the dissected and internationalized textile supply chain at the beginning of the millennium. Accordingly, MultiTex was an organization embedded in multiple fields of textile production (weaving, refinement/finishing and manufacture of home and medical textiles). This *corporate situation*, however, occurred from an act of necessity. In the course of the price competition with emerging industries, Mr. A, the managing director of MultiTex, reinforced the business orientation to fashionable home textiles in the high-price segment. The firm manufactured fabrics with variation in medium volume production for these still existing, exclusive niche markets in Germany. Beside this product family, MultiTex had specialized in (multi-)functional medical textiles arisen from traditional beddings for the same argument of avoiding price competition. The medical textiles were standard products still mainly based on cotton and manufactured in mass production. MultiTex covered the full range of production from weaving, finishing up to manufacturing of ready-made textiles (cf. Figure 07). This broad *positioning* of MultiTex was not random but in response to the breakaway of the textile supplier markets in Germany. Sourcing of materials from or outsourcing refining to foreign markets was no option for MultiTex because of the high quality requirements of the two product groups. As Mr. A stated: “Es gibt immer weniger Betriebe, die die Waren dann veredeln können. Also, das ist ein Problem in der Textilbranche bei uns in Deutschland, dass die Infrastruktur in der Wertschöpfungskette möglicherweise in der Zukunft nicht mehr hundertprozentig funktioniert.”[134] In the previous five years, four out of six refiners from the region of MultiTex went bankrupt. For the managing director, this situation involved the danger of becoming dependent on the few that still existed or to have no more options to select from at all. In consequence, Mr. A decided to be prepared for such times.

Although MultiTex’s economic situation was sound and independent from any external funding, the critical development of business conditions and future prospects were alarming. Mr. A indicated that the field of home textiles was generally stagnating with a decline in sales by 10 to 15% in the high-price segment, whereby they still got off cheaply compared to 50% decline in the low-price segment. As a consequence, Mr. A was looking for a new market with a unique selling point. “Denn wir sind hier im Heimtex-Bereich und in den anderen Bereichen, wo wir tätig sind, sicher auch mit einer gewissen Profilierung am Markt, aber nicht alleine.”[135] Hence, the company’s motivation for KIE was to have “Chancen, wirklich ein Produkt zu haben, das niemand hat.”[136] (Mr. A) MultiTex’s culture of financing and investments was another important prerequisite to set up KIE. Apart from many other firms in this time of *crisis*, MultiTex was willing to considerably invest in innovation and its market introduction. According to Mr. A, this was a necessary investment for the company’s future:

[134] There are less and less companies able to then refine the goods. Well, this is a problem of the textile industry in Germany that the infrastructure of the value chain is probably not functioning at 100% in the future (translated by author).

[135] Because here in the field of home textiles and in the other fields where we are operating we are on the market with a certain profiling, but we are not alone (translated by author).

[136] … opportunities of providing a product that really no one has (translated by author).

… und das hat uns auch in Krisenzeiten, in denen die Volkswirtschaft eigentlich gelitten hat, da hat uns das stark gemacht. Denn gerade in Krisenzeiten ist es ja, dass die Umsätze zurückgehen, dann wird jedes Unternehmen Kosten einsparen, und das ist eigentlich ein ganz fataler Punkt. Weil, wenn ich heute schon da spare, wo ich künftig Umsätze mache, das heißt, in der Kollektion oder bei den Mitarbeitern, dann setze ich einen Prozess in Gang, der eigentlich ganz schwierig zu stoppen ist. Denn ich muss gerade in Zeiten, wo es schlecht geht, Kapital haben, um das gerade einzusetzen.[137]

The *firm-specific knowledge base* of MultiTex combined knowledge from the fields of weaving, refinement and manufacturing in accordance with the introduced product-field specific knowledge bases and technological domains. Usually textile firms rather specialized in one of these fields, following the high division of labor in the textile industry. Most of the employees at MultiTex were technically educated in the field of textile engineering or textile technicians specialized in refinement, but none of them held an academic degree. More precisely, MultiTex holds knowledge in design of fabrics and textile chemistry for finishing and refining, especially in application of paint on decorative textiles and printing and in the field of dry finishing. Chemical refining without any chemical reaction of the fiber or the functionalizing of the fibers' chemical reaction are established practices of this subsector-specific knowledge base (cf. Rouette 2006: 311) that is assumed to be also held by MultiTex. In addition, dry finishing generally includes not only chemical treatment but also mechanical and thermal processes of treatment (ibid. 552) where MultiTex must have additionally been well versed. In sum, MultiTex held knowledge in many technological fields that were beneficial for the exploitation of the technological opportunity in conveyor belt advertisement, namely a process technology for a distortion-free and lasting print of images on conveyor belts.

In case of the multifunctional medical textiles, MultiTex had proven its organizational capacity in newly combining several known functions into one multifunctional product. Likewise, this example illustrates the *technological opportunity* specifically due to the machines and equipment at MultiTex: "Und aus diesen Produktionsmöglichkeiten haben wir eine Produktgruppe geschaffen, die auch völlig neu war […] vor 15 Jahren."[138] (Mr. A) MultiTex used its know-how in coating for these development activities. Medical textiles were coated, for instance, with new material to receive specific protective functions for beds in hospitals. Hence, previous to the KIE process, products with new combinations of defined functions as a form of creative accumulation built the established *practice* of innovation at MultiTex.

137 … and this had made us strong during periods of crisis when the economy suffered. Since even in times of crisis when the turnover decreases, each company will save expenses, and this is actually a disastrous point. Because, if I save money at the staff or at the collection where I like to do business in the future, then I initiate a process that is actually hard to stop. Particularly in difficult times I need to be solvent in order to invest (translated by author).

138 … and from these opportunities of production we created a group of production [medical textiles] that was completely new […] 15 years ago (translated by author).

Generally, innovating was an established practice at MultiTex right from the beginning. Compared to the initially mentioned original business of Mr. A's grandfather, MultiTex developed completely differently although they had started in the same product field of bedding with the same relations to customers and suppliers, as stated by Mr. A. The original family business that was continued by the other part of the family remained in the traditional business, whereas MultiTex started completely new and is still looking for new ideas and product lines. Following Mr. A, MultiTex's innovation activity depends on the initiative, the company culture, and on the staff and their motivation. During the last fifty years, the company diversified in new product fields like medical textiles. This reveals dynamic organizational or innovation enabling capabilities. Especially new combinations were typical at MultiTex that point to the transformative and configurationally capabilities of innovative low-tech firms (cf. Bender 2005).

Altogether, these corporate conditions disclose the individual situation at MultiTex that favored the emergence of KIE. The firm's culture was receptive to innovation and product changes with respect to entrepreneurial foresight. Moreover, diverse technological capacities and experiences in functional finishing and refining of textiles, liquid financial resources for investments up to the firm's openness towards environmental dynamics were enabling conditions. At last the firm was interested in finding a new product or market with a unique selling position. All these aspects contributed to the firm's propensity for a differing innovation through the exploitation of a new, external field in terms of corporate entrepreneurship. The key driver of the KIE process was Mr. A, the managing director and owner of MultiTex who is next presented as the entrepreneur of this case.

5.3.6 The entrepreneur

The entrepreneur in this case is Mr. A. He is the managing director of MultiTex and, since 2004, also of the subsidiary TecTex. Hence, this *position* has allowed him to strategically decide on the firm's resources for KIE activities. Also, he has organized further necessary resources for the KIE process.

Mr. A attended business school in the late 1970s and afterwards a textile professional school, where he learned to apply his business knowledge on practical problems. Hence, Mr. A was *educated* in the field of business and textiles. After that he started working at his father's company (MultiTex) together with his twin brother. In the mid-1990s, they took over the management of the family business as the third generation. Since Mr. A's brother died ten years ago, he is the only managing director.

As outlined under the corporate conditions, Mr. A's *motivation* for KIE is to distinguish the company on the market. For this objective he showed entrepreneurial capabilities in terms of a reflective stance towards business routines (new product group of medical textiles) and awareness of entrepreneurial opportunities from unfamiliar fields (advertised conveyor belts). Here, Maguire's argument (2008: 675) can be reinforced that the embedding in different fields and "positions that bridge beyond the field's boundaries" helps so-called longtime field participants to become aware of and open to alternatives.[139] The willingness to take risk needed for such entrepreneurial innovation activity he took over as a maxim from his father. Thus, Mr. A is not only a manager but also a risk taking entrepreneur with an entrepreneurial spirit in mind. He has the attitude that there is nothing that is impossible. In his opinion, many innovations fail, because no one backs them with regard to the confidence (belief) and financing. Mr. A is prepared for this "opposing wind" and cannot be stopped from following his venture. He further showed cooperative *skills* to win over supporters for the setup of the innovation. Honesty and reliability are important values of business for him to establish confidence in collaboration with partners. His *social capital* from previous network relations was not relevant in this case.

5.3.7 The KIE process

Against the background of these corporate conditions, the idea for the innovation came up randomly to Mr. A during shopping in a supermarket. He had always sensed conveyor belts at the checkout as dirty and not very aesthetic.

> *Da hab ich mir gesagt, das muss man doch irgendwie besser machen können […] und die erste Idee war, das […] antibakteriell zu gestalten, dass man einfach hier eine saubere Oberfläche hat, hygienisch, und ganz einfach das ein bisschen ansprechender macht. Und dann ist mir der Gedanke gekommen, warum nicht eigentlich irgendwie etwas Bild mäßiges draufmachen […].*[140] *(Mr. A)*

For the birth of the idea to produce advertised conveyor belts first the relatively newly arisen function of antibacterial textiles was taken into consideration. In addition, Mr. A's cognitive frame of aesthetic design from the product field of home textiles had a kind of bridging function to the field of advertisement. When the business opportunity was analyzed at MultiTex, they sensed that advertisement at the checkout area was technically not possible so far and promotion was basically not well placeable in supermarkets. Beside the market opportunity they also realized the technological problems of pioneers in this field as a technological opportunity. As a new entrant in the field of marketing, the management of MultiTex was probably not fully aware of the impeding institutional arrangement of retail chains and brand producers (Chapter 5.3.3) when it decided to exploit this entrepreneurial opportunity.

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139 „Und jedes neue Produkt hat irgendwo auch einen Lebenszyklus und irgendwann ist halt dieser Lebenszyklus auf der absteigenden Richtung, und dann muss man sich neue Ideen einfallen lassen oder neue Produktlinien. Und das haben wir rechtzeitig gemacht." (Mr. A) [Translation by author: And each new product has a life-cycle and when this life-cycle is in the declining direction, one has to come up with new ideas or new product groups. And we did this in time.]

140 Then I told myself that one could do this better, somehow […] and the idea was originally to design it antibacterially so that one has a clean surface, hygienic, and that one does it just a little more appealing. And then the thought has crossed my mind, why not put some illustration on it to push it up (translated by author).

Reconstructing the process of invention, not only a link to frames of aesthetic home textiles can be assessed but also a link to the technical frame of textile refining. As already introduced in the description of the product field-specific knowledge base of conveyor belt marketing (Chapter 5.3.1), belts usually consist of a textile base. Although at first glance they look like a plastic product, they are considered a conventional technical textile product (cf. NACE code 13.96: Manufacture of other technical and industrial textiles, Rev.1.1). The multilayered design of textile and plastics or polymers can be linked to the frame of refining processes like coating of functional medical textiles at MultiTex. Hence, initially similar technical frames from different fields of applications were affected and structured the process of invention.

Mr. A compared the process with the new recombination of existing functions for medical textiles. "[M]an erschafft jetzt nicht das Rad neu, aber man bringt mehrere Funktionen in ein neues Produkt. Beim Kassenband war es bisher nur Transportträger, und jetzt hat es halt noch eine optische Funktion bekommen. Und das ist einfach der neue Nutzen, das ist die Innovation."[141] But in fact, the process of invention went beyond the application of established solving schemes of textile refining on the field of printing of conveyor belts. During the two years of technical development, first attempts to apply conventional chemical treatment (e.g. finishing) on the fabric could not solve the problem of warpage. It led to negative results with respect to the printing, adhesion and durability of the conveyor belt (patent specification). In other words, recombining activity of established solving methods from existing technical frames was not sufficient and new solutions needed to be created as knowledge-intensive activity.

> *Und es gab auch bei der Entwicklung eine Zeit wo man gesagt hat, ob es dafür eine Lösung gibt, da sind wir jetzt nicht mehr so optimistisch. Es gab richtig Punkte, wo wir gesagt haben, das könnte scheitern. Weil die Anforderungen an dieses Produkt extrem sind und es sehr viele Zusammenhänge gab, die hier zu berücksichtigen waren. Das heißt, es war wirklich nicht nur Textil Know-how gefragt, es war auch anderes Know-how gefragt, das aus anderen Bereichen kam, und das musste kombiniert werden. Wobei die Kombination nicht das Problem war. Das Problem waren wirklich diese ganz neuartigen Problemstellungen, mit denen man auf chemische Weise zum Teil zu tun hatte, die auch wirklich noch keiner je bisher so angepackt hat, aber wir konnten sie lösen.[142] (Mr. A)*

The design process entailed many steps of trials and errors, since the requirements on the product were challenging. Finally, the technical problem was solved through an innovative design of a multi-layered structure with a thermal treatment of fabric

[141] [Y]ou do not reinvent the wheel but you bring several functions into a new product. The conveyor belt was only a carrier of transport, and now it has got an optical function as well, and this is the new use, this is the innovation (translated by author).

[142] There was also a moment during the design process when we said we are not so optimistic about finding a solution. There were points when we said this could fail, because the requirements on this product are so extreme, and there were many coherencies to take account of. In other words, not only a textile expertise was needed but also expertise from other fields, and these had to be combined, whereby the combination was not a problem. The challenge was really these completely new problems which one dealt within a chemical way and which no one had seized so far, but we could solve it (translated by author).

made of two types of fibers with different melting points (patent specification). Hence, know-how of different material properties was combined to a creative design in the coating process.

This process innovation was developed internally and without the recruitment of new, highly qualified staff. MultiTex recalled all its firm-specific know-how in refining and printing to develop a new process technology, but it also extended its knowledge. Furthermore, a customized digital printing machine was bought for more than ten million Euros to produce the new product. It was especially designed for the specific requirements of quality to imprint belts with advertisement. According to Mr. A, the machine existed only two times in the world at that time. The machine could also be used for processing other printed products of MultiTex, for instance home textiles. Thus, in fact this firm-specific knowledge and capacities of MultiTex built necessary resources or an individual opportunity to match the technical and market opportunities for this idea.

However, the existing knowledge and technological resources alone were not sufficient for the KIE process. Missing necessary knowledge of manufacturing and equipment to produce conveyor belts was organized through the cooperation with a manufacturer of conveyor belts (named ConBe in the following). For the complete processing of the innovative belt, the core competences of MultiTex in textile printing and refining of curtains were newly combined with the one of ConBe in conveyor belt manufacturing. The manufacturing process of the product was divided in 24 operations, which were partly conducted at the partner company and partly at the location of MultiTex. This way, MultiTex did not need to acquire the whole manufacturing equipment to produce the basic parts of the belt. Meanwhile, the belts are custom-specifically produced in medium volume up to mass production (cf. company questionnaire).

Altogether, the effectual logic of the firm's previous practice in recombining diverse functions determined the emergence of the idea. The following process of invention reached beyond the *mechanism* of effectuation, because not only means at hand were used. Likewise, it cannot be sufficiently described with exaptation, reusing existing features for a new market, because a new process technology was created based on knowledge-intensive activity that extended MultiTex's firm-specific knowledge base and the product-specific knowledge base of advertised conveyor belts.

The partner ConBe mainly supported the KIE process in the operative process. As stated by Mr. A, ConBe is a big family business that has been producing belts for 130 years now. It can be assigned to the low-tech metal industry, as the belt is only one component in manufacturing checkout systems. Following institutional entrepreneurship theory, the cooperation with ConBe was a strategic mobilization of a highly embedded expert (cf. Leca et al. 2008: 11) from the conventional field of conveyor belts.

In the opinion of Mr. A, the expertise of ConBe was essential for the setup of the innovation. As outlined in the description of the market conditions (Chapter 5.3.2), manufacturers of conventional conveyor belts had been aware of the new business opportunity in advertisement around this time (Liening 2005). But they had hesitated to exploit it because of the mentioned problems in the field of imprints, which was an unfamiliar technical field for manufacturers of checkout systems. Consequently, both firms benefited from the complementary competences of the partner.

The motive for collaboration emerged from a mutual interest. "Das war aber für beide eine Chance, auf einen Markt zu kommen, wo man Alleinstellungsmerkmale hat. […] und es ist klar, dass man bei so einem Produkt gerne mitmacht, auch wenn es Kosten erst einmal verursacht, die schon heftig sind."[143] (Mr. A) Hence, the partner's enthusiasm about the innovation and its shared future prospect was a necessary prerequisite for the cooperation. Moreover, it was important for Mr. A that both companies were similarly minted, as ConBe was also a sound traditional family business interested in innovation. They shared the same thoughts referring to expenses and dimensions of costs. All these commonalities point to the 'process of enabling collective attributes with supporting actors' (Snow/Benford 1992 in Leca et al. 2008: 12). These shared attributes certainly contributed to the fast establishment of confidence, although only a loose contact had existed before. They felt connected, and it fit right from the beginning. A business relation arose from the first meeting. Additionally, firm cooperation agreements were made.

In the course of the KIE process, the traditional textile firm MultiTex networked not only in the new industry of conveyor belts, it also established network relations to the advertising industry. This way, MultiTex *mobilized* important distributed sources of knowledge from unfamiliar sectoral knowledge bases. The professionalization of MultiTex in the new field of advertisement became apparent in an own conducted market study about the effectiveness of this new advertisement instrument at the POS. They measured the costs per mille (CPM) of this new medium of advertisement, which is a common indicator to assess the effectiveness of advertisement in marketing.[144] MultiTex contextualized its invention, referring to these professional marketing language and practice of survey. It used existing frames from marketing to create collective attributes with supporters (cf. Leca et al. 2008: 12) or potential users of the new product. Based on this framing activity MultiTex argued with less spreading loss and

[143] For both, it was a chance to get on a market where you have unique characteristics. […] It was clear that one likes to participate in developing such a product, even if it causes enormous expenses at the beginning. But if one is convinced of the product, then one takes it in hand (translated by author).

[144] „Und wir haben ja Analysen gemacht mit sehr hoher Beteiligung. Also, wir hatten eine Präsentation in Prag, da haben wir mit Beteiligung vom Fernsehen auch eine Umfrage gemacht mit 2.000 Konsumenten. Und von denen konnten 89 Prozent haargenau sagen, was auf dem Band stand. […] und das erreichen Sie bei keiner einzigen Werbung." (Mr. A) [Translation by author: And we carried out analyses with a large attendance. Well, we had a presentation in Prague where we carried out a survey of 2,000 consumers with the help of television. Thereof 89% could exactly state what was written on the belt […] and this you cannot reach with any other advertisement.]

higher effectiveness of this new medium than other marketing instruments at the POS. (Mr. A) This way, the high reachability and plausibility of the new alternative advertisement on conveyor belts was communicated (cf. Garud et al. 2007: 962). Likewise, this theorizing contributed to the legitimacy of this new form of advertisement and to the professional competence of MultiTex. This legitimization was crucial for MultiTex, as it was a new entrant in this field.

Compared to other pioneering competitors, MultiTex introduced a *new organizational form* for the implementation of the advertised belts. Instead of selling foils or printed belts to customers, MultiTex offered to rent the checkout counters from operators of supermarkets. As a full service provider it also took over the maintenance and change of the advertised belts as well as the rent of the advertising space to brand manufacturers or other interested parties. Based on this operator concept, MultiTex sought a win-win situation with their potential customers. “Man kann erstens mal sagen, okay, wir nehmen euch alle Kosten ab, die ihr habt. Wir mieten einfach eure Plätze, ihr habt nichts mehr damit zu tun, ihr bekommt noch Geld von uns.”[145] (Mr. A) This way, MultiTex responded to technical problems and problems of quality and warranty (cf. Chapter 5.3.1; Liening 2005: 52) caused by competitors in the early phase of this new form of advertisement. “Und die haben Produkte auf den Markt gebracht, die dir um die Ohren geflogen sind, im wahrsten Sinne des Wortes. Da haben sich die Schichten abgelöst, es haben sich die Farben verändert […] Also, da sind wirklich heftige Probleme aufgetreten […], die dadurch erst einmal eine Unsicherheit geschaffen haben.”[146] The full service concept addressed these problems by taking them off the supermarket operators. MultiTex produced new advertised belts in cooperation with ConBe, exchanged them with the existing ones in the supermarket for the duration time of the advertisement. This way, it also solved the warranty problems with original belt producers of the previous belts. After the contract duration, MultiTex changed the belts again. Because MultiTex owned the advertised belts, it could still use them in other supermarkets. For example, when a credit card institute charged MultiTex to serve advertisement at further supermarkets, the especially produced belts could be used again – given that the technical parameters of the next checkout system allowed for this (cf. Liening 2005: 50 et seq.). On the one hand, MultiTex paid for renting the checkout areas at supermarkets; on the other hand, it further rented these places to brands or other customer firms interested in advertisement at this POS. This so-called win-win-situation illustrates that MultiTex’s understood the situation and problems of supermarket chains as potential allies (cf. Leca et al. 2008: 10). Moreover, it shows how MultiTex tried to align these with its own interests and identified reasons for collaboration (cf. Leca et al. 2008: 10/14;

[145] Initially you can say: ‘okay, we take all your costs off you, we rent your places, you have got nothing to do with it any longer, you even receive money from us’ (translated by author).

[146] These [competitors] had introduced products to the market that blew up in your face in the true sense of the word. There were coatings removing, colors changing […], well, serious problems had occurred there […] and this had caused uncertainties at users (translated by author).

Garud et al. 2007: 962). Finally, this strategy discloses necessary empathetic skills on the side of MultiTex (ibid.).

The technical effort for the installation and maintenance is only profitable, when the promotional belt is not exchanged too fast, unless it can be used again. But usually advertisement like special offers change weekly in supermarkets. Consequently, the prices of advertisement had to cover these costs, which were set by MultiTex. Moreover, as a full service provider, MultiTex did not address its service of advertisement to single store runners or franchisees, but to big retail chains. Thus, the region-wide equipment of all branches implied higher volumes and enabled effects of scales in production. Against this organizational form, a competitor from Holland just delivered and installed custom-specific advertised belts to single store runners. These rented their conveyor belts to third parties on their own (cf. Liening 2005: 53). The store runners or franchisees received additional revenues from which the producer of belts did not benefit. A subsidiary of the Dutch competitor optionally offered marketing and mediating services to customers. Compared to this, MultiTex and later TecTex internalized this service while the region-wide maintenance service was taken over by freelancers. Altogether, this operator concept of MultiTex was a new organizational form in this context. Accordingly, MultiTex appeared as a third, alternative party in the *institutional arrangement* between retail chains and customers of advertisement, as it stepped in the business of mediating advertisement at conveyor belts in supermarkets. This alternative organization leads over to the discursive dimension in the process of this case.

As outlined in the institutional entrepreneurship concept, the alignment of the new idea with established values and interests of “dominant coalition members” is particularly central in mature fields (Sudabby/Greenwood 2005; et al. in Leca et al. 2008: 14). More precisely, MultiTex’s new organizational form or business concept broke with the established coalition of supermarket chains and interested parties of advertisement in these supermarkets. The sensitivity of this business field was already introduced in the description of the institutional business culture (Chapter 5.3.3). The supermarket chains are interested, at least, in a balance of own advertised and brands’ products. The rent of their spaces of advertisement by a third party implied that they gave up this control of selection. From this it follows that MultiTex had to expect resistance from these actors. Accordingly, the access to business partners and customers of the retail market, indeed, turned out difficult. “Also, was wir gemerkt haben, bis ein Vertragsabschluss zustande kommt, sind in Deutschland durchaus ein bis zwei Jahre vergangen. Weil, es geht ja um entsprechende Größenordnungen.”[147] Mr. A also became aware of MulitTex’s *position* as a lateral entrant in this field that still missed legitimacy. “Es gibt Machtstrukturen in solchen Märkten, das ist klar. Wo viel bewegt wird, da sind auch Strukturen, die wirklich gewachsen sind, und da muss

[147] Well, what we noticed was that it takes one to two years until the completion of a contract in Germany, because it is about relevant scales (translated by author).

man erst einmal sich dann auch einbringen."[148] (Mr. A) To overcome this challenge, Mr. A responded that insistence and a reliable product ready for series production were essential prerequisites. Beside these time consuming negotiations with potential business partners in Germany, MultiTex sensed alternative business opportunities for the market introduction. They started to look for customers in foreign markets. "In Deutschland […] muss ja alles funktionieren, durch verschiedene Instanzen gehen. Und das hält oft sehr auf [...] was in anderen Ländern viel, viel schneller geht".[149] Mr. A explained the better business opportunities in other countries, foremost in Eastern Europe, with companies that were interested in faster business development and that just embrace all chances. In addition, he indicated that these companies might be less impeded by too many decision-makers compared to the ones in Germany. The case study cannot afford an analysis of the institutional conditions of all foreign business markets from that time, but what seems comprehensible is that especially in those Eastern European transition countries, institutional structures and power relations in the field of retail and marketing were likely not as established as in the German matured market economy. Following Dorado (2005), these markets seemed to be more opportunity-open.

After the first fails that had caused uncertainty, an important condition for the belts' successful market introduction was to secure that they could be installed nationwide and that the product functions reliably.

> *Das war alles von Anfang an serienreif gemacht. Weil, sonst kann man so etwas nicht riskieren. Weil, da gehen Sie Risiken ein, das kann tödlich sein. Denn wenn Sie heute einen Auftrag bekommen, und […] wenn Sie da flächendeckend in einem Supermarkt installieren, dann sind Sie in solchen Größenordnungen, wenn das schiefgeht, und Sie haben Reklamationen, dann sind Sie erledigt. Also, das Produkt muss absolut passen von der Qualität, von der Zuverlässigkeit. Und nur wo das gesichert war, sind wir dann in den Markt gegangen.*[150] *(Mr. A)*

In this respect, they built up a service infrastructure based on freelancers. If someone charged the firm for the equipment with advertised conveyor belts in Greece, for instance, then MultiTex guaranteed this countrywide within two or three weeks. Maybe for this reason they started in smaller countries in Eastern Europe. But right from the beginning, the launch was started in several countries at the same time. This disclosed a high professionalism. The use of an *institutional project* to establish this new organizational form could not be deduced from the data available for the case. In its place, MultiTex pursued a strong offensive strategy in entering several markets to

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148 There are structures of power in those markets, sure. Where much is moved, there are structures, too, that are really grown, and there you have to apply yourself first of all (translated by author).

149 In Germany everything […] has to work out, go through diverse official channels, and this is often impeding […] which is much faster in other countries (translated by author).

150 Everything was ready for series production, because otherwise one cannot risk this […], because you run a risk which can kill you. Since when you receive an order to install nationwide at a supermarket, […] then you have such scales, and if this went wrong and you have complaints, then you are done. Hence, the product must absolutely meet the quality and reliability, and only when this had been secured we entered the market (translated by author).

gain legitimacy. According to Mr. A, no one had expected from MultiTex that it would be present so fast in so many domestic markets. In the end, MultiTex created a professional identity with this market dominating strategy that helped to overcome institutional barriers and to match the technological opportunity with the market opportunity.

MultiTex's solvency was an important precondition for these enormous investments in the market-wide infrastructure and the successful market introduction. In relation to the expenses for R&D activities it was as much again, or even three times as much, according to Mr. A. Nonetheless, MultiTex bore all costs for this innovation that was estimated with 4% on average of the annual turnover (company questionnaire).

In 2004, the new business achieved such an extent that an independent company (TecTex) was spun off MultiTex. Moreover, Mr. A indicated that these new business activities were not appropriately marketable beside the two established product families (trademarks) at MultiTex. In the meantime, an international network of key account managers is coordinating the bookings of supermarkets and brand owners in 34 countries. In summary, the establishment of an independent business as well as the diffusion of the business in so many countries can be taken as an indication that the advertised belts reached an institutional threshold. MultiTex remained responsible for the production of the belts. In 2009, the share of this new product family[151] amounted 35% of the total sales, while it was 35 and 30% for the two established product families (company questionnaire). In conclusion, MultiTex still benefits from KIE as the production of new technical textiles became another equal pillar of its new business. An independent start-up would likely not have been able to organize these resources or to set up such a professional market entrance strategy in the early stage without any incomes.

5.3.8 Conclusions from the case of MultiTex

This case of MultiTex discloses that established firms are also able to exploit widely independently an entrepreneurial opportunity in an unfamiliar field.

Again a systemic opportunity of KIE was not observed in this case. However, a generally existing technological opportunity in finishing for new technical functions could be identified in the TIS. The firm did not sense profitable market opportunities in weaving or manufacturing of home textiles, since new technical functions in these fields had been widely grasped at that time. For this reason, it was also hard to find any institutional opportunities that matched the loose technological opportunity in finishing with specific valued market opportunities. Conversely to the possible, existing opportunities, the consideration of exploited opportunities in this case discloses no systemic opportunity of any innovation system for the field of advertised conveyor

[151] The product family of technical textiles also included the production of technical textile used in work wear besides the printing of belts. Almost parallel MultiTex had developed an innovation in this field, too.

belts. Actually, it builds a new technical fusion of two existing fields (transportation on conveyor belts and POS marketing). MultiTex was not the first who thought of this fusion, but the emerging field cannot be clearly allocated to a sectoral innovation system. Any institutional opportunity matching technologically with market opportunities was absent in the emerging field as well as in the TIS. In its place, the first technical solutions failed and created uncertainty on the user side. Additionally, the field was structured by an actor constellation of a few powerful retail chains and brand companies that built an institutional barrier for new entrants like MultiTex.

Distinct from pioneers in marketing or conventional belt manufacturers, MultiTex had favoring technical competences and the necessary entrepreneurial propensity at command. Due to the crisis in the textile industry and dissolving supplier markets, MultiTex had increased the real net output ratio. The firm's capacities from finishing and refining of home textiles and medical beddings offered a technological opportunity.

The idea to exploit something in an unfamiliar field can be traced to Mr. A's entrepreneurial alertness and reflective stance towards business. Effectuation logic influenced the deviation from routine business as the entrepreneur initially thought to apply the firm's established innovation practice of recombining existing functions. During the development process it turned out that conventional solving schemes in finishing or refining were not sufficient, and a new knowledge-intensive solution needed to be created. MultiTex autonomously mobilized resources for the invention, while it was also able to internalize new knowledge from external fields like marketing for the process of implementation. The theorizing of the new form of POS advertisement with marketing studies proved its efficiency and dynamic innovation capabilities of the firm. Again, abstract theorizing alone was not sufficient for a professional identity and the market entrance. Serial production, product reliability and a countrywide full service contributed to gaining the customers' confidence. Contrarily, open beta versions of a new product known from software ventures, for instance, would not have worked out in this customer market. In addition, MultiTex strategically decided on an operator concept with direct access to the user market. The company also internalized processes downstream the product supply chain. This proceeding broke with the established institutional arrangement in POS marketing, but it helped to gain a better position in aligning its own interests with the differing interests of the established retail and brand companies. The operator concept built the base that enabled the aggressive market entry in several countries. MultiTex's strong market presence finally led to its legitimization as new entrant and its product. In case the firm had remained a supplier, it could have not been in the position to influence such entering strategies. As we learned earlier, producers have often not been satisfied with the way their products were marketed by retail (cf. Reinhold 2003: 18).

Subsequent to the conclusions drawn from each case, especially the commonalities across the cases are now worked out in the final chapter of the case study analysis.

5.4 Results from cross-case study analysis

Altogether, the three case studies illustrate different challenging constellations of KIE, but all of them extend the stereotype logic of KIE from the literature review with regard to necessary knowledge sources or organizational setting. Despite the peculiarities and variance of the cases, some commonalities can be deduced from cross-case analysis. Those point to inter-subjective structures in the environment of the textile industry supporting the reliability of the case study results. The following presentation of the common results will particularly cover the opportunity dimension, actor constellations and mechanisms of KIE.

After the single presentation of cases it becomes clear that the selection of these cases in the sample is not random. New technical textiles emerged foremost through innovation activities in the pre-stage of the textile value chain (cf. cases of FuncFiber and E-Thread). Additionally, finishers or refiners were predestined for new functions at the textile surfaces with their integrating and interdisciplinary knowledge across the fragmented textile supply chain (cf. case of MultiTex). Begemann, managing director of the Forschungskuratorium Textil (1993-2008), summarizes the opportunities of these specific fields (2003: 261):

> *Da die Konkurrenzfähigkeit in der Produktion von Standard- und Massenware kaum noch gegeben ist, findet in den Vorstufen der Textilindustrie nach und nach eine Umorientierung auf Textilien mit funktionellen Eigenschaften und für technische Anwendungen statt. Entsprechend nehmen die Umsätze im Bereich der Technischen Textilien zu, wobei insbesondere Chancen in der Funktionalisierung textiler Materialien durch gezielte Oberflächenmodifikationen und in der Verarbeitung zu innovativen Produkten für neue Anwendungsfeldern liegen [emphasis added by author].*[152]

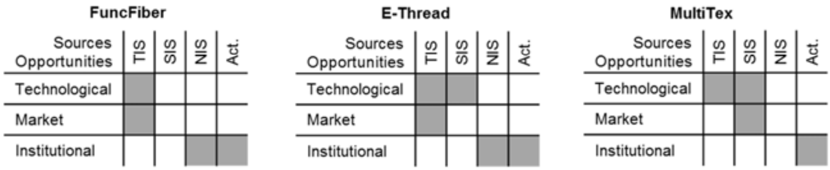
When selecting the cases following the selection criteria (cf. Chapter 3.1), this structural coherence was not clear to the researcher. Moreover, the cases of differently positioned firms in the textile supply chain enabled to illustrate interactions and institutional arrangements from different angles and to understand motives for absent interactions. This enables to gain more information about the few data from the investigation of the TIS in Chapter 4.

Starting with the analytical dimension of *opportunities*, a difference from the common assumption of low-tech industries' low technological opportunity can be assessed (cf.

[152] Since competitiveness was not given any longer in the manufacturing of standardized and mass-produced goods, bit by bit a reorientation to textiles with functional properties and for technical applications occurs in the pre-stage of the textile industry. Accordingly, the sales in the field of technical textiles increase, whereas chances particularly lie in the functionalization of textile materials through targeted modification of surfaces and in the processing into innovative products for new application fields (translated and emphasis added by author).

Figure 21). In all three variant cases of KIE technological opportunities came from the TIS. In addition, the analysis of the TIS in Chapter 4 confirms various new opportunities in the field of new technical textiles and materials (e.g. Konrad 2001; Begemann 2003; Meyer-Storck 2006; Knecht 2003b). New functions of technical textiles merged with other technological fields and opened up new markets outside the traditional TIS. That is why the entrepreneurs did not sense market opportunities from the TIS in any case. In two cases where market opportunities from the TIS were exploited, the analysis of the KIE process discloses that these came from emerging markets with still weakly developed demand or market articulation. At that time, several new technological opportunities and first failings in exploitation created uncertainties on the customer side that counteracted emerging market asymmetries (opportunities).

Fig. 21 KIE's sources of opportunities in the German textile industry



Note: TIS: textile innovation system; SIS: any other sectoral innovation system; NIS: national innovation system; Act: actor (individual or collective).
Source: Own illustration.

This leads over to the institutional opportunities. Despite the technological and partly market opportunities, no institutional opportunity from the TIS was used to match these. In its place, entrepreneurship and entrepreneurial experimentation impeding or wrongly oriented institutions were identified in the analyses of the cases' institutional environment. One may argue that the restrictive institutional environment was a stimulating structural institutional opportunity for a few entrepreneurs, while the majority was discouraged by these constraining institutions. However, such a form of institutional opportunity does not systemically match technical and market opportunities or overcome institutional barriers in the sense of Radosevic et al. (2011). An entrepreneurial innovation system would contrarily address the innovation activities towards such a match (ibid.). In the empirical investigation, such a systemic entrepreneurial opportunity from within the TIS could not be assessed for any of the cases (cf. Figure 21). Therefore, the results from the case studies support the argument of an absent systemic opportunity for KIE in the TIS between 2000 and 2006.

The consideration of the sources for institutional opportunities to match technological and market opportunities offers further insights. All entrepreneurs organized institutional opportunities either from national innovation system (NIS) or from actors external to the field of innovation (cf. Figure 21). Formal institutions from the NIS enabled entrepreneurship through financing entrepreneurial experimentation in terms of cooperative and application oriented research projects. These kinds of free utilities were not industry-specific but addressed towards general growth promotion in newly formed German states or in new interdisciplinary materials. Field external actors helped to sense opportunities, to match technological with market opportunities or created institutional opportunities in terms of institutional projects or new organizational forms. Conversely, in the case of MultiTex, the firm became an external actor in the field of POS marketing outside the TIS. The textile firm matched technological opportunity from the textile industry with the market opportunity in the POS marketing on conveyor belts. With the spin-off and full service operator concept, it created an institutional opportunity in response to the restricting institutional environment.

Altogether, institutional entrepreneurship activity helped to deal with absent systemic opportunities in the TIS. Missing knowledge, creative and financial entrepreneurial resources were organized from other external fields or partners. The case of MultiTex again constitutes an exception, as it most autonomously mobilized and created resources for KIE. Compared to the other entrepreneurial actors, this entrepreneurial firm particularly showed the most KIE enabling resources: entrepreneurial skills such as entrepreneurial alertness, risk taking, reflective stance towards routines in person of the owner and managing director and dynamic capabilities for knowledge-intensive activity. Distinct from this, the entrepreneurs in the other cases organized missing resources and competences from partners. This complementary *actor constellation* enabled the initiators to compensate their disadvantaged position at the beginning of the KIE process. In consequence, the initially disadvantaged environmental and actor conditions could not keep the entrepreneurs from KIE activity.

Entrepreneurial action was stimulated by crisis in all three cases. The research director Mr. R faced cuts in public funding of the institute financing and pressure by a state agency's expectation to exploit the promoted application oriented research. Mr. C faced the crisis in thread production not directly but feared the ending of the main products life-cycle and faced the shareholder group's expectations. Mr. A experienced the crisis of the textile industry in decreases in the traditional textile business and breakaway of suppliers. All three entrepreneurial actors share the motivation to make provision for the future in the situation of a more or less directly effecting crisis.

While the informal institutions and arrangements of the established TIS could not adapt so fast to these environmental changes and new technological opportunities, the entrepreneurs of the cases managed to sense opportunities from other innovation systems or fields outside the TIS. Beside those distributed opportunities, the entrepreneurs used specific *mechanisms* during the process of KIE. Although knowledge-intensive innovations are new and unique by definition, mechanisms as common mechanic explanations with a common logic (cf. Maurer/Schmid 2008: 2879 et seq.) can be found in the different case studies. These mechanisms help to reconstruct the phenomenon of KIE in the specific environment of the textile industry. Following sociology, mechanisms connect the interplay of situation and action (cf. ibid. 2883) similar to the nexus of opportunity and entrepreneur in entrepreneurship theory.

In the first process of deviation, a specific common logic in practical techniques can be assessed as well as in strategies during the process of implementation in relation to the specific situation of the KIE cases. First, the mechanism of effectuation partly explains the deviation activity of KIE from existing practices and knowledge bases. The previous logic of effectuation, like research on cellulosic fibers, entwisting yarn to elastic threads or finishing decorative home textiles, had an effect on the resulting innovations (new functional cellulosic fibers, conductive elastic threads and advertised conveyor belts). The previously existing knowledge of the actors and affected knowledge bases structured the nexus of opportunity and entrepreneurs but it was, nevertheless, not sufficient. More precisely, the idea of deviation was affected by effectuation, while the following steps in development and implementation of the innovation required other mechanisms.

Moreover, the knowledge-intensive innovation activity differs from the mechanism of transposition identified for matured fields (Maguire 2008). The innovations of the cases cannot be described with adaptations in terms of imported practices from other fields or bound to existing functions. Conversely, the ideas have been affected by established practice and knowledge from the entrepreneurs' fields. The innovative deviation occurred through exaptation where new functions and features of existing means at hand are discovered and a new function or end is created (Pacheco et al. 2010: 1003), e.g. function of additives in cellulosic fibers, conductive function of elastic threads, function of advertisement on conveyor belts. In the case of FuncFiber the misappropriation occurred randomly as a byproduct during contract research, while the new use of the elastic threads took place in a more systematically organized idea finding process by an expert of innovation management (InnoServ). Also, in case of MultiTex, a new use of finishing textile surfaces was discovered. But in this case it was rather problem driven by a defined end (advertised conveyor belts), while the first means used in the emerging field were not reliable or sufficient. More generally, all cases of KIE reveal the mechanism of bisociation as previously isolated "ideas from different knowledge domains" (Koestler 1964 in Garud et al. 2007: 960) were newly combined. Yet the identified mechanisms of effectuation, exaptation or bisociation do not fully describe the knowledge-intensive activity and innovation. Indeed, means at hand were newly combined with other existing functions or transferred into other contexts, but the institutionalized resources (means and knowledge schemes) from the direct environment were not sufficient. Additional means had to be acquired or developed for the exceptional combination as well as new problem solving schemes.

What becomes finally apparent in these common mechanisms of practical techniques for deviating innovation is that it is initially structured by previous frames and knowledge and practices from the entrepreneurs' textile specific environment. The influence of effectuation logic is not astonishing, given the fact that all three cases describe corporate entrepreneurship. None of the entrepreneurs acted independently from an existing organization (cf. Sharma/Chrisman 1999: 18). The entrepreneurs of FuncFiber created the new firm and innovation foremost with the research institute and the entrepreneurs of the two other cases depended – not exclusively but also – on tangible and intangible resources of established companies. For another reason, effectuation builds a necessary mechanism for KIE in matured low-tech environment. Following the effectual logic of established practice, the entrepreneurs connected their deviating activity with existing cognitive frames and extended them. This reframing or use of existing frames enabled the entrepreneurs to align interests and values of relevant established actors (of the organization) and to win over their acceptance for the new idea and its new framing. This reframing is one necessary strategic mechanism known from institutional entrepreneurship in matured fields (cf. Leca et al. 2008: 13).

Against this, the process of implementation of the cases discloses more idiosyncratic mechanisms in obtaining support and legitimacy. Starting with the consideration of mobilized supporters, it is striking that in the stage of implementing the innovation, no existing “core agents” or “professionals and experts” (DiMaggio 1988: 15) from the entrepreneurs’ field were mobilized. Generally, those backers help to delegitimize established practices and legitimize the new practice. The main supporters can be found in the first stage of the KIE process. Moreover, all of them were newly mobilized TIS external professionals (cf. Leca et al. 2008: 11), like the experienced entrepreneur, the service provider or the conveyor belt manufacturer. They contributed to the initial KIE process with knowledge resources but also helped to organize financial resources from investors or public funding agencies. Nevertheless, this support could not sufficiently legitimize KIE at the field constituents and customer market. Therefore, all entrepreneurs similarly used a specific mechanism.

As we learned from institutional entrepreneurship literature on matured fields, entrepreneurs particularly have to reconcile the interests of diverse field participants (cf. Leca et al. 2008: 14). This also applied for the textile industry as well as the field of POS marketing. Moreover, some authors observed that institutional entrepreneurs especially used existing institutional arrangement (Greenwood et al. 2002 in Leca et al. 2008: 118) or professional associations for discursive arenas in this environment (ibid.; Maguire 2008: 677). However, in none of the cases one of these strategic actions could be found. None of the interviewees mentioned any industry associations in their descriptions of the KIE process. The analyzed existing institutional arrangements were sensed as restricting.[153] Additionally, none of the entrepreneurs established in the textile field (Mr. C and Mr. A) could make any use of their previous networks or social capital. All relevant network relations were newly established.

[153] Both the director of the research institute as well as the other managing director of the fiber spin-off stated to see no reason in talking first to producers of threads to launch their innovation. In their views thread producers only react on innovation if demand is articulated by manufacturers or retail. On the other hand, E-Thread, the elastic thread producer, initially had problems to find a research institute that collaborated in innovation, particularly due to this restricting institutional arrangement.

The entrepreneurs created new institutional arrangements that all departed from the vertically disintegrated organization of the textile pipeline's direction. All of them overcome the fragmented groups and interests by orienting to the end-user market. While they still missed legitimacy from field constituents, they started to take in hand the development activity for their innovations' application in end-products (e.g. cleaning towel, heating vest, complete installation of advertised belts). Subsequently, they addressed their marketing activity directly to manufacturers of end-products. Once these field constituents had been convinced by the new products, their demand and powerful position in the product supply chain aligned the diverse interests along the fragmented supply chain. In other words, the entrepreneurs used the actors' power as a kind of free rider.[154] On the other hand, the entrepreneurs also provided support to their customers. FuncFiber supported processors of the fibers with marketing activities. E-Thread developed prototypes and MultiTex offered a full service for the belts' installation, maintenance and marketing. Instead of finding supporters, the entrepreneurs of the KIE cases became themselves supporters, as they internalized or organized processes downstream the product value chain during the KIE process. This strategic institutional arrangement was not planned but rather emerged in response to difficulties in entering the market. Finally, this new institutional arrangement occurred next to existing arrangements without substituting them. Likewise, no action of deinstitutionalization of institutional arrangements can be assessed distinct to institutional entrepreneurship theory.

Different to the state of the art on institutional entrepreneurs, the KIE entrepreneurs avoided a direct discourse and reconciliation with actors from their low-tech environment. At the same time they went beyond their original interests and took over entrepreneurial experimentation and risks of their customers. Regarding the position of FuncFiber and E-Thread, this input or problem solver strategy was especially risky, as the new entrants missed experiences at the user market. The development of end-products implied the risk of not adequately estimating the weakly articulated emerging market demand at that time. On the other hand, the development of end-products showed reasons for common business and later on for collaboration (cf. Leca et al. 2008: 20; Garud et al. 2007: 962). With the initiation of end-products, the entrepreneurs created new business opportunities for processors, manufacturers or retail firms inside and outside the textile industry. But this initiative was not, in any case, because of clear absent alternatives, nor did the entrepreneurs assemble field participants to discuss some problems, as observed for institutional entrepreneurs (cf. Maguire 2008: 677). However, the widely autonomously organized setup of end-products into serial production confirms a necessary professional identity of the entrepreneurs. They theorized themselves as problem solvers instead of peripheral or

[154] The case of MultiTex builds again an exception, as it established its own access to the user market. Different to its competitor who only offered to exchange belts, MultiTex, as a full service provider, benefited from the revenues of renting the POS of belts to customers. Due to this new arrangement it gained a more powerful position than a technical supplier of large retailers.

new entrants that typically lack power for institutional entrepreneurship or rely on central players (cf. Maguire 2008: 674). This specific form of professionalization and theorizing depict crucial mechanisms for the legitimacy of the entrepreneurial organizations and the KIE process in the institutional environment of the textile industry.

In conclusion, the entrepreneurs' strategies to gain legitimacy are more based on internalizing and dominating than cooperative behavior during the process of institutionalization. E-Thread decided to become a system supplier and MultiTex an international full service provider. This unconventional behavior for new entrants certainly has to do with the entrepreneur's confidence from previous established business.[155] Distinct from this, FuncFiber could not afford such a dominating strategy next to a monopolist. FuncFiber's development of consumer products finally convinced the dominant actor to take over the production of fibers. What can be concluded from this is the high influence of the field's *actor constellation* on the entrepreneurs' activities. Beside this minor difference in the implementation strategy, the commonly found mechanisms of internalization and free riders point to particularities of KIE in this environment. Although the cases display entrepreneurs with different, more or less entrepreneurial skills and resources and positions they converge in applying the same mechanism for implementation. Hence, independent from the differing actor enabling conditions, the same mechanisms were applied, which argues for the influence of a specific environmental structure.

Summing up the results of the cross-case study analysis, more details on opportunity, entrepreneurial activity and environmental conditions could be won. The sources of exploited opportunities were not systemic and reveal no insights in systemic KIE. Nevertheless, the TIS offered technical opportunities and weak, underdeveloped market opportunities. The system's missing entrepreneurial orientation and mismatch with established institutions was overcome by institutional entrepreneurship activity. Additional necessary opportunities and resources were organized from distributed sources across other innovation systems and industrial knowledge bases. Moreover, different agency or mechanisms at different stages can be assessed during the KIE process. At the beginning, especially effectuation and exaptation can be observed for deviation. Besides, cooperation with external supporters was relevant for de- and re-contextualization of existing means and resources. During the process of implementation, internalization for professionalization and the free-rider mechanism were used as specific mechanisms of power. As a specific form of theorizing, the KIE organizations framed themselves as problem solvers. Overall, strategies of dominance were applied to gain legitimacy at customers, avoiding the discursive moment. The reasons for this will be discussed together with the results from the TIS analysis in the next chapter.

[155] However, their previously earned legitimacy from former business was not particularly helpful during the implementation process of KIE.

6 Discussion

After the empirical investigation of the German textile industry (Chapter 4) and multiple case study research on KIE (Chapter 5), the results are merged in this chapter. Their meaning for KIE in low-tech industries is discussed based on supporting evidences from state of the art on KIE and low-tech innovation studies (see Chapter 1.1/1.2). Likewise, possible limits of the results in respect to the outlined objectives should be made comprehensible. Following the outlined objectives, first insights from environmental conditions of the German textile industry are evaluated for their general contribution to KIE in low-tech industries (Chapter 6.1). Linked to these specific environmental conditions, the characteristics of KIE are discussed with the state of the art on KIE (Chapter 6.2). Finally, the low-tech institutional environment's influences on the KIE process are derived from the identified specific mechanisms of KIE in the German textile industry, as they respond to these influences (Chapter 6.3).

6.1 Environmental conditions for KIE in low-tech industries

The analysis of the textile industry reveals difficult environmental conditions for business in general and in particular for innovation and entrepreneurial activity. In line with the characteristics of matured industries, many textile firms exited the market or relocated their business to markets in newly industrialized countries (NICs) (Eurostat; Löbbe 2008; EPPA/CEPS 2002). The domestic textile supply chain was not independently existing anymore (Mr. A /MultiTex; Meyer-Storck 2006). Moreover, at the time of investigation NICs had caught up in technology development and quality (cf. von Tunzelmann/Acha 2005: 411 et seq.). This catching up development especially of Asian NICs led to an increased pressure on innovation and technology development in technical textiles (Potters 2009).

Though the textile production of technical and functional textiles increased (interview with executive secretary of textile research board in 2009; Gesamtverband der dt. Textil- u. Modeindustrie 2006), the amount of firm investments in R&D between 2000 and 2006 (Eurostat) does not reflect this (cf. Chapter 4). The case study research helps to comprehend this contradiction and reasons for the textile firms' weak R&D and cooperative activity. The investigation of the institutional environment and practices from the cases' perspective provides additional insights. During the previous decades, a specific mentality on efficiency and price margins had evolved that affected the textile industry's culture on innovation. Experts of the service provider for innovation (InnoServ) indicated that in the last 30 years the majority of textile companies gained for cost leadership, but not for innovation leadership. The textile firms

I. Schwinge, *The Paradox of Knowledge-Intensive Entrepreneurship in Low-Tech Industries,*
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were “ausgereifte Industriebüros” [fully developed industrial offices] (Mr. IS2) above all that sought to produce cheaper textiles or clothing. Accordingly, the pressure of efficiency was affecting the companies’ strategies and technical frames. This reduced the firms’ ability to take a reflective stance on established practices and look ahead (cf. Mr. IS1; Chapter 5.2.3).

The low investments in R&D and prevailing intramural or corporate innovation activity are displayed by the two cases of KIE in established firms. The description of previous corporate conditions for KIE discloses typical low-tech innovation activity in matured industries. E-Thread carried out intramural improvements for customers through combining means at hand (bricolage) without any relevant external sources. The previous innovation practice at MultiTex illustrates transposition and translation of new functionalities from other fields. The textile manufacturer combined them, like thermo regulation and transport of humidity in medical beddings. These product variations can be internally designed without major efforts in R&D, as the parameters of the new functions are known. They are just adjusted in terms of creative accumulation known for routinized innovation regimes. The assumptions on the “phase of LMT innovations” (Pavitt 1984 in Heidenreich 2009: 484) and matured industries additionally explain the firms’ behavior. At this stage of the industry, R&D investments in matured technologies do no longer pay off in terms of size effects (ibid.; Peltoniemi 2011: 354).

New emerging R&D on technical and functional products was contradicted by the dominant culture on efficiency and profit margins. According to the director of the TITV, the traditional clothing industry was indeed willing to incorporate new additional functions, but not to bear the additional costs (Möhring in Froitzheim 2009: 2). They maintained their business calculations (ibid.). This practice can also be observed in the case studies of FuncFiber and E-Thread (cf. Chapter 6.3). Mr. IS2 from the innovation service provider (InnoServ) further explains the consequences of this maintenance:

> *Das ist ein Spezifikum in der Textilindustrie, da wird das knochenhart einfach sozusagen multipliziert über jede Wertschöpfungsstufe. Der Einkäufer schlägt noch was drauf und der Nächste noch mal und noch mal und […] selbst wenn man [die Technologie] 20 Euro zusätzlich kostet, die kostet dann im Geschäft auf einmal 100 oder 150 Euro zusätzlich.*[156]

Retail traditionally calculates with higher margins in case the whole collection cannot be sold. But this way consumer prices become unappealing and inadequately high. Another habit in the textile industry is the forwarding of investments in R&D and innovation upstream the textile supply chain. Experts further assessed the firms’ upstream orientation to the fiber industry in search for innovation (cf. Hübner 2001: 283; Knecht 2003b: 14). Indeed, in the 1980s the occurrence of membrane and functional textiles built a new drive of innovation. However, the innovators were only a few

[156] It is particular for the textile industry that it is ruthlessly multiplying across each value-added step. The purchaser is adding and the next again and again [...] and even if the technology costs an additional 20 Euros, then it additionally costs 100 or 150 Euros in the store (translated by author).

firms, like Sympatex, Lycra or Goretex. Their success stories (cf. Reinhold 2003: 212 et seq.) created expectations at the buyer side. Firms from the pre-stage established own brands for the diffusion of their innovative material at business customers and consumers. The aggressive market launch cost the suppliers enormous investments in marketing (ibid. 213 et seq.). These stories established an expectation on the side of retail and other producers along the textile chain. They were not willing to invest to such an extent in innovation. Put it in another way, it reveals a rather passive, supplier-dominated habit of textile and clothing manufacturers in innovation activity, whereas the fiber industry strongly influenced the direction of research and knowledge creation. The majority of small- and medium-sized producers from the textile pre-stage, however, did not have the financial sources or saw no pay off for such marketing investments, as they remained unknown on the market (ibid. 217). Thus, these expectations on upstream innovation activity in combination with the institutional arrangement of vertical organization help to understand the general low R&D expenses and weak cooperation performance of the majority of firms. The indications of different conditions and opportunities for textile companies from the sectoral analysis of the TIS are further confirmed and explained by case study research. The managing director of InnoServ, Mr. IS2, observed typical specialization of the textile firms: "die [wissen] oftmals sehr genau natürlich Bescheid […], was im eigenen Betrieb passiert, aber ein, zwei Stufen weiter überhaupt keine Ahnung schon mehr haben, […] was mit dem später gemacht wird, mit den entsprechenden Stoffen oder Garnen".[157] In conclusion, the permeability of knowledge flows through the textile supply chain was restricted. The steady internationalization of textile supply chains contributed to disintegration and competitive, adversarial interactions among business partners, which further negatively affected new knowledge exchange and diffusion.

The effects of fragmentation on innovation cannot only be observed in the textile industry. Likewise, in the case of the Australian meat industry, Pitt (2007: 94) assesses overspecialization and a "lack of innovation in value chain thinking". She concludes from her investigation on the role of entrepreneurship for innovation in the Australian red meat industry (Pitt 2007: 93 et seq.):

> *The fragmented structure of the meat industry was seen to have a significant and primarily negative impact on the level of innovation. Participants believed that a lack of integration across the supply chain is resulting in a generally poor flow of information and market signals may not always be getting through to individual firms.*

In Pitt's study also "adversarial behavior patterns" (ibid. 94) between suppliers and manufacturers were assessed, which impeded cooperation and innovation along the supply chain. This example of another low-tech industry with similar conditions on knowledge creation and innovation is an indication for a general condition of low-tech industries. With the maturity of a low-tech industry, the division of labor between firms

[157] Of course they often know what's happening in their own company, but one or two stages further they have no idea […] what is done with the fabrics or yarns later on (translated by author).

along the supply chains increases, and thereby also the firms' specialization. Accordingly, Hirsch-Kreinsen (2008) identifies low-tech firms as process-specialists with customer-oriented innovation strategies across low-tech industries, which additionally supports the indication of a common condition of low-tech industries.

Continuing with the impacts on this fragmentation in the textile industry, the manufacturers' weaknesses in participating in new developments and market articulation contributed to technology driven products such as textile circuit keyboards (Möhring 2006: 320) or pulse measuring bras (Albaum 2003: 91). Customers do not accept all of these technology driven innovations (Reinhold 2003: 216). What is more: These fails damaged the image of emerging functional clothing (ibid.) and discouraged manufacturers that were not used to such market fails anymore. Those failings are common in the early stage of new technology development. It is comparable with the era of ferment with several new technological designs without any dominant design (e.g. Murmann/Tushman 2001). In consequence, many manufacturers were overloaded by so many new technological opportunities of new functions, new fibers and materials and their complexity that created uncertainty on the demand side.

Further uncertainties can be observed for formal institutions. The promotion of national and European programs contributed not only to substantial but also to eccentric product ideas (Froitzheim 2009: 1). Innovation theorists call this typical problem of coordination or the dilemma of contingent innovation processes (e.g. Rammert 1988; 2008: 312). Sectoral and case study analysis together show an intermingling of formal promotion programs from national institutions like the Federal Ministry of Education and Research and the European growth and innovation programs (Froitzheim 2009: 1; Begemann 2004: 22 et seq.). The textile unspecific programs implied dealing with budget freezing, cutbacks and SME unsuitable programs (Begemann ibid.). This unstable condition impeded financial planning for development projects and the use of these programs by industry as well as textile research institutes. More generally, both national and European policies were mainly oriented to deregulation promoting competition and creating uncertainty in the textile industry (e.g. Löbbe 2008: 63 et seq.).

Public funding of development and innovation were differently evaluated. The textile research board calls for a rise of public funding to give incentives to SME (Meyer-Storck 2006: 52; Begemann 2004). Meyer-Storck indicates that medium-sized companies especially face difficulties in finding the right middle course between joint precompetitive development and a permanent distinction of an own market niche (ibid. 50). Besides precompetitive research, the textile research board promotes the transfer of research through so-called research transferring projects ["Transferforschungsprojekte"] (Gesamtverband der dt. Textil- u. Modeindustrie 2004: 5). The requirements of these projects have a contradictory effect on firms. Companies have to acquire a financial interest to participate in the transfer, but at the same time the results of these transfer projects have to be disclosed to the whole industry (ibid.). This way, unfair competition should be avoided (ibid.). Against this, the textile firms are interested in finding an advantage in technology for a unique selling position. The textile research board acted in the collective interest of the coalition of established textile and scientific organizations. The maintenance of formally fair joint industrial research was the justification for legitimacy of this institution of the matured TIS. But the organization of precompetitive research for creative accumulation along established technological paths does not correspond with the unequal emerging opportunities and distinct requirements on research for entrepreneurial experimentation. Mr. IS1, manager at InnoServ, confirms the central role of public financing policies. He regrets that more far reaching innovation and development activities without any public promotion and research hardly exist in the German Economy. This implies that the institutionalization of innovation by industrial research was still effective in controlling for the destructive power of innovation (cf. Rammert 2000: 167).

Alternative private funding sources were rare in this institutional environment of the textile industry, as the NetFinTex report (2007) shows. Given the advanced stage of the industry and its general shrinking, interactions with venture capital firms or large investors were missing (ibid. 37). Beside the industry's medium-sized corporate structure, the few big investors, like chemical concerns, had already withdrawn from their textile fiber divisions since the 1990s (cf. Löbbe 2008: 122 et seq.) because of their low or negative growth expectation. It is more than likely that the established actors, be it companies, research organizations and industrial associations or the textile research board, broadly underestimated the new potential, but also the exceptional huge necessary investments compared to previous research and innovation activities (cf. NetFinTex 2007). Exceptions from this faced the problem of missing established relations to financing sources and the industry's image of bad prospects (ibid.). Additionally, the complexity and elusive character of the new technological opportunities was difficult to communicate to potential outsiders. KIE's specific conditions of financing and the challenge to organize its "extensive assets" (Ben-Ari/Vonortas 2005) through external financing were generally introduced in Chapter 1.2. Especially venture capital was emphasized for KIE in combination with debt finances or public funding to frame the risk (ibid.). In the textile institutional environment, however, neither venture capital funding nor private equity nor public funding was an established practice of financing innovative ventures (NetFinTex, cf. also the case of MultiTex). In its place, the European policy was mainly oriented in reducing overcapacities and prohibiting aids for growth struggling industries (Löbbe 2008: 28; EPPA/CEPS 2002: 8 et seq.). The "multisectoral framework on regional aid for large investment projects" explicitly prohibits investment projects in the synthetic fiber and steel industry (European Commission 2002). More generally in "sectors where serious structural problems prevail […], [n]o regional investment aid will be authorised" (ibid. 5./31.).[158] In conclusion, general, restricted conditions of public funding can be

[158] "The Commission has consistently considered in the past that investment in sectors that do, or might, suffer from serious overcapacity or persistent decline in demand increase the risk of distor-

assumed for the institutional environment of other low-tech manufacturing industries as well.

Fragmentation is not only observable for the textile supply chain and capital market (cf. NetFinTex 2007: 38) but also for relations with scientific organizations. Along with the advanced technological stage of the textile industry, R&D investments had become unattractive for most textile firms that focused on product innovation in terms of variation. Against this, studies on KIE particularly emphasize the meaning of scientific institutes as “knowledge institutions” (Groen 2005: 70) and identified R&D as the main field of cooperation (Malerba 2010b: 18). The sectoral and case study analyses of the textile industry consistently point to distinct conditions. The lacking relations are particularly illustrated in the case of FuncFiber, from the perspective of a research institute, and in the case of E-Thread, from the perspective of a traditional low-tech firm. The director of PrivIn described the interaction of the private research institute with industry partners. The application oriented textile research institute acquires contract research from manufacturers of textile end-products because of their market know-how. These organize further necessary partners from the supply chain for development activity. The research institute would never directly communicate with producers of threads or fabrics (cf. footnote 51). Applied research institutes with contact to the industry noticed the power of manufacturers. Their responding orientation on end-producers reinforced the gap to firms from the pre- and inter-stage, as the case of E-Thread shows. The managing director of E-Thread, Mr. C, could not find any research institute interested in cooperation with the traditional thread producer before the professional support of the external partner InnoServ.

Literature on KIE and sectoral innovation systems has widely neglected the differing and partly converse interests of scientific and commercial organizations. The scientific organizations’ function is originally the production of new scientific knowledge and scientific problems. Recently their economization and the blurring of its borders to the economy are discussed, e.g. under the term of ‘mode 2’ knowledge production (cf. Rammert 2000: 167; Bender 2006; Neidhardt et al. 2008). Differing from the first impression on the infrastructure of research institutes in the sectoral analysis, case study research draws a more sophisticated picture of these long-term participants in the TIS. Mr. IS1 from the industry external service provider InnoServ indicates that after the German reunion the competition for public funds became fierce, as the number of research institutes had grown by Eastern German research institutes. The institutes’ survival broadly depended on public funding, since most of them were organized as non-profit organizations without any reserves (Begemann 2004; Mr. R), like PrivIn. According to Mr. IS1, in the following years after the reunion much funding was primarily used on the maintenance of research institutes, especially in Eastern

tion of competition, without bringing the necessary counterbalancing benefits to the region concerned. The proper way to recognise that these investments are less beneficial from a regional point of view is to reduce investment aid to projects in sectors where structural problems prevail, to a level below that permitted for other sectors.” (European Commission 2002, 5./28.)

Germany due to lobbying and in the course of reconstruction of this area. Hence, new knowledge for innovation or its transfer into the industry was not necessarily the first interest of research organizations in those days. Long-term research projects and follow-up projects were the main income source to secure the scientific workforce (cf. Begemann 2004: 22).[159] Indeed, PrivIn particularly used funding from East-German growth programs for previous research. The new scientific knowledge that was financed this way later contributed to the founding of FuncFiber. On the other hand, cutbacks in public funding and the plan of the institute's director to become more independent from this funding were main drivers for the spin-off. In general, the decreasing share of public funds among textile research institutes did not lead to any noticeable increase in academic spin-offs from textile research institutes (executive secretary of textile research board 2009).

Furthermore, the argument of established firms' disadvantageous path dependence and persistence towards distinct innovation can be similarly applied on long-term established research organizations. As outlined before, the new technological opportunities required distinct research activity (Meyer-Storck 2006: 42) and the establishment of relations with research institutes from other sectoral or emerging innovation fields (like micro-system-technology). The EPPA/CEPS study (2002) in this respect calls for more interdisciplinary cooperation among research institutes. Research organizations might probably be more used and flexible to exploit new fields of knowledge than traditional firms, but they also entail institutionalized practices and are specialized in fields along technological paths in industrial research. Pitt's empirical investigation of the meat industry supports this assumption. Pitt (2007: 99) describes R&D in the Australian meat industry "focused on reactive short term problem solving and […] not […] helping the industry to proactively develop completely new concepts." An interviewed research program manager criticizes the persistence of "old scientific paradigms" and divided languages among scientists and between actors from science and industry (ibid. 99 et seq.). It is highly questionable if established research institutes in matured low-tech innovation systems and in general can take over such proactive function and development. Recalling the meaning of entrepreneurial experimentation, it is important that this form of knowledge development is to be distinguished from R&D activities of scientists, because it additionally tests the application of new technologies and reduces uncertainty (Bergek et al. 2005: 15). Basically, this cannot be expected from research institutes and their workforce, because they are usually not trained for entrepreneurial experimentation and industrial processes. Probably this capability was underdeveloped or had formed back in case of most established companies as well as their motivation for risky entrepreneurial

159 In one case of KIE in the German metal industry for AEGIS case study research, the chairman of the spin-off reported on conflicting interests between the start-up's marketing strategy and the research institute's acquisition for follow up research projects. The calls for further research (funding), e.g. in technical journals, questioned the applicability of the spin-off's new technology.

experimentation in low-tech innovation systems. In its place, they expected it from research partners.

Pitt (2007: 100) concludes from this fragmentation that "[i]t will be critical for linkages to be developed to bridge the 'cultural divide' between researchers who have the technical skills to produce new ideas, and industry that has the skill to execute solution." The allocation of roles for scientists' as producers of ideas and industrial actors as executors of their ideas and solution for industrial innovation can be reasonably questioned. In its place, the empirical findings show the importance of entrepreneurial actors who neither strictly follow conditions of scientific nor economic knowledge production. The researchers from the case studies did not provide ideas or solutions for innovations. Rather, the advantage of scientific knowledge is that it is alternating from established economic knowledge of industrial knowledge bases. It can be considered as one alternative, but not the only alternative to deviate from established knowledge, as the case of MultiTex shows. In the case of FuncFiber, it was the experienced entrepreneur and not the scientific inventors of the platform technology who had the idea for consumer products and enabled the innovation. In case of E-Thread, the role of the established company cannot be reduced to an executor. Thus, abstract scientific thinking and developed technologies serve as means for alternative knowledge production and innovation but holds no monopole as a knowledge source for KIE. In conclusion, bringing scientists and companies together is not a sufficient condition for distinct innovation.

Summing up the conditions of the German textile industry, the institutional environment can be characterized by contradictions of institutional practices and orientations of scientific organizations and industrial actors. Although such newly emerging technological opportunities in the textile industry cannot be assumed for every low-tech industry, the logic of missing interactions between these two groups can be transferred to further low-tech industries. The weak interactions between textile firms and scientific organizations and likewise missing institutional arrangements along highly specialized supply chains hamper knowledge diffusion, the development of the industrial knowledge base as well as innovation actions.

One may argue that the situation of knowledge creation, actors and interactions create opportunities for a few entrepreneurs, probably new actors, with superior knowledge, but at the same time the institutional environment argues against the necessary support of such ventures. Pitt (2007: 132 et seq.) lists requirements of sectoral innovation systems for successful entrepreneurial firms. In other words, these necessary institutions of a sectoral innovation system can be taken as kinds of institutional opportunities for entrepreneurship. Firstly, the acceptance of regulating instances is necessary. In case of the TIS, this was neither given by formal European and national level of regulation nor by central market players. Secondly, "knowledge from R&D institutes" (ibid.) is indicated. The economic value of knowledge from this source is questionable because of path dependences, precompetitive research and divergent interests of established textile research organizations as well as publication duties. Thirdly, the “access to a pool of appropriately trained workers” is difficult to evaluate. On the one hand, many experienced workers might be made redundant in the course of the shrinking labor market at that time. On the other hand, these redundant employees are not necessarily properly trained for new ventures. Generally, the proportion of higher-trained workforce is low in the textile industry (Frietsch/Gehrke 2005: 11). In addition, higher educational institutions were cut down because of the general shrinking and demand (EPPA/CEPS 2002). Finally, Pitt lists “positive reputation with finance sector” (ibid.) as a requirement for successful entrepreneurial firms. As outlined, this condition also was not given in TIS (NetFinTex 2007). Altogether, the environmental conditions of the TIS mainly did not support entrepreneurial firms.

Indeed, some new institutional initiatives can be found that oriented towards the improvement of communication along the textile supply chain and cooperative arrangements among the diverse actors. These new institutions indicate a situation of change. However, in none of the KIE cases such an initiative played a role. Apart from this, the initiatives commonly oriented towards established actors of the TIS. Following the dynamic perspective on sectoral innovation systems, their structure usually changes during their evolution (Malerba 2006: 26; Bergek et al. 2005: 14). Changes in one component affect the stable mutual interaction of the system’s components (cf. Bergek et al. ibid. 4) that need to be newly aligned and cannot be considered optimal (ibid. 14). As the components are assumed to interact also unintended (cf. ibid. 4), resulting coordination problems (ibid. 4) cannot easily be solved and take time. Applied on the TIS, changes in the actor component can be observed due to firm exits and technical changes in response to catching up in NICs. Both changes destabilized the components’ mutual interactions and also explain the disarrangement between entrepreneurial opportunity components. The exit and relocation of actors insecured the business relations in general. The resulting technological opportunities were differently penetrating actors, markets and existing institutions. They primarily addressed fiber producers and finishers of textile material (e.g. Begemann 2003: 61; Knecht 2003b: 14), which is also displayed by the case study analysis. This in turn, created information asymmetries among actors and therefore market opportunities. On the other hand, the ferment character of new scientific technologies and functions impeded the exploitation of these market opportunities by insecured and inexperienced customers. Indeed, many German textile companies had established themselves in specific niche markets because of the advanced stage of industry and competition. Some had regained market shares from exiting competitors. For new, external entrepreneurs as well as large investors, market niches in matured industries are generally less attracting, as they promise limited growth. On the other hand, many of the established firms struggled to find a new, distinct market niche (Meyer-Storck 2006: 50). This situation affected the demand side and weakened the entrepreneurial opportunities. Mr. L reported, for example, of customers who complained that he was the hundredth salesman trying to market antibacterial textiles. The more uncertainty emerged among the companies to decide on one of various technological opportunities, the weaker became the market articulation and the weaker the incentive for entrepreneurial exploitation.[160]

Von Tunzelmann and Acha (2005: 426) observed further disarrangements between the technological opportunities and institutional conditions of knowledge diffusion in the textile industry: “It is indeed the case that the recent developments have been slow to diffuse, but this probably has less to do with technological limits than with organizational aspects. The textile-clothing industry is still largely based on a pre-industrial vertical structure that is highly segmented […]”. Hence, the institutional disarrangement further slowed knowledge and innovation processes and discouraged new entrants. The changing situation in the textile industry implied disarrangements in the TIS that argue against a systemic entrepreneurial opportunity. Radosevic et al. (2011: 65) defined a systemic entrepreneurial opportunity through complementary interrelations between market, technological and institutional opportunity components. The absence, underdevelopment or wrong orientation of one opportunity component leads to matching problems (Radosevic 2010: 66). In fact, new technological opportunities can be assessed in the textile industry, but the emergence of the technological component does not automatically lead to complementing market opportunities and institutional opportunities, even though complementary interrelations can be assumed. Likewise, the results from the case study research support the argument of an absent systemic opportunity for KIE in the textile industry between 2000 and 2006. In none of the three different cases of KIE, the technological, market and institutional component were altogether exploited from within the TIS. In particular, the established innovation activity and informal institutions in the TIS were not compatible with entrepreneurial activity. This led to matching problems with in fact assessable technological and market opportunities. The insights in the textile industry’s conditions, innovation activity and opportunities do not point to entrepreneurial activity and experimentation so that a low entrepreneurial propensity of the TIS must be assumed.

Considering this results, it is questionable if matured low-tech sectoral innovation systems can generally offer a systemic opportunity for KIE and proactively change to an entrepreneurial innovation system. Given the persistence of the components’ stable interrelations, a systemic entrepreneurial opportunity appears paradox. Both the sectoral and case study analysis do not disclose any industry-specific institution that enhanced entrepreneurship in terms of mobilizing and legitimizing resources. No indications can be found that the TIS rebalanced or reduced the new uncertainties through stimulating entrepreneurial experimentation at established or new actors. While the institutions of the established innovation system could not adapt so fast to

160 Radosevic et al. (2011: 18) explain that “the (non)existence and the type of market opportunities may greatly impact on the nature of entrepreneurship that emerges which in turn may be greatly influenced by the role of the institutional system in conveying information and creating incentives among similar or identical technological opportunities.“

environmental changes and new technological opportunities, the entrepreneurs of the case studies managed to sense opportunities from other innovation systems or fields outside the low-tech innovation system. In place of a systemic opportunity, in all three cases KIE was driven by crisis and institutional entrepreneurship action. In conclusion, the TIS can be described with contradictory or paradox conditions for KIE. On the one hand, the advanced technologies and competition reinforce established actors to look for unique selling points that favor KIE activity in terms of distinct and superior innovation. Hence, this stage offers an opportunity for KIE, since following established paths of innovation promises no growth and stimulates ideas of deviation (cf. Deutschmann 2008: 111). On the other hand, the difficult institutional environment and advanced innovation system entail barriers for the exploitation of this opportunity. Especially new entrants with new knowledge for variation might be discouraged by this entrepreneurially unreceptive institutional environment.

Finally, it must be admitted that the specific situation of technical change and technological opportunities cannot be simply assumed for other low-tech industries. What can be assumed are similar conditions in growth, advanced technological paths and competition as well as fragmentation with regard to vertical division of labor. Likewise, established actors in these industries have the same motives for unique selling arguments and KIE. Other low-tech industries face maybe changes in different components of the innovation system such as demand or changing institutions (e.g. regulations) which tensions lead to opportunities. Alternatively, entrepreneurial actors are stimulated by the stagnation of their surrounding innovation system. In any case, similar conditions of the low-tech innovation systems are likely not entrepreneurially oriented and imply disarrangements with single changing components. For that reason, a systemic entrepreneurial opportunity for KIE can be most likely excluded from low-tech industries. This negative characterization leads over to the discussion of the next objective.

6.2 Characteristics of KIE in low-tech industries

The cross-case analysis of KIE cases in the textile industry reveals insights in opportunities and particular mechanisms of KIE. The meaning of these empirical findings should now be discussed with regard to characteristics of KIE in low-tech industries. Therefore, initially the sources of different opportunity types are considered as the bridge between environmental conditions and KIE activity. Subsequently, the structure of this section follows the main elements of KIE outlined in the developed concept for the low-tech context (cf. Chapter 1.4). Accordingly, the deviation and organizational setting of KIE is discussed on the base of the empirical findings. Then the resources and knowledge-intensive activity found in the multiple case studies are compared with the state of the art on KIE (Chapter 1.3). As research on KIE has mainly neglected mechanisms and the process of KIE, the empirical results from the

German textile industry are controverted with insights from institutional entrepreneurship studies on mature institutional fields and their transfer to low-tech industries. Finally, the outcome of KIE case studies needs to be critically reflected with regard to differences to institutional entrepreneurship and idiosyncrasies.

The analysis of the exploited *opportunity components* and their *sources* in the textile industry illustrate that entrepreneurial opportunities do exist in low-tech industries. Information asymmetries and advanced vertical division of labor in low-tech industries basically offer excellent market opportunities to entrepreneurs with superior knowledge. On the other hand, these conditions might have a significant influence on actors to sense existing or newly emerging opportunities. In the case of E-Thread, for instance, it is not very likely that the established thread specialist had discovered the opportunity of elastic conductive threads without external support. In contrast to this, MultiTex with a higher vertical range of manufacture was able to sense an entrepreneurial opportunity from a completely unfamiliar business field.

The question if opportunities were discovered or created by the entrepreneurs cannot be answered from the empirical investigation. In fact, most of the exploited opportunities within the different case studies existed independently from the entrepreneurs and might have been exploited by other entrepreneurs. For instance, the platform technology on incorporating additives that was offered for licensing, the problem of bend-break-resilience of conductive textiles or the problem of fixing advertisement on conveyor belts existed as independent opportunities from their exploiters. However, a passive perspective of discovering existing opportunity would not comply with the observations from the case studies. The empirical investigation shows the entrepreneurs' active matching of opportunity components. In all three cases, the entrepreneurs or entrepreneurial firms were in a critical or disadvantaged situation and also searched for opportunities outside their direct environment and innovation system.

Some of the opportunities emerged or were newly sensed during the process of KIE after initial market or technological opportunities did not work out or were not adequately valued. Delmar and Wennberg (2010: 11) explain this by the difficulty to anticipate the value of an opportunity and communicate it to others. In addition, an opportunity usually offers several new combinations for innovations (Shane 2003 in ibid.). The management of E-Thread admitted, for example, that they did not know at the beginning which of the several opportunities for the new threads' application they should exploit. Not least because of the weakly articulated demand of this newly emerging field. Altogether, the multi-case study analysis agrees with the dynamic recursive view on opportunities (cf. Spilling 2008: 154; Sarason et al. 2010; Sarasvathy et al. 2005 in Pacheco et al. 2010: 1000) that opportunities emerge in interactions of entrepreneurs with their institutional environment in the course of the entrepreneurial process. Particularly the estimation of market opportunities changed over the process of KIE. In the case of FuncFiber, the experienced entrepreneur Mr. L had not expected the slow decision making of textile customers, and E-Thread had expected a strong market pull. In consequence, the sensing of opportunities went on during the process of KIE. Thereby, objectives and preferences develop and are adjusted through the process of KIE activity and new interpretations of changing situations and conditions (cf. Deutschmann 2008: 105). During this process, the entrepreneurs indeed succeeded to create new opportunities and turn critical situations, particularly in consequence of missing institutional opportunities or the difficult market environment. The development of institutional projects such as end-products, for example, created new institutional and market opportunities. Through opportunity creation, the entrepreneurs responded to restricting institutional arrangements and the not entrepreneurially oriented institutional environment of the textile industry.

Altogether, insights in the conditions and prevailing innovation activity of the TIS between 2000 and 2006, as well as the identified sources of exploited opportunities of variant KIE cases lead to the conclusion that there was no systemic opportunity for KIE in terms of matched technological, market and institutional opportunity components. The reasons for the industry's mismatch of opportunity components can be mainly referred to the institutional environment and its wrongly oriented informal and formal institutions (cf. Chapter 6.1). Even though new technological opportunities as observed for the textile industry cannot be basically assumed for other low-tech industries, a similar institutional environment with missing entrepreneurial propensity can be expected from them, too. As described in the introduction, the matured stage of technologies in low-tech industries make investments in R&D costly and inefficient. Most firms carry out internal innovation through specialization, step-by-step or customer-oriented strategies within vertically organized supply chains (Hirsch-Kreinsen 2008). As Heidenreich (2009) shows for aggregated data of low-tech industries from the Community Innovation Surveys (CIS) 2004 and 2006, the firms of these industries performed poorly in cooperation on innovation. These evidences on institutional conditions of low-tech industries additionally support the argument of absent systemic opportunities for KIE.

In place of systemic KIE, the sources of exploited opportunities from the case study research reveal that the entrepreneurs overcome the system's underdeveloped institutional and market opportunities by sensing opportunity components outside the TIS and creating own institutional opportunities in form of new institutional projects and arrangements. External opportunity components were then matched with the TIS's technological opportunities. Mobilizing and creating institutional opportunity point to activities described in the institutional entrepreneurship concept. Additionally, the matching of opportunities that are distributed across different sectoral and national innovation systems or newly emerging fields reminds of the low-tech innovation practice of sourcing knowledge from distributed knowledge bases (cf. Robertson/Smith 2008; Bender/ Laestadius 2005). However, in the KIE cases the actors went beyond the sourcing and combining of existing knowledge from other fields.

What remains to be outlined from the case studies is the use of opportunities from the NIS. Distinct to Malerba's (2005: 394) critical argument on impeding effects of

NIS on sectoral innovation systems (SIS) and mismatches, several interdisciplinary and industry-unspecific programs were used from this level. These institutional opportunities helped to finance research activity, contact potential supporters and provided the entrepreneurs, to a certain extent, with legitimacy. Thereby, not all used promotion programs were oriented to specific new composite material and the particular technological situation of the textile industry. Also, general growth programs were used. In other words, entrepreneurs in persisting low-tech SIS may benefit from opportunities of other innovation systems. But the objection must be made that these opportunities were foremost used by scientific actors or experienced partners in the field of such national promotion programs. The established actors of E-Thread (at least at the beginning) and MultiTex were not able or not willing to sense and exploit such opportunities. Moreover, the interrelations with European industry and innovation policies mainly counteracted beneficiary national programs for matured industries (cf. Multisectoral framework on regional aid for large investment projects 2002) at that time. In conclusion, these kinds of institutional opportunities literally have a rare and not a general character.

The prospect to unique selling points was a central incentive or opportunity for the KIE entrepreneurs in the case studies, as it promised an adequate return on investment. This was the main empirical motive for *deviation*. In general, problematic situations that inhibit routine action make actors reflect their targets, rethink and reinterpret established rules as well as schemes of problem solving (Deutschmann 2008: 105). In such critical situations, the necessary creativity emerges and stimulates KIE. The problematic situation in the textile industry was not that entrepreneurs missed the artificial category of a systemic opportunity. In fact, they all noticed a critical situation in the course of the textile industry's shrinking, but it was not as critical as daily routine actions were blocked. Mr. R feared further cuts in public funding; E-Thread and MultiTex were alerted because of relocations of customers and decreasing demand. Nevertheless, they all continued their daily business during the process of KIE. Even more, the daily business was an important pillar during the first years until the pay-off of KIE. The entrepreneurs' interpretation of the situation at that time and certain expectations of investors led to a reinterpretation and reorientation of the organizational goals and look for new uncommon combinations of means.

Even if not all entrepreneurs were aware or could anticipate the true extent of deviation of the following KIE process, it was in all three cases an unusual event that they had not experienced in this extent before (except maybe the experienced entrepreneur Mr. L). Hence, the empirical cases agree with the preliminary concept of KIE as a rare event instead of a knowledge-intensive firm. The case selection criteria do not exclude this, but if we consider the three case companies, they could not be characterized as knowledge-intensive firms either after the KIE process. All three pioneering firms would not meet the criterion of 30% staffs with high academic and doctoral degree (cf. Starbuck 1992: 719). Also, the spin-off FuncFiber does not fulfill this criterion, because it sources necessary R&D from its partner PrivIn. The chairman and second entrepreneur Mr. L is a good example against this kind of operationalization. He founded several companies in his life in different branches without any official education certificate. In all three cases, the firms further implemented follow-up innovations from their KIE activity. But this innovation activity is not comparable with the efforts during the KIE process. For most case firms it is questionable if they would repeat it again. The investigation cannot answer this question. In any way, the operationalization of KIE as a rare phenomenon helped to find these cases.

The next issue in the KIE concept concerned its *organizational setting* that could not be clearly determined from the literature review. For that reason, the preliminary concept of KIE in low-tech and the case selection criteria included both settings of KIE as a new firm as well as corporate entrepreneurship. The cases found in the textile industry turned out to all be cases of corporate entrepreneurship. Following the definition, all entrepreneurs created a new organization depending on an existing organization (cf. Sharma/Chrisman 1999: 18). In two of the three cases, a new firm was founded (FuncFiber and TecTex), and in the case of E-Thread a new business unit was established. The illustration of the cases leads to the assumption that the foundation of these new organizations independent from the research institute PrivIn or the parent firm (MultiTex) is hard to imagine, as these existing organizations vitally supported these KIE ventures with crucial resources. Hence, for good reasons it can be assumed that the setting of corporate entrepreneurship in the sample is not random. Moreover, corporate entrepreneurship – independent from the innovation intensity – was not a completely uncommon institutional practice in the textile industry, according to textile experts. Representatives of industrial associations observed that established textile firms responded to previous technical changes with corporate entrepreneurship, but mostly by following new technical trends and not exploring them. Depending on the success and growth, a new business unit was established (diversification) that was later either outsourced or led to the whole new restructuring of the established firm. This meets Parhankangas' and Arenius' (2003) general observation on corporate entrepreneurship as a mechanism for restructuring in low-tech industries.

The literature review for approaching KIE in low-tech industries discloses a contradictory discussion on advantages and disadvantages of new firms versus established firms with regard to the industrial life-cycle and innovation. The KIE case research illustrates how established firms dealt with these common disadvantages. In case of E-Thread, the path-dependency (cf. Faulkner 1994: 441; Malerba 2005a: 388) and limited perception of the industry of the employees specialized in elastic thread design was overcome with the help of researchers from InnoServ that have a more abstract (scientific view) on the properties of the elastic threads. The manager of the new business unit at E-Thread described it with the metaphor that InnoServ opened a window for E-Thread to show the staff that there is much more to discover outside. In the case of MultiTex, the firm autonomously succeeded to leave its established path while addressing a new unfamiliar field. Distinct to E-Thread, MultiTex had shown in the past of the firm's history that it is not settled to a single product or technology (dynamic capabilities). The embeddedness in various technological fields such as weaving, refining and finishing was an advantage in this respect. Nevertheless, the previous capabilities and technologies were not completely left aside, even though the description of knowledge-intensive activity of the two established firms clearly show that they went beyond "incrementally refining the dominant design of the previous technology cycle" (Murmann/Tushman 2001: 193 et seq.). As described in the cross-case analysis, the mechanisms of effectuation and exaptation determined the process of deviation. Both firms used their established equipment and process capabilities for the development of the distinct innovation, which still demonstrates the effect of existing paradigms. But distinct to incremental and adapting innovation practices bound to the existing function that is known from low-tech innovation studies, these means were not sufficient for KIE. Instead, deviation was reached in all three cases of corporate entrepreneurship through unconventional variation. Opportunities for such unconventional variation came from multi-field embedded actors (cf. Leca et al. 2008: 13) like Mr. L, the experienced entrepreneur, or InnoServ, the laterally thinking consultancy across industries, or MultiTex, the multi-product and -technology based firm. In other words, actors embedded in other contexts and cognitive frames help to take a different reflective stance on routines or established means. They contributed to alter them through de-contextualization and re-contextualization. In conclusion from these empirical insights, the innovations of these corporate entrepreneurship cases of KIE cannot be termed radically "competence-destroying" but "competence-enhancing" (Lam 2005: 135; Delmar/ Wennberg 2010: 14). The weakness of established firms in matching new knowledge with economic knowledge (Delmar/Wennberg ibid.) was overcome by the involvement of partners from external fields. The case of FuncFiber additionally illustrates the complementary case. After new scientific knowledge was created, it is likewise important to find a person who is able to match and translate this new knowledge into applicable knowledge and products.

The argument from life-cycle theory of entrance barriers in mature industries was not only problematic for new entrants as individual entrepreneurs (cf. Köhler 2008: 6). Also, in cases of corporate entrepreneurship, KIE actors had to deal with established actors that seek to hold on to the status quo (cf. Peltoniemi 2011). The insights from the case study research illustrate that all entrepreneurs exploited specific niche products or markets with high capital intensity and development times of two years on average without any significant profits in this time. Entrepreneurial experimentation generally requires time for new ideas to be developed and grow (van de Ven/Garud 1993 in Garud/Karnøe 2001: 6). Likewise, Knecht (2003b: 13) observed for the newly emerging textiles that many technical requirements already existed, but the implementation into innovation still lasts. Established firms carrying out corporate entrepreneurship have a significant advantage, because they can partly save such investments due to existing facilities and additionally have incomes from their main business. Against this, individual entrepreneurs who depend on external financing face serious problems to convince investors under these conditions (cf. Ben-Ari/Vonortas in Malerba 2010b: 11).

In addition, the empirical findings reveal that potential customers from established industries were quite suspicious after first failings. They were obviously not used to such experimentation and failings anymore. Hence, the expectations on product reliability and the competence to translate prototypes into standard production were vital for the market implementation. This holds not only true for the textile customer markets but also for the grocery industry, which MultiTex entered. The cases show that the external partners (InnoServ, ConBe) alone were not able to match new knowledge with practical industrial knowledge that was "needed for developing complex products, modularity in product design and openness in the interfaces" (Malerba 2010b: 8). Exactly this Malerba denotes as "very important elements that shape entry and competition." (Ibid.) Overall, these insights in the conditions from the case study research argue against KIE in the setting of a newly entering firm, but for the specific form of corporate entrepreneurship. Likewise, in other low-tech industries with the same conditions of low-growth, capital intensity and niche innovations, this organizational setting can be assumed. The empirical results point to a sectoral peculiarity of KIE in terms of corporate entrepreneurship setting that differs from the traditional dichotomous view on entrepreneurial and routinized regimes of industrial life-cycle theory.

The contribution of established firms to KIE has been assessed in previous research within the KEINS project (2005). Manuel Godinho and Ricardo Mamede (2005) observed that spin-offs source considerable knowledge about technologies, products and markets and financial support from them (ibid. in Malerba 2010b: 9). Moreover, the KEINS survey discloses different sources between investigated industries like biotechnology, electronics and medical devices (ibid. 18). Biotechnology spin-offs, for instance, used knowledge about products while spin-offs in electronics and medical devices obtained knowledge about customers from their previous employer (ibid.). These first insights and further sources identified from KIE in the literature are *compared* with the sources of KIE cases from the textile industry. Starting with sources from existing supporting organizations, financing and technical infrastructure and particularly processing knowledge were most relevant sources across the cases. Also, in case of the non-profit research institute, seed financing was provided through the subsidiary and equipment in form of the pilot plant (cf. case of FuncFiber). Distinct to the identified sources in high-tech industries from above (cf. Godinho/Mamede 2005; Malerba 2010a/b), knowledge on customers or products cannot be identified as particularly important, because product innovations for new customer markets were exploited that were also new to the established organizations. The existing organizations are important sources of financing instead of venture capital that was stressed in previous studies on KIE (cf. Lenzi et al. 2010; Ben-Ari/Vonortas 2005; Malerba 2010b). As the general relations to venture capital firms are underdeveloped and an uncommon practice in the textile industry (cf. NetFinTex 2007), corporate entrepreneurship seems to be an alternative and specific form of financing in this context. As the reasons for the absent venture capital and private equity can be likewise applied on other low-tech industries with low growth rates and technological dynamics (cf. Rammer et al. 2004; von Tunzelmann/Acha 2005), corporate entrepreneurship can be probably assumed as a characteristic of other low-tech industries. Apart from the advantages of corporate entrepreneurship, the previously earned legitimacy of these established actors was not a sufficient source for legitimating the new organizational form and innovation of KIE. Likewise, the networks of established organizations were of little relevance for the KIE cases observed.

More important were actors from other fields and their differing knowledge and skills for creative and knowledge-intensive activity. Therefore, the initiating entrepreneurs' ability to mobilize and organize missing human, creative and financial resources also from outside the SIS was a basic requirement. The importance of dispersed and distributed resources converges with the literature of KIE in the context of knowledge-intensive industries (cf. Lenzi et al. 2010: 181; Groen 2005). But different to the mainly quantitative investigations on KIE, the empirical findings of the case studies show that creative skills are not necessarily bound to formal education or a scientific context. The majority of entrepreneurs and employees involved in the KIE processes in the textile industry has no doctoral degree or comparable expert status (cf. Starbuck 1992: 719; Delmar/Wennberg 2010). Central sources were actors skilled in disengaging from the affected product field as well as integrating new knowledge, processes or products into established industrial systems and technological frames. In some cases, these central actors became entrepreneurs, in others they became supporting partners. The externals' different social capital and network relations built another relevant source for KIE. For instance, investors were organized from Mr. L's social network or the professional network of InnoServ that was consulted in the idea finding process. The entrepreneurs went beyond knowledge-based activity and learning of new symbols, as they created new knowledge and symbols (cf. Deutschmann 2008: 107) during the creative process of KIE. Concretely, they generated new functions and sense of cellulosic fibers, elastic threads and coating of textile surfaces.

Following the state of the art of KIE particular sources are scientific research organizations, their networks and scientific knowledge (cf. Groen 2005: 70; Lenzi et al. 2010: 181; Malerba 2010b: 13). For example, R&D is denoted the main field of cooperation (Malerba ibid. 18). Indeed, in case of FuncFiber and E-Thread, R&D cooperation was an important source for the emergence of KIE and it can also be identified as the main field of cooperation but rather because of the poor cooperation with established actors from the field. Besides this conformance, the cases of KIE in the German textile industry go beyond the coordination and integration of external scientific knowledge with internal knowledge (cf. Malerba 2010b: 7). The different case studies disclose that new scientific knowledge can be one possibility for deviation from the existing knowledge base, as shown in the case of FuncFiber. The cases of MultiTex and E-Thread demonstrate that for the creation of a new idea, R&D and scientific knowledge are not necessary. In the case of E-Thread, the different systematic and more abstract view and thinking of the consultants from InnoServ was sufficient compared to the entrenched thinking of E-Thread's employees. Hence, scientifically educated actors like the ones from InnoServ can help to abstract from contexts to de- and re-contextualize ideas and knowledge schemes, but this is not the only source for creative and knowledge-intensive activity, as the case of MultiTex illustrates. The introductory case of Mrs. Mayer's innovative cardboards from the paper industry (Pollack 2007; Nagel 2011) is another evidence for this scientifically independent occurrence of KIE beside the textile industry.

The empirical cases confirm the alternative broad concept of KIE (Chapter 1.4) that neither scientific nor other external knowledge is necessary for KIE, but that superior knowledge is just being created during the process of KIE. Specific, new knowledge on additional function of materials was created that in turn required the development of new problem solving schemes and the translation into industrial processes or products. Thereby, the entrepreneurs went beyond pre-defined knowledge schemes and knowledge-based activity. They created products of fibers with superior incorporation of additives, textile electronic devices for clothing, and a sustainable imprinting technology for advertisement on conveyor belts. All of the newly developed solving schemes were patented, which argues for their uniqueness, though not necessarily for their superiority. In any way, the innovation activity of the KIE cases clearly departs from common innovation in low-tech industries, as the *knowledge-intensive activity* went beyond the re-combination of existing knowledge typical in mature industries (Maguire 2008). Likewise, it reaches beyond transposition, i.e. sourcing of external developed (high-tech) knowledge and its adaption with existing internal knowledge assets (cf. Bender 2005; Bender/Laestadius 2005, etc.).

In conclusion, the empirical results of the case studies display the broad operationalization of the developed KIE concept. The assessed variety of knowledge sources and form of corporate entrepreneurship extend the stereotype logic of KIE from the literature review. The results mainly support the assumed differences between industries due to different conditions and institutional influences and their identified main factors (Malerba 2010b: 18; Lenzi et al. 2010: 181). The maturity of an industry characterizes its knowledge base and types of knowledge held by companies, their linkages to other actors, particularly scientific organizations. Complementary to this, dominant paradigms and actors' deficiencies determine the resources used or not used for KIE. However, the narrowed studies on specific industries, scientific knowledge or actors does not allow for the conclusion that alternative resources play a more important role for KIE in the textile industry or low-tech industries than in other industries. Previous KIE studies could have simply not considered or measured these alternative sources. Brink and McKelvey's conclusion on KIE in biotechnology give an indication for this. They found prospering spin-offs in the biotechnology industry that were also not highly science-intensive or radical innovators (Brink/McKelvey 2010 in Malerba 2010b: 21). They stress the importance of knowledge integration, as well (ibid.). Consequently, it is not very reliable to conclude discriminating knowledge sources of KIE in the textile or low-tech industries, as a broader concept was applied. The different cases of KIE show a variety of knowledge types and sources. Apart from the type of knowledge, rather the creative moment and integration into existing economic or technological systems are essential for a distinct innovation within KIE. What occurs substantially idiosyncratic for KIE in capital-intensive low-tech industries compared to high-tech and knowledge-intensive industries is the organizational setting of corporate entrepreneurship. Different evidences from the sectoral analysis, state of the art of low-tech industries as well as the institutional environment observed in the case studies support this low-tech industrial peculiarity. Even though corporate entrepreneurship cannot be excluded from high-tech industries, their environmental conditions are expected to be more favoring new entrants and independent entrepreneurs. Moreover, closer relations to actors like venture capital firms or research institutes are assumed for KIE in high-tech institutional environments (cf. Ben-Ari/Vonortas 2005; Groen 2005: 70; Malerba 2010b: 18).

The analysis of specific *mechanisms for KIE* in the textile industry adds significant insights in further characteristics. They can be only selectively compared with state of the art literature on KIE, because the mainly economically driven studies have not investigated the process and mechanisms of KIE comprehensively (cf. Chapter 1.2). But, for example, the main field of cooperation in R&D assessed from the KEINS project (cf. Malerba 2010b: 18) points to such selective mechanism of KIE. The analysed opportunities reveal that a systemic entrepreneurial opportunity was not exploited in case of KIE in the textile industry but distributed opportunity components from across different innovation systems and emerging fields. More generally, missing knowledge, creative and financial resources were organized from other external fields or partners that describe institutional entrepreneurship activity (cf. Maguire 2008; Garud et al. 2007). The institutional economic entrepreneurship theory likewise focuses on previous circumstances and outcomes, whereas the other strand of institutional theory offers some explanations on changing processes and mechanisms (cf. Pacheco et al. 2010: 974 et seq.). A few studies have thereof considered especially the circumstance of such changes in established institutional fields that should now be compared with the empirical insights from the multi-case study research on the textile industry.

At the beginning of the KIE process, institutional entrepreneurship mechanisms of effectuation and exaptation (cf. Sarasvathy 2001; 2008 in Pacheco et al. 2010: 1003) can be assessed in the deviating activity. Existing means and work of the research organization and the other firms also affected the deviating innovation activity. But different from routine adaptation, the new, knowledge-intensive innovation was not bound to previous functions (cf. ibid.). New properties and functions were discovered in materials that was originally used for different purposes, sometimes goal-oriented and sometimes randomly as a byproduct (cf. cellulosic fibers or elastic threads or even the conveyor belts). The following exploitation of these new functions deserved knowledge-intensive activity that created new problem solving schemes (the new platform technology for integrating additives, the textile electronic connection to supply systems, or the new coating design for imprints on conveyor belts). In all cases, the means at hand and existing knowledge was not sufficient for the implementation of the new idea. However, the investigation cannot provide a common mechanism of creative activity or additional insights in this underexposed issue. In some cases, new means were developed or additional customer-specific machines were purchased in others additional employees and cooperation partners were mobilized.

More striking is that across the different cases, the mechanisms of theorizing and professionalization changed in the course of the KIE process. While at the beginning collaborative projects on R&D prevailed for convincing investors and partners (FuncFiber and E-Thread), later in the phase of implementation this mechanism of professionalization was not sufficient towards potential customers. Hence, the new empirical results of this study prove only partly the insights from the KEINS project on the meaning of R&D cooperation (Malerba 2010b: 18). The consideration of the KIE processes discloses additional significances. All supporters from this early stage were not established in the TIS (Mr. L; investors from Mr. L's network; InnoServ) or came from the periphery (textile research institutes from interdisciplinary project on advanced materials). In both arrangements – a research institute that organized an external business partner for a spin-off as well as the thread producer who collaborated with an external service provider for innovation – the entrepreneurs clearly broke with the institutional practice of joint industrial research and corporate innovation practice of textile firms. In the further process of exploitation and implementation, the situation and mechanisms altered as the actors (potential customers) changed. Actually, this change is only logic, because mechanisms are said to connect the interplay of situation and action (cf. Maurer/Schmid 2008: 2883). All entrepreneurs from the different cases firstly decided to market their innovation to established actors from the textile industry (respectively from the retail industry in the case of MultiTex). At the beginning of the implementation, the entrepreneurs indeed still preferred cooperation with potential customers. E-Thread and its partner InnoServ announced their cooperative intentions along the supply chain, for instance, in a technical journal. As we learned from Deutschmann (2008: 105), the estimation of situations and opportunities changes over time, especially under the contingent and unsecure situation of innovation processes. Individual entrepreneurs also as well as a group of entrepreneurial individuals are only to a certain extent able to anticipate market response and development (cf. Deutschmann 2008; Granovetter 1985; Grichnik 2006). After first fails in marketing and vertical integration in supply chains, all entrepreneurs decided on a strategy of internalization. They took over the development of end-products, organized the manufacturing and gained direct access to markets of end-products. This implementation strategy has the character of an institutional project, while none of the two material supplying companies planned to turn permanently into a producer of end-products.[161] Nonetheless, it was a risky venture and probably not economically rational (e.g. InnoServ advised against this taking over) from the point of view of an economic actor. From this point on they carried the whole risk and necessary investments alone. They risked not meeting adequately the market of end-products because of missing competences and technical requirements in the market field (cf. the case of E-Thread). However, this way they took over entrepreneurial experimentation and integrating activity of potential business customers that the market was afraid of or not willing to do. With these institutional projects of single products that reached up to first scales of industrial production, the KIE firms reduced uncertainties and gained a professional identity and legitimacy from market actors. Economic sociologists explain this behavior by basically distinguishing entrepreneurial and innovative activity from economic activity, because they do not meet general "Realitätsmaßstäbe" [reality scales] (Deutschmann 2008: 105) of economic action (cf. also Rammert 2008). This economically irrational action does not imply a basic rejection of rational benchmarks that are independent from the situation (Deutschmann ibid.). The KIE cases show that the entrepreneurial managing directors simultaneously carried on previous business. "Was ‚rational' ist und welche Regeln und Maximen daraus folgen, verändert sich in Abhängigkeit von der Situation." (Ibid. 105)[162]

In addition, initiating strategies, especially from the beginning of the textile supply chain, were also promoted by textile experts at that time. Konrad (2001: 391) states, for instance, that:

> *Textilunternehmen – in ihrer Funktion als Zulieferer – werden verstärkt gefordert, rechtzeitig auf zukünftige Entwicklungen ihrer Kunden bzw. der Kunden der Endprodukte zu reagieren. Eigeninitiierte Entwicklungen, die hier Problemlösungen aufzeigen, versetzen Textilunternehmen verstärkt in die Lage, die Rolle des Entwicklungspartners einzunehmen.*[163]

The case studies illustrate that the KIE firms theorized themselves as such professional problem solvers apart from their actual peripheral position, lack of power and reliance on central players (cf. Maguire 2008: 674). Moreover, institutional projects and internalized developments enabled the KIE firms to frame their innovation in a concrete context and illustrate their economic value by potential end-products. How-

[161] MultiTex differs from this as it purposefully internalized the whole business with the advertised conveyor belts. Without this vertical integration, the single supplying service of refining belts would not have been profitable enough.

[162] What is 'rational' and which rules and maxims occur from these changes depends on the situation (translated by author).

[163] Textile firms – in their supplier function – are increasingly requested to react timely to prospect developments of their customers or of the customers of end-products. Individually initiated developments that herein demonstrate problem solutions increasingly enable textile firms to take the role of a development partner (translated by author).

ever, this internal framing of exemplary economic use bears the risk of being non-compatible with the frames of users. Different to this, institutional entrepreneurship theory assumes that institutional entrepreneurs are able to change frames to their interest and embed them into existing rules and organizational fields (cf. Walgenbach/Meyer 2008: 144). Against this, the empirical findings reveal that the KIE companies rather struggled with the discursive moment and assembling of various field participants (cf. Maguire 2008: 677).

What is more is the particularly challenging situation of entrepreneurs in established institutional fields. In mature fields, institutional entrepreneurs particularly have to harmonize the interests of diverse field participants (cf. Leca et al. 2008: 14). The case study research shows that this diversity applied for the textile industry as well as for the field of POS marketing (in case of MultiTex). But the strategies to deal with this situation described in institutional entrepreneurship literature, like using professional associations for discursive arenas (ibid.; Maguire 2008: 677), cannot be assessed from the empirical findings in the textile industry. The situation is different with the use of existing institutional arrangements (Greenwood et al. 2002 in Leca et al. 2008: 118). While the cooperative arrangements with external supporters broke with existing institutional arrangements, the assessed free-rider mechanism refers to the established arrangement of powerful end-producers from vertical supply chains. The KIE firms particularly addressed their marketing activities to these powerful actors after they found out that their direct buyers from the supply chain could only be convinced, unless an end-producer articulated the demand and interest on the innovative material. By using the legitimacy and power of end-producers, the fragmented groups and interests along the supply chain were aligned. Both mechanisms of internalizing and free-riding entail no cooperative or discursive activity as described for institutional entrepreneurship (cf. Pacheco et al. 2010; Leca et al. 2008). Instead, they point to either cooperative-hostile and entrepreneurship-hostile environment or weaknesses of the entrepreneurial actors in institutional entrepreneurship skills. The internalization may be a hint for shortcomings in framing capabilities in order to organize missing resources from others (cf. Rao et al. 2000 in Leca et al. 2008: 12). In addition, the mechanism of internalization displays the dominant institutional practice of intramural innovation activity among the textile firms (cf. analysis of the German textile industry).

Certain social skills are assumed with institutional entrepreneurs, e.g. to win the “interpretational sovereignty in a specific social arena” (Deutschmann 2008: 106) and to align the different interests in his or her favor (ibid.). The two mechanisms from above rather show an avoiding strategy of the entrepreneurial actors in the KIE cases. Against this, institutional entrepreneurs are said to succeed in motivating others to cooperate due to specific communication strategies or so-called story telling (Fligstein 2001 in Deutschmann ibid.). In case of external supporters, indeed, the KIE entrepreneurs succeeded to cooperate with them. This might be derived from information asymmetries of the externals, but on the other hand, it can additionally be argued for the particular difficulties to cooperate with established field participants.

Different to the described function of institutional entrepreneurs, the contribution of the KIE entrepreneurs from the case studies to develop new frames and question existing rules as well as identities (cf. Deutschmann 2008: 106), remains questionable. All of the entrepreneurs framed their innovation, especially through end-products, but whether these new frames were taken over and reproduced by competitors or customers cannot be exactly evaluated. In case of FuncFiber, the monopolist later took over the production of the new functional, cellulosic fibers, which is an evidence for the institutionalization of the innovation beyond the scope of the KIE firm. In case of MultiTex, it is more difficult, as the patent limits the reproduction of the practice of advertising conveyor belts by other firms to become an institutionalized rule. On the other hand, the application of this innovation in 34 countries indirectly proves the threshold of institutionalization. And in case of E-Thread, a technical journal denotes the company as the pioneer of conductive threads in the field of electronic textiles that can be taken as indication for its institutionalization in the field. However, all resulting innovations did not really question existing rules of the institutional environment in terms of deinstitutionalization, nor did they install new generic rules of paradigms (cf. Groen 2005: 70 et seq.; Deutschmann 2008: 111). In this respect, the researchers of institutional entrepreneurship studies concede that institutional projects can be “more or less ambitious” (Colomy 1998; Perkmann/Spicer 2007; et al. in Leca et al. 2008: 10).

In conclusion, compared with the concept of institutional entrepreneurship, KIE deviated in the first part of the KIE process from institutional arrangements of innovation through uncommon, cooperative arrangements. But these altering arrangements occurred next to institutional arrangements without deinstitutionalizing them. In the phase of implementation, the entrepreneurs used existing arrangements (internal organization of innovation and power relations) in favor of their interests (cf. Pacheco et al. 2010: 975). Altogether, it remains open if the KIE cases led to a (re-)design of a new institutional arrangement in their institutional environment reproduced by other actors. A change in such institutional arrangements would describe a case of institutional entrepreneurship (Pacheco et al. ibid. 979).

Finally, the empirical *outcome of KIE* cases as the last element of the KIE concept is more broadly discussed in entrepreneurship and innovation literature. Schumpeter and his followers typically spring from a destructive moment in the context of entrepreneurship. Following Beckert (1999: 788), “entrepreneurs destroy existing institutions”. This certainly does not hold for the case studies of KIE investigated. In place of creative destruction we better describe the empirical activity as creative deviation that is nevertheless to be distinguished from creative accumulation in routine, matured innovation systems (Malerba 2005a; Spilling 2008) or from supplier-dominated innovation in low-tech industries (Heidenreich 2009). Dopfer criticizes the focus on destruction in dealing with creative phenomena (2006: 24):

> *Destruction, undoubtedly, is important. And it is, methodologically, most helpful because it does not call for any assumptions about cognition, creativity or ideas. A dog can throw down a vase, and the Taliban could destroy the Buddha statues. Both rely on ignorance. It does not require much knowledge to destroy. However, it does require knowledge to build up. Economic development relies not only on creative destruction, but also on creative construction.*

It is also possible that the traditional focus on creative destruction might be a misinterpretation of Schumpeter's early work. Actually, Schumpeter acknowledges that these new combinations are not immediately taking the place of the old ones but start producing beside them (cf. Schumpeter 1964: 101).[164]

Coming back to the textile industry, the evaluation of RWI (2009) indeed compared the innovation of technical textiles with creative destruction because of their substituting character. New materials based on functional fibers with superior absorption of additives and the light and bend-break-resilient, conductive threads have the potential to substitute common materials, and the reliable technology of imprinting conveyor belts can also substitute the approach of foils. All of these technological applications foremost address niches. Likewise, Deutschmann (2008: 106) acknowledges that entrepreneurs, if not questioning or creating generic rules, at least build niches that allow their survival. The empirical cases show in addition that these niches alone did not secure the survival in any case (questionnaire data 2009 of E-Thread and MultiTex). The niche innovations were developed beside the companies' main product fields. In case of MultiTex, after around five years the new product group of technical textiles reached the same proportion of home textiles in sales.[165] In case of FuncFiber, the income from sales of fibers was extended by consumer products and their licensing, which led to an enormous increase in value of the firm. Altogether, until the time of measurement (2009-2011) the niche innovations of the empirical cases did not remove the business of any existing firms involved in the KIE process or displaced other firms which applied established, defeated technologies. In other words, they did not render existing technologies obsolete or destroy existing competences, as assumed for competence-destroying technical change through new firm population of dominating entrants (cf. Tushman/Anderson 1986; 1990 in Garavaglia/Grieco 2005: 36). Just as little the KIE cases can be sufficiently described with competence-enhancing technical change, which is assumed to favor incumbents (cf. ibid. 37). Different to this, the KIE cases show that the existing organizations could not solely rely on their accumulated knowledge, experiences and competences for the exploitation of new technologies and KIE. Their equipment and know-how in processing was certainly an advantage compared to new individual entrants. In brief, these niche innovations explain the absence of new entrants and advantage of es-

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164 "Vielmehr treten der Idee und auch der Regel nach die neuen Kombinationen bzw. die sie verkörpernden Firmen, Produktionsstätten usw., nicht einfach an die Stelle, sondern zunächst neben die alten, die aus sich heraus meist gar nicht in der Lage wären, den großen Schritt zu tun" (Schumpeter 1964:101). [This excerpt could not be found in the English version.]

165 Under this product group the production of advertized conveyor belts as well as specific (illuminating) work wear is accounted.

tablished firms. In particular, the established KIE firms consciously looked for such niches that competitors deterred to follow and secured a monopolistic or leading position for preferably high innovation benefits.

The KIE cases deviated from their corresponding reference system of innovation routines through the exploitation of new niches for textile material and technologies. Some of the resulting innovation can be classed high-tech applications or are used in high-tech applications (electric micro supply systems), in other cases the entrepreneur purposefully decided against such high-tech applications because of the unprofitable additional investments and longer development times (cf. Mr. L from FuncFiber). However, all technical innovations included more or less formal R&D activity but not in any case from scientific research organizations or internal R&D departments, as the case of MultiTex demonstrates.

Furthermore, the extending impact of KIE on the sectoral knowledge base or product field is difficult to prove with the applied research design, even if the cases analysed had already emerged at the beginning of the new millennium. The case research illustrates the entrepreneurs' particular interest in protecting their niche innovation and therefore the diffusion of the newly created knowledge. Contrarily, extending the sectoral knowledge base would imply the incorporation of the new knowledge and share or application by other actors from the product field or industry. At least parts of the new knowledge and solving schemes are disclosed in patents. In case of FuncFiber, this was even licensed to the monopolist of the specific cellulosic fibers. Apart from competitors, one can argue that the innovations of KIE extended the knowledge base of partners and customers in respect to superior means or better problem solutions. Thereof, they do not take over the same knowledge on these new combinations but the necessary part to use it. Finally, the diffusion and institutionalization of new basic materials, as in case of FuncFiber and E-Thread or distinct innovation in general must be expected as very slow and cannot finally be evaluated in this investigation.

Summing up the discussion on characteristics of KIE from the empirical findings in the German textile industry, some differing and additional insights could be gained that confirm the assumption on sectoral differing forms of KIE (Malerba 2010b; Malerba/ McKelvey 2010; Lenzi et al. 2010). At the same time it can be acknowledged that some cases of KIE do not greatly differ from the description of central resources, linkages by the previous high-tech oriented literature on KIE in the early stage (cf. Lenzi et al. 2010: 181). Independently from the generally assessed fragmented linkages between research and industry and low R&D intensity of the textile industry, KIE in case of FuncFiber was driven by scientific research and knowledge. Likewise, E-Thread cooperated with a partner from the so-called knowledge-intensive industry (InnoServ) and other research institutes. In this respect, differences to the pronounced indicators of R&D and science intensity of KIE in high-tech sectors can hardly be assessed. Similarly to the assessed commonalities of innovative firms in high-tech and low-tech sectors (cf. Kirner et al. 2009a), these cases of KIE maybe have more in common with the academic spin-offs from previous studies than with most of the textile and even innovative textile firms. However, it is also important to include cases like in the form of MultiTex. This case illustrates an alternative to the established view on KIE and firms from low-tech industries. MultiTex neither relied on any external sources nor can it be described as science-intensive or R&D-intensive. Conversely, it solved a technical problem for an unfamiliar industrial field. Thereby, it departed from the assumed technology frames and variation of firms in low-tech industries (cf. von Tunzelmann/Acha 2005: 419). Distinct from this, MultiTex did not define the role of the technology, as the function was already fixed. It autonomously designed "how the technology [of imprinting conveyor belts] should develop" (ibid.) which is generally ascribed to technology frames of high-tech firms.

What the three different cases have in common and what distinguishes them from KIE cases in other sectoral environments becomes evident considering the whole KIE process. The KIE entrepreneurs exploited no systemic opportunity from their innovation system but a bundle of opportunity components distributed across other innovation systems. The sensing and matching of different opportunity components from inside and outside the sectoral innovation system point to institutional entrepreneurship activity instead of systemic KIE. In particular, corporate entrepreneurship is assumed an important setting of KIE in the textile and other low-tech industries providing necessary capital and fixed assets. In addition, the different stages of the KIE process reveal different actors and agency (cf. Leca et al. 2008: 20). While at the beginning cooperation with external supporting actors was used as a mechanism for deviation, later the KIE firms used existing arrangements of domination and internalization for the implementation and gain legitimacy of KIE from established actors. By implication, no central actors from the established field could be won for cooperation in the early stage. This coherence can also be assumed for other low-tech industries, because it responds to the competitive, suspicious, and entrepreneurially unreceptive environment that must be basically expected from matured low-tech industries. Finally, the creation of niche innovation describes another characteristic of KIE in low-tech industries owing to their advanced stage of technologies and markets. In turn, this reinforces the setting of corporate entrepreneurship compared to new independent entrants.

Altogether, these cross-case characteristics could be won from diverse sources and independent from varying enabling characteristics of individual entrepreneurs. It confirms the significant, specific influence of the institutional environment on the emergence of KIE, which was taken as a starting point for the investigation (cf. Malerba/McKelvey 2010: 8; Malerba 2010b: 23). As the influence of sectoral innovations systems or generally the institutional environment on KIE has been barely studied (Malerba 2010b: 13), the last part of the discussion draws on insights from the empirical findings.

6.3 Institutional influences of low-tech industries on the KIE process

The influence of the institutional environment on KIE in the German textile industry did not has the character of enabling systemic KIE in the sense of Radosevic et al. (2011). Rather, crisis and missing effective institutions stimulated the entrepreneurs in the cases of KIE. Beside this initial influence on KIE, further effects of the institutional environment can be assessed in the course of the KIE process.

The initial discussion on the environmental conditions (Chapter 6.1) preempts the characterization of the institutional environment in the case of the German textile industry. Recalling the model of different institutional layers, the institutional environment generally refers to layers of informal and formal institutions and technology (cf. Groene-wegen/Van der Steen 2006: 281). The institutional environment consists of specific configurations of rules and requirements from these institutions (Scott 1995: 132 in Garud et al. 2007: 958). Organizations need to comply with these rules, if they want to be accepted and supported by other organizations from this environment (ibid.). Malerba applies this on the sectoral level and describes this effect in terms of the sectoral knowledge base, demand and technological environment that influences which problems and solutions firms perceive and which innovation activities are carried out in response (cf. Malerba 2006: 28). When actors decide to deviate from the institutional environment, they do not only risk their legitimacy and support from others organizations but also sanctions (Garud et al. 2007: 958) and resistance from established actors that benefit from the status quo (Peltoniemi 2011: 352). Likewise, Groen (2005: 69) describes barriers for KIE in established structures and their basic influence on KIE.

Altogether, for the time of investigation (2000-2006), the institutional environment of the German textile industry was in a *changing situation* in which institutions from the past were still effective while simultaneously new technologies and configurations of rules and requirements emerged. In the past decades, dynamics in the institutional environment of the German textile industry did not draw on changes in the technological environment but rather on crises in the business environment. Competitive advantage was gained from product differentiation and cost efficiency as generally common for low-tech industries (von Tunzelmann/Acha 2005: 413). These advanced and highly efficient technologies and technological processes were basically hard to deinstitutionalize, but at some point they could not secure growth anymore. At a certain point, this institutional rule was not effective anymore in competition with low-wage NICs and their catching up. In response to this, textile firms either relocated their firms to these emerging industries or they tried to maintain the advantage in technology. Potters uses in her general deliberations on low-tech industries the example of textile firms (2009:13): “some enterprises in these sectors have become important generators of new technologies by developing new materials (e.g. technical textiles in the textile industry), enabling them to obtain new, highly added-value products for multi-sector applications.”

The problem in this changing situation was not necessarily missing technological opportunities, as these were provided by institutions like the industrial joint research and application oriented research institutes. Also, von Tunzelmann and Acha (2005: 429) generally acknowledge that "low-tech sectors do not lack for technological opportunities, nor indeed for appropriability and other factors associated with benefiting from technological innovation." Rather, persisting informal and formal institutions were problematic that did not comply with these new developments, such as the identified culture in ruthless calculation on price margins along the product supply chains. This impeding *informal institution* holds not only true for the textile industry but must be assumed for any other traditional vertically organized low-tech industry. As mentioned earlier, Pitt (2007: 96) also assessed for the Australian meat industry that "this […] traditional industry [is] characterized largely by a culture of suspicion, lack of trust and ruthless competition." She further explains the problem when "companies have enjoyed substantial success based on this paradigm […] they may not be willing to accept that the environment is changing and that new innovative business models will be required in the future." (Ibid.) In case of the textile industry, an expert calls for rethinking the culture of price calculation at that time. "Eine neue ‚geistige' Innovation und gedankliche Flexibilität ist erforderlich. Indem sich das branchenübliche Abgrenzungsdenken verliert, indem ein neues Effizienzdenken auch in struktureller, organisatorischer oder finanzieller Hinsicht aufkommt und indem nach fortschrittlichen Lösungen gesucht wird, die alle Beteiligten, auch die nächsten Generationen, zu ‚winner' machen."[166] (Hübner 2001: 287) What Hübner denotes "mental innovation" is actually a renewal of cognitive frames in the culture of innovation and efficiency.

The change in culture seems to be a necessary condition for the establishment of cooperative *arrangements*. But the vertical organization and common business model of textile firms do not promote this. Heterogeneity and variance in the textile industry imply several small and medium-sized specialized firms which business model is orientated towards restricted margins and investments. This institutional structure and arrangement could keep single entrepreneurial actors to deviate from this environment. Likewise, actors who decide for KIE were indirectly negatively influenced by this structure in the organization of support, legitimacy and implementation of KIE. Different *effects* of the changing institutional environment can be observed for KIE in the textile industry. Initially, the technological opportunities of new technical and functional textiles were mainly exploited by producers of fibers. They primarily benefited from this change (cf. Knecht 2003b). However, they also relied on the diffusion and exploitation of their new developments downstream the textile supply chain. This in

166 A new mental innovation and intellectual flexibility is necessary […] [t]hrough which the thinking of demarcation common in the industry disappears, through which the emergence of a new thinking in efficiency as well in structural respect and through searching for advanced solutions arises that make winners of all participants (translated by author).

turn, broadly collided with the established business model and institutional culture of the following processors.

In 2006, an expert attested an advanced stage of many new technologies for functions, such as temperature or chemical resistance and light fastness (van Delden 2006: 17). At that time, no distinct innovation was expected from new materials any longer, rather a focus on R&D process downstream the supply chain was necessary for the exploitation of new functional end-products (ibid.). The problem of this advanced changing situation is that first failures in R&D and product launches further created uncertainty, risk adversity and resistance among firms downstream the textile supply chain. The institutional environment had not elaborated new configurations on selection and exploitation of these new technologies, as observations in case of the Australian meat industry illustrate.

> *Past R&D failures and lack of commercialization success were thought to have produced a very risk adverse culture. Participants reported that most companies were not willing to be the first to try anything new. Innovation is perceived to be too risky and disruptive to production schedules which firms can not [sig.] afford due to small margins and cut throat competition. Many companies have explicit strategies of either being 'fast followers' or replying on innovations to filter into the Australian market from overseas. (Pitt 2007: 96)*

Similar observations can be found for the case studies in the textile industry. The entrepreneurs made related experiences. When they tried to sell their new materials to textile manufacturers, they faced disillusioned and risk-averse potential customers. Specialized producers of standardized textile components or textiles products had mostly not been sufficient know-how and other necessary resources at command to sell the new complex and higher-priced technical textiles or components. What becomes obvious in this respect is the influence of the interplay between institutional culture, institutional arrangements and individual actors. Usually it is assumed that an industry's entrepreneurial orientation (informal institutional level) affects how its actors perceive entrepreneurial opportunities and how, in turn, their exploitation of opportunities helps the sector to proactively respond to changes (Pitt 2007: 149; Pitt/Nelle 2008: 4). In case of missing established entrepreneurial orientation, the majority of actors is not used to proactively respond to outpacing changes. The trouble that entrepreneurs of the KIE cases faced during the market introduction and the mechanisms that they developed in response to this, indirectly prove this influence and leads to a specific form of KIE (cf. Chapter 6.2).

Further literature on sectoral innovation systems confirm the problems that can emerge through institutional changes. Bergek et al. (2005: 11) acknowledge that uncertainties are not only conceivable for the early stage of sectoral innovation systems but can also emerge in later stages. Many characteristics that are used to describe the formative stage of an innovation system (ibid. 16-18) can be likewise applied on the changing situation in the textile industry, e.g. "uncertainty in terms of technologies, markets and regulation" and "small niche markets" or "the absence of powerful self-reinforcing features (positive feed-backs) and insignificant 'free utilities'". Otherwise, other characteristics like "entry of many firms" and "formation of 'political networks' or advocacy" cannot be observed, whereas "entrepreneurial experimentation", "variety creation" and "institutional change" were less typical in the investigated situation of the textile industry (ibid).

The study of different sectoral innovation systems by Bergek et al. (2005: 20) provides explanations that can be taken over for the TIS's weak supporting influence on KIE. Accordingly, the promoters of new technological opportunities like research institutes and single fiber producers or industrial associations were "organizationally too weak to influence the function 'legitimation'" (ibid.) towards risk averse textile companies or a broader group of routinized textile innovators. In this uncertain stage, the promoters of change and new technologies often "lose in the 'battle over institutions' [e.g. on profit margins], if they attempt to achieve institutional alignment to the new technology with regard to the regulatory framework or the functioning of the educational and capital markets" (ibid., cf. also Möhring in Froitzheim 2009). Furthermore, *institutional disarrangements* contributed to poor performance in new market formation and influence on the direction of search and entrepreneurial experimentation (cf. Bergek et al. 2005: 20). The development of pulse measuring bras and textile circuit keyboards serve as examples in this respect. Likewise, "[u]nderdeveloped competence among potential customers may lead to an absence, or poor articulation, of demand" (ibid.). On the other hand, the potential value of these new complex materials was hardly perceivable by salesmen or consumers from traditional textile and clothing markets (cf. Albaum 2003: 91 et seq.; Reinhold 2003). Altogether, these disarrangements counteracted market and technological opportunities and the implementation of new ideas through KIE. Finally, the assessed "poor connectivity between actors" (Bergek et al. ibid.) explains the absence of supporting networks and fails of established networks (ibid.). In consequence, the situation of the textile institutional environment and sectoral innovation system was not supporting systemic KIE through enabling the match of technological, market and institutional opportunity components. Conversely, the institutional entrepreneurship concept assumes that especially such institutional tensions or crises and jolts are enabling conditions for institutional entrepreneurship (Maguire 2008: 675; Walgenbach/Meyer 2008: 144; Child et al. 2007; Greenwood et al. 2002; Fligstein 1997/2001; et al. in Leca et al. 2008: 7). In the textile industry, it was foremost the situation of crisis that stimulated the entrepreneurs for KIE, while later the institutional disarrangements negatively affected the organization of supporters from this institutional environment and establishment of KIE.

In *response* to missing cooperative institutional arrangements and entrepreneurial propensity, the KIE actors organized supporting partners from external fields. Afterwards the KIE firms turned for the same reasons to mechanisms of internalization and domination instead of discursive collaboration. Likewise, it must be assumed for the established KIE firms at least that these had internalized these mechanisms from the time before the KIE process. The embeddedness and socialization of established

KIE actors in this institutional environment might have been an advantage over new entrants, as they were used to this difficult institutional environment. The dynamic innovation capabilities that MultiTex developed over the decades in response to several technological and market changes were certainly helpful during the KIE process. Similar innovation capabilities are also observed for other low-tech innovators (cf. Bender 2005; Robertson/Smith 2008; Hirsch-Kreinsen 2008).

Moreover, the assumed dominant setting of corporate entrepreneurship for KIE in the textile and other low-tech industries can be traced back to the institutional environment's influence. This internal organizational practice of innovation had been observed for previous environmental changes, even though the firms rather followed innovation trends instead of carrying out entrepreneurial experimentation, as observed in the KIE cases. It is open to debate if this tradition in corporate entrepreneurship can be considered a specific institutional opportunity in this context that enables the emergence of KIE in low-tech industries in terms of re-using an institutional practice/arrangement. It raises the question if established low-tech innovation systems might not change to known entrepreneurial innovation systems (cf. Radosevic et al. 2011) but to a specific form of corporate entrepreneurial innovation system.

Another influence of the established institutional environment on the KIE entrepreneurs can be assessed for the orientation on established customers. Although at least in two of the KIE cases several new fields of application in newly emerging institutional fields emerged, the entrepreneurs preferred to exploit value adding products in broadly existing markets (clothing market). Not only the established KIE actors, also Mr. L, an external entrant, concentrated on established actors and existing frames to which functions or value was added. Again institutional entrepreneurship research explains this strategy. Newly emerging institutional fields for electronic textiles or industrial applications of fibers such as fibers with added ceramic gave hardly any orientation and were difficult to anticipate. Against this, "highly institutionalized fields [like the clothing industry] offer a more certain predictable environment for strategic action" (Beckert 1999; Oliver 1992 in Leca et al. 2008: 8). In this phase of institutionalization, the external supporters from the beginning of the KIE process research or production partners like InnoServ or ConBe could not support the KIE firms any longer. The developed institutional projects with external partners, for instance prototypes, were not sufficient to convince established, central actors from the institutional environment. In case of FuncFiber, the monopolist took over the production of fibers, not before the KIE firm had reached a certain volume and professionalism in production. Likewise, E-Thread could not win over a central actor from the clothing or textile industry and responded with the development of an own consumer product. MultiTex responded to long lasting negotiations with established German retailers by shifting its marketing strategy to less institutionalized and more open retail markets in new Eastern member states of the European Union.

Altogether, the changing institutional environment of KIE in the textile industry simultaneously entailed on the one hand what Dorado (2005) describe as tightly closed institutional fields and on the other, newly, partly too open institutional fields. *Highly institutionalized fields* like the cellulosic fiber industry with the monopolistic structure or the elastic thread industry are considered opportunity opaque, because the promotion of creative action and various institutional referents is less likely (cf. ibid. 392). Tightly closed fields are characterized by institutions and power structures that impede the questioning (Berger/Luckmann 1967; Zucker 1977 in Dorado 2005: 394) and deviation from this structure through rejection and sanctions of powerful actors (Lukes 1974; DiMaggio 1988 in Dorado ibid.). In case of E-Thread, the external partner InnoServ and also the new business unit manager Mr. I attested the traditional thread producer a tunnel view and blindness of the industry to see opportunities outside their institutional field. In the case of FuncFiber, for instance, the research institute PrivIn found no interested party from the fiber industry to exploit the new technology. Additionally, the monopolist from this field had sued a plant construction firm and its subsidiary for patent infringements, which gives an example of the power structure and sanctions towards new entrants. Opportunities are typically not provided or almost absent in these extremely institutionalized and/or isolated fields (Dorado 2005: 394). These conditions of the institutional environment can be widely assumed for low-tech industries in general. It leads KIE entrepreneurs to look for opportunities in other, emerging institutional fields. But institutionally closed environments influence the permeability of opportunities from other fields (ibid.). The restricted openness due to the high degree of institutionalization and actor constellations could be observed for the German textile and clothing industry. Similar conditions can be assessed for the Australian meat industry (Pitt 2007; Pitt/Nelle 2008), which implies to be likely the case in other low-tech industries. In such opportunity opaque fields, “the ability to identify and introduce new combinations and gain access to resources to support them will be almost impossible” for actors (Dorado ibid.). This difficult condition of the institutional environment is also assessable for the case studies of KIE in the textile industry. At the beginning, PrivIn and E-Thread had to organize resources and support from external actors like Mr. L and his investors or InnoServ. Later they adapted their market strategies to this institutional environment by using mechanisms of internalization.

Simultaneously, new institutional fields emerged with the development of new technical textiles and technologies in case of the textile industry. These can have the effect to be too open and opportunity hazy because of high uncertainty and complexity. Many co-existing practices in *emerging institutional fields* lead to a low predictability of opportunities (Duncan 1972 in Dorado 2005: 392). This institutional environment can be assessed for electronic textiles, for instance. Different technical systems emerged (e.g. textile-adapted, textile-integrated and textile-based in Möhring 2006: 318) as well as potential fields of application. Compared to opportunity transparent and institutionalized fields, too many opportunities can raise the problem to predict their value and to decide which should be gripped (Leca et al. 2008: 9). This problem also happened in the case of E-Thread. In consequence, the firm firstly decided on an application in an institutionalized field (heatable sportswear). In low institutionalized fields, entrepreneurs have to develop first of all a sense for their new combination (Dorado ibid.). E-Thread was not used to such institutional work. The example of the heatable vest illustrates this difficulty. After this, they turned to application of seat heating in cars, where product development and approval is still ongoing. In the end or from the retro-perspective, the managing director of E-Thread welcomed competing firms that could have helped to institutionalize and open up the new markets for conductive elastic textiles. It finally points to another idiosyncratic difference of KIE in the textile industry and probably other low-tech industries compared to newly emerging industries. “In the early stages of a new industry, interactions are co-operative rather than competitive, and this is when collective learning takes place.” (Peltoniemi 2011: 352) Given the particular conditions (corporate entrepreneurship, niche innovation, internalization) and weak cooperative actor constellations in the institutional environment of low-tech industries such collective learning is hardly conceivable – not least because the motive for established KIE actors is the deviation from competitors through a unique selling position. Against this, inter-organizational learning in entrepreneurial communities “encourages firms to follow each other to new markets and to develop new technologies to match or surpass those of competitors” (Windrum/Birchenball 1998 in ibid.). In conclusion, KIE activity during changes in established industries differs from newly emerging industries. Depending on the industrial life-cycle, the receptiveness or entrepreneurial orientation of the institutional environment particularly influences KIE in the stage of institutionalization with respect to sources of opportunities, mechanisms and outcome.

Lastly, the specific situation of the textile industry where technological inventions offered opportunities for KIE in established as well as in newly emerging institutional fields cannot be necessarily transferred to other low-tech industries. For some low-tech industries, opportunities for KIE are likely not linked to emerging technological fields (e.g. meat industry). Independent from the extent of change and if entrepreneurs address established or newly emerging institutional fields, similar impeding influences of persisting elements from the broader low-tech institutional environment on the process of KIE can be assumed.

7 Conclusions

Though it sounds paradox that in matured low-tech industries innovation is organized through entrepreneurial activity, KIE emerges in this specific institutional environment. The empirical, explanatory investigation of the German textile industry's example delivers relevant insights in characteristics of KIE, how it is influenced by low-tech innovation systems, and how entrepreneurs respond to this.

Recapitulating the starting situation and analytical procedure of this work, the gap of research was worked out through presenting the state of the art on low-tech industries and KIE. The paradox of KIE could be made comprehensible through recourse to research history on entrepreneurship theory and industrial life-cycle theory. Narrowed concepts on innovation, low-tech industries and KIE could not explain the emergence of KIE in the institutional environment of low-tech industries. For that reason, a concept was developed to approach KIE in this low-tech environment. Accordingly, the objectives of this thesis address insights in low-tech environmental conditions, characteristics and influences of the institutional environment on KIE. A conceptual frame of reference was developed, taking the main dimensions of industry, innovation and entrepreneurship into account. Because of the common assumption that slow growing and technology matured industries offer weak or no opportunities for KIE, the conceptual frame of systemic concepts on SIS and systemic KIE were extended by the institutional entrepreneurship concept. It particularly conceptualizes entrepreneurs as willful actors who are able to disengage from their socially constraining context. From this conceptual frame, the main analytical dimensions and diagnostic questions for the empirical investigation were derived. The methodological approach to implementation and analysis of the empirical research was presented. The investigation started with the sectoral analysis of the textile innovation system (TIS) in order to characterize the environmental conditions and its entrepreneurial orientation. The results give a first view of the conditions and situation of the TIS in the period between 2000 and 2006. The following case studies provide deeper insights in the environmental conditions for opportunities and the overall emergence of KIE in the textile industry from that time. Subsequently, the interim results from both analyses (sectoral and case study) were discussed in respect to their meaning for existing findings and their transferability to the low-tech sector. The conclusions from this investigation are drawn in the following sections.

The conclusion takes up the results of the empirical investigation and discussion to respond to the main research question of the thesis, how KIE emerges in the institutional environment of low-tech industries (Chapter 7.1). In addition, reverse consequences are sketched regarding KIE's contribution to the innovativeness of low-tech industries (Chapter 7.2). The final section gives a research outlook derived from the

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limitations and further queries that appeared in the course of this examination (Chapter 7.3).

7.1 The emergence of KIE in low-tech industries

The empirical investigation of KIE in the textile industry leads to the conclusion that KIE emerges most likely not through systemic KIE but through institutional entrepreneurship activity in low-tech industries.

Basically, sectoral innovation systems (SIS) differ "extensively in the process of variety creation and of heterogeneity among agents." (Malerba 2005a: 396) The variety in products and technologies as well as heterogeneity among specialized actors is already well-marked in low-tech SIS so that creation of new variety and actors proves difficult. That is why low-tech SIS are supposed to offer no or only few entrepreneurial opportunities. This was the reason for additionally investigating disengaging entrepreneurial action besides systemic enabling or disenabling conditions. After the sophisticated investigation of different opportunity components, the initial proposition on absent or weak opportunities in low-tech innovation systems must be revised. Entrepreneurial *opportunities* definitely exist in low-tech industries. Problematic rather is the institutional environment that does not support isolated technological, market or institutional opportunity components. A systemic opportunity for entrepreneurial activity that balances uncertainties through supporting entrepreneurial experimentation or entrepreneurial alertness, as it is assumed for entrepreneurial innovation systems (Radosevic et al. 2011), seems paradox in low-tech industries, given the persisting components and missing entrepreneurial propensity of established low-tech innovation systems.

The industry-specific *institutional environment* has a significant determining influence on KIE regardless of existing isolated opportunity components. Taking the particular example of the textile industry where research organizations are main sources for distinct technology creation, "opportunity exploitation through new firm formation", as generally assumed in this case (cf. Shane 2003: 121 et seq./123; Malerba/McKelvey 2010; McKelvey/Heidemann Lassen 2013b), did not take place. It remains unclear if industrial joint research becomes a more important technology creator in low-tech industries the less attractive and more costly it becomes to incumbent firms. Generally, the pressure on advantage in technology to secure competition and growth is likely the same as in other (Western) low-tech industries (cf. Potters 2009; Mendonça 2009; von Tunzelmann/Acha 2005). Even if more market than technology driven opportunities might arise in other low-tech industries, in the end, the problem of missing entrepreneurial orientation remains the same. For the textile industry, we can clearly assess – around 10 years after the investigated period and though significant new and valuable technological opportunities arose – that the innovation system of the textile industry did not turn into an entrepreneurial innovation system with a new population of firms. It illustrates the complex, intended and unintended interactions (cf. Bergek et al. 2005: 4) within innovation systems that are not simply controllable or changeable by single proponents (ibid. 20).

The chain of evidences from sectoral analysis and rival explanation building on case studies argue against entrepreneurial innovation systems that matches technological, market and institutional opportunity in low-tech industries. Independent from technological changes KIE actors established in the textile industry are not driven by enabling institutions, but likely by crisis and stagnation and a unique selling position. This probably stimulates disadvantaged, peripheral participants of low-tech innovation systems to carry out creative deviation in terms of KIE. The stimulation for deviation through crisis and technological stagnation on the one hand and difficult environmental conditions for the implementation of KIE on the other hand, constitute the paradox of KIE in low-tech industries. The low-tech innovation system affects the emergence of KIE in so far that it requires institutional entrepreneurship activity from the entrepreneurs. They need to overcome and break with established, ending innovation paths and institutional arrangements. KIE entrepreneurs sense and exploit missing opportunity components from other *sources* outside their low-tech institutional environment. Thereby, distributed opportunities across different innovation systems from the sectoral and national level, but also from emerging interdisciplinary fields, are matched.

Supporting actors from external fields and multi-embedded actors play a decisive role in the process of deviation. While alliances and cooperation with field externals prevailed in the early stage of the emergence of KIE, the legitimating power of these external supporters towards established customers in the low-tech industry remained restrictive. For the stage of implementation, *specific mechanisms* across varying case studies could be identified in the German textile industry that are likely transferable to low-tech industries in general. These mechanisms appeared in response to the difficult low-tech institutional environment. As the conditions of the textile industry agree with the generally described conditions for low-tech industries, the responding mechanisms are also likely to correspond. More precisely, professional theorizing through internalizing the development of end-products and the free-rider mechanism, using the power of manufacturers of end-products, are particular mechanisms for the establishment of the KIE organization and innovation in the low-tech institutional environment. Mechanisms of cooperation and discourse are not used to convince field participants. Rather, the KIE actors fall back on existing institutional arrangements and practices when they re-use existing vertical arrangements of the supply chain to their favor or internalize development practices comparable with traditional internal innovation habits of low-tech firms (cf. corporate innovation paradigm of the 20th century, Soete/Freeman 2009: 587).

The multi-case study analysis, including diverse actor perspectives and firms of different positions in the textile *supply chain*, delivers supplementing explanations on the interrelations between actors and the industry-specific environmental conditions. Especially external actors were surprised by the extent of division of labor in the textile industry and the specialization of firms. The business models behind this industrial structure significantly limit the permeability of new knowledge exchange and diffusion. The business models of specialization and scale effects drastically reduce the likelihood that KIE emerges in these firms. Moreover, as potential customers downstream the supply chain, these firms hamper the establishment of KIE actors because of their missing sources and receptiveness to integrate the new technologies or KIE product components in their processes and products. For this reason, KIE actors took over these development steps up to standardized producible end-products (or at least their organization). The institutional environment and its effects on KIE are transferable to other low-tech industries. Even if in other low-tech industries the extent of inter-organizational labor division, internationalization and firm specialization might be comparably lower than in the textile industry, an increasing trend can also be attested to them (cf. Heidenreich 2008; Robertson et al. 2009; Potters 2009). Supply chain structures have a significant influence on innovation systems and the emergence of KIE in low-tech industries, while in newly emerging industries such structures have still not been well-marked.

Furthermore, the empirical evidences from rival explanation building on the *setting* of KIE argue for another characteristic. The emergence of KIE in low-tech industries seems to differ from high-tech SIS in so far that it is not necessarily a matter of the rate of entry of new firms (cf. Malerba 2005a: 396) but of their origin and composition in terms of corporate entrepreneurship. Again, this can be traced back to restricting environmental conditions for new entrants and missing entrepreneurial enabling institutions as well as to the high capital intensity of firms in low-tech manufacturing industries.

Summing up the main results on the characteristics of KIE in low-tech industries: (1) KIE emerges mainly through institutional entrepreneurship activity deviating from dominant low-tech innovation practices and matching missing opportunity components with opportunities from outside the direct institutional environment; (2) because of the hostile institutional environment for KIE specific mechanisms of institutionalization are applied, i.e. internalizing processes of product design downstream the supply chain and using the free-rider mechanism to reorganize unreceptive processors from the supply chain; (3) these activities, mechanisms and related necessary resources finally argue for the specific organization of KIE in the setting of corporate entrepreneurship.

Altogether, KIE is not only formed by its institutional environment and sectoral innovation system. Reversely, it is also expected that KIE shapes innovation systems and contributes to industrial transformation processes (cf. Malerba 2010b: 3 et seq.). Likewise, differences in the extent of this contribution are presumed according to the specific industrial innovation system (cf. Malerba 2005a: 396) that is treated next.

7.2 The contribution of KIE to innovation in low-tech industries

Low-tech industries are mainly considered as aged in their industrial life-cycle (Robertson/Jacobson 2011b: 4). They are typically characterized by matured technologies and slow-growing markets, often facing overcapacities and price competition (cf. Robertson et al. 2009: 441). Innovation is said to be incremental and low for product as well as process innovation in these industries (Heidenreich 2009; Robertson/Jacobson 2011b: 4). Many of them became "prime candidates" (Robertson/Jacobson ibid.) for relocation to emerging economies. At the same time, their product and manufacturing processes are complex and capital-intensive (Robertson et al. ibid.) but still dynamic (Robertson/Jacobson ibid.). Yet, low-tech industries fill a relevant position for general economic dynamics; that is why their innovation is of basic economic concern (ibid.; Directorate-General for Enterprise and Industry 2013; Hirsch-Kreinsen et al. 2008). Although in a matured stage and confronted with transformation processes for decades, restructuring will prospectively hold on in low-tech industries (cf. Pitt/Nelle 2008: 2). Thereby, it is more than likely that this restructuring will change its form and dimensions than research hitherto observed.

Which role KIE, defined as a mechanism for rejuvenating existing industrial structure (Malerba 2010b; Malerba/McKelvey 2010, Groen 2005), will play in this specific context cannot be answered by this work. The investigation provides some first insights how KIE can contribute to renewal of low-tech industries apart from general assumptions on the impact of KIE. Younger entrepreneurship research has rediscovered the Schumpeterian function of the entrepreneur to economic growth. Entrepreneurship is denoted as a "missing link" (Audretsch/Keilbach 2010: 286) or an "important mechanism" (ibid.) to commercialize new knowledge into economic growth. Likewise, in the concept of SIS the "creation of new agents – both new firms and non-firm organizations is particularly important" (Malerba 2005a: 396), because they introduce new knowledge and other resources into the SIS (Bergek et al. 2005: 15). New firms enlarge the base of actors and enable established firms of the system to contribute to "knowledge development and diffusion and […] to participate in entrepreneurial experimentation" (ibid.).

In case of KIE in low-tech industries, the empirical observations are limited in this respect. Indications for new firm population in low-tech industries could not be assessed. Knowledge development and diffusion to existing participants of the innovation system as well as their participation in entrepreneurial experimentation was rather restrained. Overall, the investigated KIE cases give no insights that they contributed to the legitimization of a new entrepreneurial innovation system (cf. Caroll 1997 in Bergek et al. 2005: 15). This would describe a case of powerful institutional entrepreneurs who are able to change institutional arrangements and later whole systems. Such a change could not be proven for the empirical findings, nor were the KIE entrepreneurs able to mobilize or strengthen "'political' power of advocacy coalitions"

(Bergek et al. ibid.) that are necessary for change in matured low-tech innovation systems. In its place, the empirical investigation concludes that KIE in low-tech industries needs to be thought of as not solely dependent on new firm creation and knowledge intensity and opportunities equated with R&D intensity (cf. Shane 2003: 121 et seq.; Delmar/Wennberg 2010; Malerba/McKelvey 2010) but in its likely setting of corporate entrepreneurship. The debate on the European paradox (Audretsch/ Keilbach 2010) and knowledge filter clearly shows that high investments and performance in technology and R&D alone do "not automatically spillover for commercialization and economic growth" (Audretsch/Keilbach 2010: 286; European Commission 1995). Measuring the impact of KIE in terms of knowledge spillover is difficult. The limited explanatory power of economics and management theories for new firms creation (cf. McMullen et al. 2007: 281) likely holds, vice versa, for knowledge spillover from these new organizations. At least in case of corporate entrepreneurship it can be emanated from the extension of the parent's firm-specific knowledge base.

Latest contributions on the impact of KIE (Kastelli/Caloghirou 2014; McKelvey/Heidemann Lassen 2013b) still evaluate the performance and output of KIE firms according to common economic measuring parameters of growth, turnover, patents, job creation, etc.. With regard to knowledge creation in low-tech industries, some researchers still fall back to Pavitt's taxonomy of 'supplier-dominated low-tech firms' (McKelvey/Heidemann ibid. 124). This understanding of knowledge creation still orients towards knowledge production outside the low-tech innovation system and/or incremental process innovation. But KIE particularly deviates from this kind of knowledge production and innovation practice, as the empirical cases from the German textile industry illustrate.

Generally, evaluating the contribution of entrepreneurship and entrepreneurial activity to economic systems and institutions still remains a shortcoming in research. "Die Bildung wirtschaftlicher Institutionen kann als ein Prozess interpretiert werden, der durch das Handeln unternehmerischer Individuen vorangetrieben wird.“ [167] (Deutschmann 2008: 84). Likewise, the social structure of knowledge creation and its effects on KIE need to be evaluated when considering the contribution of KIE to industrial innovation. Some insights can be assessed from the empirical findings that seek to take into account the social character of knowledge. KIE emerged not necessarily in terms of traditional new firm entry (cf. Bergek et al. 2005: 15). Nevertheless, it introduced new actors and knowledge into the low-tech SIS: e.g. the lateral entrant Mr. L and his investors, the service provider for innovation management in SME (InnoServ), which had following projects and customers in the textile industry after collaborating with E-Thread. Hence, through this cooperation, new links with new actors from outside the established innovation system emerged. The KIE firms mobilized not only resources for themselves, their new products or materials also created new opportunities of innovation for purchasers and/or processors from low-tech in-

[167] The establishment of economic institutions can be interpreted as a process that is driven by the action of entrepreneurial individuals (translated by author).

dustries. MultiTex, for instance, initiated cooperation on production of the new products with a traditional belt producer from another low-tech industry. Moreover, KIE actors took over the development of single end-products and contributed thereby to market formation and reduction of uncertainties. FuncFiber, for example, succeeded in winning the monopolist to take over the production of FuncFiber's newly established fibers although this implied adjustment of the monopolist's production line. In addition, the KIE firms even supplied other industries like retail or automobile and electro industry with innovation opportunities. Altogether, these KIE firms and their linkages to new, external customer industries contribute to the necessary increase in prestige against the low-tech sector's prevailing image of "being somewhat old-fashioned" (Robertson et al. 2009: 441).

Indeed, in all KIE cases innovations emerged, restricted to specific market niches with lower volumes that might not attract new entrants, given the high seed capital for machines and equipment. For low-tech parent firms, the niche products became attractive additional sales markets that help to secure their workload. Even if no additional jobs have been created, in some cases the distinct innovation contributed to maintaining the existing workforce that had been otherwise downsized. Effects of scales could be approached again through extending the niche markets to foreign markets. The case of MultiTex shows that new export markets are sometimes easier to open up than highly institutionalized, domestic (low-tech) markets.

Finally, the contributions of KIE have to be relativized, given the challenges that KIE actors had to face during implementation and when convincing actors due to the persisting, innovation-hostile and entrepreneurship-hostile institutional environment. In consequence, even though KIE will likely not appear as a mass phenomenon or a new entrepreneurial population in low-tech industries, rather it functions as a kind of leverage for innovation and change. How these effects of KIE on low-tech innovation differ from the high-tech sector cannot be reliably answered by the findings. In any case, it is worthwhile systematically adding this phenomenon and its effects to the research agenda on low-tech innovation and transformation of low-tech industries. Once the pioneering research on innovation in the low-tech sector "led to a new understanding of the restructuring of economic landscape of knowledge-based countries" (Hirsch-Kreinsen 2009: 95). Now KIE can help to rethink transformation and innovation in low-tech industries. KIE research provides an additional perspective on change between continuous incremental transformation from within existing technical or sectoral innovation systems (cf. ibid.) and external high-tech driven transformation (cf. Mendonça 2009). Alternatively to these endogenous/exogenous perspectives the developed concept of KIE treats creative deviation from existing technologies initiated from within the system but with help of external sources and actors. Cases of creative deviation and new path creation ought to be more taken into consideration, especially with respect to the sustainable competitiveness and innovativeness of industries from the low-tech sector. A necessary precondition might be to understand entrepreneurial activity not exclusively and distinct from economic action but as an important and basic component of it so that it becomes a taken for granted equal perspective for the analysis of transformation processes in established industries.

7.3 Research outlook

The research outlook arises from limitations of the investigation as well as new questions that developed through the investigation. The explanatory investigation of the multi-dimensional phenomenon KIE and the first approach to analysing it systematically in the context of low-tech industries entails limitations and problems that lead to further research and research questions.

First of all, the developed broad, alternative approach to evaluate KIE in the context of low-tech industries varies from existing concepts in both strands of research: KIE and low-tech innovation studies. The possible differences, additional insights and commonalities between the main assumptions of the state of the arts and the alternative approach of the thesis shall be comprehensible. But due to the differing understandings, the empirical results are difficult to compare with previous studies that mainly apply narrower perspectives on innovation and entrepreneurship. Similarly, findings from case study research need to be assumed to differ in design and depth among researchers and disciplines (e.g. Radosevic et al. 2011; McKelvey/Heidemann Lassen 2013a).

Apart from the introduced literature review, the empirical investigation of this work contributes only limited to the open issues of creativity and the nexus of opportunity and entrepreneurs. This weakness is owed to the open research process where the conceptual issues were worked off after most of the explorative case data had been collected (within the AEGIS project, 2009-2012). In consequence, these open issues were not particularly operationalized or intensively treated in the interviews. On the other hand, the response of interviewees could not be influenced in this respect. Afterwards, additional sources, like technical journals, were used for assessing intersubjective opportunities. As a result, the findings of the investigation contribute only limited to additional explanations on creative deviation or the nexus of opportunity and entrepreneur. In other words, the analysis of entrepreneurial opportunities that Sarasvathy et al. call “the greatest intellectual puzzle of our time, namely the creation of new value in society” (2005: 158), still remains to be solved.

Empirical evaluations of entrepreneurial opportunities and their sources are a delicate issue, because all existing opportunities even just for a specific field or case cannot be entirely reconstructed from a researcher’s retro-perspective. More important than analysing solely independently existing opportunities is actually the nexus of an opportunity and entrepreneurs. But here as well a (mono-)causal logic to explain the nexus seems to be difficult and not rewarding. Opportunities have a fuzzy character (Delmar/Wennberg 2010: 11; cf. Dorado 2005), as their value and exploitation do not only depend on the entrepreneurs' intellectual skills but also if potential customers and partners share the same opinion of their value (Delmar/Wennberg 2010). Accordingly, the opportunity-entrepreneurship nexus describes only a part of the whole KIE process, because even if

> *[…] an entrepreneur (firm or person) has the vision to bring together all pieces of required and helpful knowledge and combine them with the financial, material and human resources needed to develop the idea into a product […] even then history shows that it is the market and a considerable share of luck that determines which innovations succeed and which fail. (McMullen et al. 2007: 280)*

The process perspective, however, helps to deal with this contingency. Through the case studies changes in opportunity exploitation and entrepreneurs' decision against some opportunities could be additionally disclosed.

The situation when evaluating institutional conditions is similar to the fuzzy opportunities. As initially mentioned, the "study of the role of institutions in sectoral systems is still considered to be in its infancy." (Pitt 2007: 128) For that reason, the investigation oriented to the layered institutional model (Groenewegen/Van der Steen 2006) that helps to distinguish between (industry-specific) enabling and constraining institutions, informal and formal institutions, and institutional arrangements right up to firm-specific cognitive frames. But also in this respect the researcher can only gather a selection so that the investigation of institutions and their complex interrelations can make no claims of being complete.

Finally, to reasonably generalize the explanatory findings for the emergence of KIE in low-tech manufacturing industries, the external validity of multi-case research needs to be extended to additional low-tech industries and to prove the replication logic of the findings (cf. Yin 2003: 34/37). The case of Mrs. Mayer from the paper industry is a starting point, while it is not clear if it is a contrasting case and/or a case of failure. Mrs. Mayer entered the paper industry as a lateral entrant (Pollack 2007: 18). She has a degree in informatics from the former East Germany and was retrained in office management after she had been unemployed. She started to work at a producer of traditional paper combs and soon changed to the sales department. In contact with customers she hit on ideas for new applications. But unlike the managing directors of the investigated cases in the textile industry, her employer was not interested in exploiting her idea. In difference to the other corporate entrepreneurship cases, she succeeded as an independent entrepreneur in winning over a holding for industrial packaging as shareholder. Her start-up began to supply components to the automotive industry. After four years in the fiercely contested automotive supplier industry impaling commitment to continuous cost cutting, Mrs. Mayer diversified her business from mouldings to bulk goods used in caravans, cruise ships and furniture (Nagel 2011). The Bayer AG supported Mrs. Mayer in her new business strategy (ibid.). However, according to unternehmensregister.de, the Wabenfabrik was deregistered in 2012. The reasons for this closedown cannot be determined from the analysis of secondary data. Nevertheless, this case could further improve the insights in the emergence of KIE in low-tech industries.

It is interesting that in this KIE case, supply chain structures seem to be significant as well. The experienced entrepreneur Mr. L from the case of FuncFiber consciously decided against starting with the exploitation of ceramic fibres in the automotive industry, probably for similar reasons and experiences he had made with a start-up in the electronic industry. The influence of supply chain structures on KIE activity emerged during the research process, supplementing the literature review and conceptual frame. That is why it was not extensively considered during the data collection process. In consequence, supply chain relations need to be more systematically included in prospect research. Because of the existing multiple dimensions, such venture can easily become an even more complex task (cf. Schwinge 2014). Beyond single, specific industry contexts or systems, the analysis of supply chain influences seems a promising though challenging research approach, since many innovation activities start from upstream the supply chain. “General purpose technologies [with high potential for deviation] arise commonly (though not invariably) in ‘upstream’ activities – […] in equipment and capital goods, in motive power and in basic materials – from which they trickle down to user industries.” (Von Tunzelmann/Acha 2005: 416 et seq.) The explanatory KIE cases of this work illustrate very well that this down-trickling does not happen automatically. It largely depends on the institutional environment, actor constellations and strategic as well as financial resources of entrepreneurs. Compared to some high-tech industries, right from the beginning of business high professional standards in processing are expected from entrepreneurs in manufacturing industries. This professionalism goes beyond first prototyping or a beta version, as failures in (low-tech) customers’ mass production immediately cause high losses. This professionalism in processing is usually not expected from most academic entrepreneurs or other lateral entrants.

Further research on cases from other low-tech industries, likewise case studies from high-tech industries, could advance the discrimination and sector-specific characterization of KIE in this low-tech context. Research findings as well as previous studies point to some commonalities that require more precise analyses. Brink and McKelvey (2010), for instance, conclude from their study on start-ups in the bio-technology industry that these also grow without being radical innovators or “highly science intensive” (ibid. 240). This might be an indication that the developed alternative concept for measuring KIE in low-tech industries can add further insights applied on high-tech industries as well. Further comparable studies of KIE in high-tech industries also need to open their sampling to cases of corporate entrepreneurship. High-tech industries, like the information and communication industry or biotechnology, have matured and entered new life-cycles. KIE may emerge in this sectoral context in the setting of corporate entrepreneurship as well. It still remains open if particular institutional differences in relations to parent organizations and mechanisms during the implementation process can be assessed here or not. Integrating entrepreneurial action more systematically in the analysis of economic processes implies to include corporate entrepreneurship as well – even if this construct is more difficult to operationalize (cf. Parhankangas/Arenius 2003; Godinho/Mamede 2005; Sharma/Chrisman 1999; Covin/Miles 1990). In addition, the concept of path creation seems promising in this respect. It systematically considers entrepreneurial activity of willful economic actors between path dependence and path creation (cf. Deutschmann 2008: 84; Meyer/Schubert 2007; Windeler 2003).

Finally, more and advanced concepts are necessary to research KIE's effects on industries in general. Indeed, knowledge about innovative businesses has basically increased in research. However, "the picture remains rather vague and unclear in many respects" (Fritsch 2011: 376) as, for instance, in case of corporate entrepreneurship. Traditionally effects on "technological change, competitiveness and growth" are of main interest. It is explicitly called for more research on "indirect effects that innovative new business have on the incumbents and on the development of the market." (Ibid.)

All in all, investigating KIE in its industrial context still raises many questions that point to several directions such as the evaluation of opportunities, the institutional conditions and the role of supply chain relations, its emergence as corporate entrepreneurship and measuring effects of KIE on industrial dynamics. The explanatory investigation helps to understand the paradox of opportunities and barriers for KIE in low-tech industries. Moreover, the developed alternative research approach of this work enriches first, narrowed approaches of KIE and low-tech innovation studies.

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9 Appendices

App. 1 Template of standardized company questionnaire (AEGIS case studies)

21/10/2010

AEGIS

Advancing Knowledge-intensive Entrepreneurship and Innovation

for Economic Growth and Social Well-being in Europe

WP 1.3

- Questionnaire -

Name of the firm: ………………………….. Date: …………………….

Name and job title of the respondent: ……………………………………………………

Personal data is requested for the purpose of research only, will not be shared with other third parties and will be recorded in a secure and protected database. All your answers will be treated anonymously. Please read our enclosed Privacy Statement for more information.

I. General information about the firm

Q01. When was the company founded? ☐☐☐☐

Q02. What is the legal form of the company? ………..

Q03. The company is a

- ☐ independent company without branches
- ☐ part of a combine or a group of companies, as a:
  - ❑ department
  - ❑ legal independent subsidiary
- ☐ Other...

I. Schwinge, *The Paradox of Knowledge-Intensive Entrepreneurship in Low-Tech Industries*,
DOI 10.1007/978-3-658-10937-0, © Springer Fachmedien Wiesbaden 2015

Q04. To which industrial sector does the company belong?

....

Q05. According to which structure is the company subdivided into branches/departments?

☐ Functional, and in fact:

....

- ☐ Divisional/branches:
- ☐ according to products
- ☐ according to regions
- ☐ according to customers

☐ Matrix, according to …………………………………….......

Q06. What is the total number of

Full-time employees in your company? ………

Part-time employees in your company? ....

Q07. Please estimate the percentage of the employees' qualification in your firm as

Qualification	**In 2000 in %**	**In 2005 in %**	**In 2009 in %**
Semi-/unskilled			
Skilled			
Masters			
PhD			
MBA			

Q08. Please estimate the turnover and ratio of profit to sales in **2009**.

Turnover ………. in million €

Ratio of profit to sales ………. in %

II. Product(s)

Q09. Which product families are produced in the company mainly?

(Just name the three most important, please)

Product families		
I	II	III

Q10. Please estimate their share of turnover in %:

Product families		
I	II	III

Q11. Which *array of product* is characteristic here?

(Please tick the appropriate)

	Product families		
	I	II	III
Custom-made products	☐	☐	☐
Products with custom-specific variations	☐	☐	☐
Products with variations	☐	☐	☐
Products without variations	☐	☐	☐

Q12. Which *way of manufacturing* regarding the final products is prevailing?

(Please tick the appropriate)

	Product families		
	I	II	III
Batch production	☐	☐	☐
Single or low volume production (< 20 pieces)	☐	☐	☐
Medium volume production (20 - 1.000 pieces)	☐	☐	☐
Mass production (> 1.000 pieces)	☐	☐	☐
Continuous process-production	☐	☐	☐

III. The Value Chain

Q13. What are the current numbers of the company's suppliers regarding their size?

Size of supplier enterprise	**Number of suppliers**	**How many of them are localized in the region?**
1 - 9 employees		
10 - 49 employees		
50 - 199 employees		
200 - 499 employees		
500 - 999 employees		
≥ 1000 employees		

Q14. What are the current numbers of the company's customers regarding their size?

Size of customer enterprise	**Number of customers**	**How many of them are localized in the region?**
1 - 9 employees		
10 – 49 employees		
50 – 199 employees		
200 - 499 employees		
500 - 999 employees		
≥ 1000 employees		

Q15. What is the typical structure of your sales?

Sales	**in %**
Local	
National	
Europe	
South-East Asia	

IV. Innovation

Q16. Please estimate your annual amount of *expenditures for innovation* activities (include personnel and related costs) as % of turnover on average: ………%

Q17. Please estimate your annual amount of *expenditures for R&D* (include personnel and related costs) as % of turnover on average: ………%

Q18. Please estimate the annual average of total innovation expenditures as % of turnover for the *investigated innovation*: ...…..%

Q19. Please estimate the following expenditures as % of the total innovation expenditures for this innovation:

Share of total innovation expenditure	**in %**
Intramural R&D[168]	
Extramural R&D	
Acquisition of machinery & equipment	
Market introduction of innovation	
Training	
IPR (copyright, trademarks, registered design, etc)	
Acquisition of other external knowledge	
Other	

Q20. How are the employees who were involved in the innovation process distributed to the different departments of the company?

Departments	**Number of employees**
Commercial management	
R&D	
Design	
Production planning	
Manufacturing and production	
Quality management	

[168] Intramural R&D includes expenditures for R&D personnel and further R&D costs and investments.

Purchasing & logistics	
Marketing & sales	
After sales service	
Other	

V. Growth/impact

Q21. Please estimate the following annual average growth rates during the last 4 years since the introduction of the investigated innovation:

Annual average growth rates	**in %**
Growth in sales	
Growth of employment	
R&D to sales ratio	
Growth of exports to sales	

Thank you very much for taking the time to fill in this questionnaire.

Unit of analysis	**Concept**	**Dimension**	**Diagnostic questions**	**Sources of evidence** (not complete)
Sectoral analysis	Sectoral systems of innovation	Knowledge	What are the knowledge domains of the industry? What kind of opportunities for innovation do they offer? How are the relevant sources of knowledge accessed?	Industrial reports (e.g. MIP data on sources of information), technical literature (e.g. Begemann; 2003 Rouette 2006)
		Actor	Who are the actors mainly involved in innovation activity, knowledge production and technology development? Can entrepreneurs be identified among the innovators of the SIS? Which dominant competencies of the innovators can be identified? Which established practices of the innovators can be identified? What kind of prevailing interactions can be assessed for innovators?	Share of innovators (process/product, MIP); sector-specific founding intensity (MUP); share of R&D employment & expenditures (Eurostat); cooperation on innovation (ZEW); et al.
		Institutions	Are there any industry-specific institutions influencing the direction of knowledge and innovation development? Can any entrepreneurial orientation be assessed in terms of entrepreneurship enhancing institutions through legitimizing and mobilizing resources?	Industry reports/studies (EPPA/CEPS 2002; Forschungskuratorium Textil 1999; NetFinTex 2007; et al.)
	Systemic KIE	Opportunities	Which technological, market and institutional opportunities exist for KIE? What are their sources (NIS, TIS, other SIS or entrepreneur)?	Technical literature, Euro-stat detailed enterprise statistics on growth in turn-over, firms etc., interviewees (from industry associations; KIE cases)

Case study analysis	Institutional entrepre-neurship	Entrepreneu-rial propensity of SIS	Which disarrangements might exist for matching the different opportunity types? Does the innovation system offer a systemic entre-preneurial opportunity?	Case study data; expert interviews with industry associations; analysis of German TIS
		Entrepreneurs	What was the entrepreneurs' motivation? How can the entrepreneurs' position in the field be described? With which did skills the entrepreneurs contribute to the entrepreneurial process? Were intangible resources such as social capital or previous earned legitimacy necessary?	Case study data, inter-views
		KIE process	Did the entrepreneur(s) break or deviate from any routine or institutional arrangement? Were institutional arrangements deinstitutionalized and newly designed? How were resources organized or mobilized for a new organizational form?	Case study data, inter-views
		Mechanisms	What kind of strategic or practical mechanisms can be observed for KIE? (Theorizing, professionaliza-tion, exaptation, other)	Case study data, inter-views
		Institutional environment	How can the institutional environment be character-ized regarding crises and jolts, degree of institutional-ization, institutional heterogeneity, and actor constel-lation? How open is the organizational field for tensions and new institutional arrange-ments? Are there any jolts or crises in the field or neighboring environment? What kind of constraining conditions can be identi-fied? Which enabling conditions or opportunities can be found?	Case study analyses, analysis of German TIS